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2023
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PROCEEDINGS

EASTERN INTERNATIONAL UNIVERSITY SCIENTIFIC CONFERENCE 2023 (EIUSC 2023)

The university scientific research activities in the context of the Fourth Industrial Revolution

NOVEMBER 8, 2023

Organized by
Eastern International University

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INTRODUCTION

At Eastern International University (EIU), we firmly believe that scientific research remains the cornerstone of progress and innovation, pushing the boundaries of our understanding and paving the way for sustainable development in the era of Industry 4.0. Obviously, Industry 4.0 has brought forth a wave of unprecedented technological advancements. As EIU witnesses the integration of artificial intelligence, robotics, big data, and the Internet of Things into the very fabric of our industries, we recognize the urgent need for interdisciplinary research that can effectively harness the potential of these emerging technologies. Therefore, EIU is striving to develop a comprehensive ecosystem that fosters innovation and transformation in the Industry 4.0 context, such as Advanced Manufacturing Center, Industry 4.0 Innovation Center, Cyber Security Center, and more. To sustain that ecosystem, one important activity is to create a platform for researchers, and scholars from various fields to converge, exchange ideas, and collaborate towards impactful research outcomes.

Following the success of the EIUSRC 2022, the EIU Scientific Conference 2023 has been successfully held with the theme "The University Scientific Research Activities in the Context of the Fourth Industrial Revolution". This iteration of the conference witnessed the active participation of over 250 EIU researchers, lecturers, staff, and students, alongside presentations from internationally invited speakers. The conference proceedings, comprising 57 selected papers by our scientific committee, revolve around five main themes: Economics, Business and Management; Engineering; Health Sciences; Information Technology; University Administration and other topics. It can be said that EIUSC 2023 has served as a dynamic forum for participants to share expertise, foster connections, and ignite new ideas. Each interaction holds the potential to stimulate further research and leave a lasting impact beyond the conference.

Lastly, we extend our sincere gratitude to all contributors who played a vital role in making EIUSC 2023 a success. We hope that participants had a rewarding experience and invite comments, recommendations, and continued engagement in Eastern International University's forthcoming research activities.

Warm regards,

The Organizing Committee

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PART I.

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DIGITALIZATION OF BLOOD INVENTORY SYSTEM AT BECAMEX INTERNATIONAL HOSPITAL (BIH)[❁]

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Abstract: The blood supply chain encounters multiple obstacles, including uncertain demand and supply patterns, interdependencies among different stages of the chain, and the inherent characteristics of the product [1]. The presence of an unpredictable setting and the limited durability of products, along with a significant emphasis on service delivery within healthcare, can result in excessive inventory [2]. Having a finely tuned inventory management system is particularly vital in hospital blood banks, which directly serve patients, to prevent unnecessary wastage. Previously, BIH relied on a paper-based system to record and oversee blood usage, expiration dates, and blood consumption. The approach was suboptimal and susceptible to errors. This paper presents the implementation of a digital blood inventory management system at BIH, leveraging IoT and mobile technology. The system aims to optimize blood inventory practices, enhance data accuracy, and improve overall operational efficiency. By utilizing an online app developed with Google AppSheet, staff members and managers interact with the system to track blood availability, usage, and suitability. Results indicate reduced blood wastage 13.2%, blood management related errors by over 10%, staff satisfaction increase of over 65%, ultimately improving the hospital's blood management performance.

Keywords: *blood management, inventory, Google Appsheet*

I. INTRODUCTION

Blood inventory management is a critical aspect of healthcare operations, with the ongoing challenge of aligning blood supply with demand [3]. Every year, over a million blood units are donated globally. Despite this considerable contribution, the demand for blood remains urgent and unfulfilled [4]. Efficient management can help patients in need with life-threatening conditions, reducing mortality rate. Inadequate synchronization within the hospital's blood database results in readiness shortages, preventing patients from receiving the appropriate blood promptly [5].

Diverse healthcare sectors can utilize the Internet of Things (IoT) and web applications to tackle a range of issues and obstacles. IoT offers a perspective of enhanced intelligence through

[❁] Best oral presentation award - Lecturer session

enabling communication between devices and individuals using the internet [6]. These technologies ensure accessibility by remotely monitoring patients, documenting product statuses, and tracing medical equipment like blood bags or intelligent labels for recognizing patients' blood groups, assessing compatibility, and tracking the history of blood bag testing [7].

This paper focuses on the digitalization of the blood inventory system at BIH, addressing the need for efficient blood tracking, usage analysis, and real-time data access. The traditional manual management methods lack precision, leading to potential errors and inefficient allocation of resources. Leveraging IoT and mobile technology, the digital blood inventory system aims to revolutionize blood management practices at the hospital.

II. METHODOLOGY

A. Google AppSheet development

To address these challenges, an online app was developed using Google AppSheet. The app provides a user-friendly interface for staff members and managers to interact with the digital blood inventory system. The system focuses on digitizing records, maintaining activity history, and facilitating information extraction for quality assurance and reporting purposes. The app allows users to interact with the blood inventory system and enables push notifications through Telegram bots for timely updates and automated actions.

B. Data model of the app

Previously, data was manually recorded in separate notebooks without any connections, leading to significant challenges in tracking and comparing. Data is fragmented and lacks comprehensive interconnection among tables. This approach was prone to errors, including missing entries or duplicate counts (depicted in Figure 1).

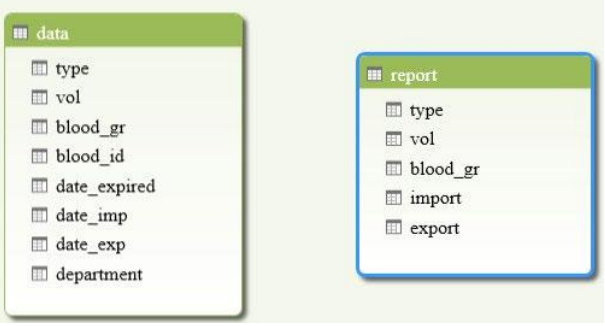

Figure 1. Illustration of previous data management system

With the new data model, all databases are synchronized and retrieval is very straightforward. Furthermore, all databases will be situated on a cloud server, enabling convenient access through a web browser on various devices, such as PCs or mobile phones. This transition enhances scalability and reliability.

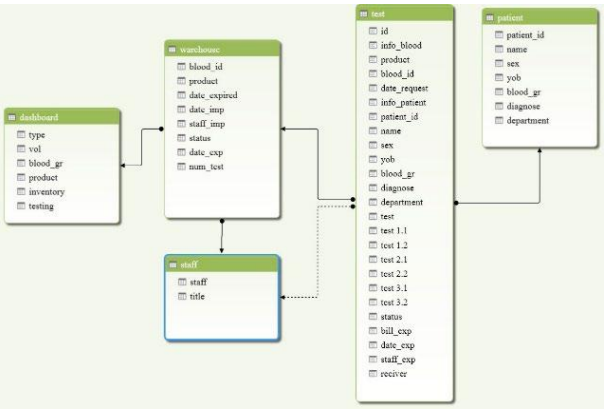

Figure 2. BIH's AppSheet new data model

C. Architecture of the app

A user-friendly mobile app assists staff in systematically recording information and

facilitates seamless interaction through guided steps. Visual alerts regarding expiring blood bags enhance staff utilization and minimize wastage. Recorded data seamlessly flows into a real-time dashboard on Google Data Looker. Moreover, information is integrated with Telegram, allowing users to access essential data at any time and activate predefined automated actions. This comprehensive suite effectively addresses the issues highlighted in the fishbone diagram.

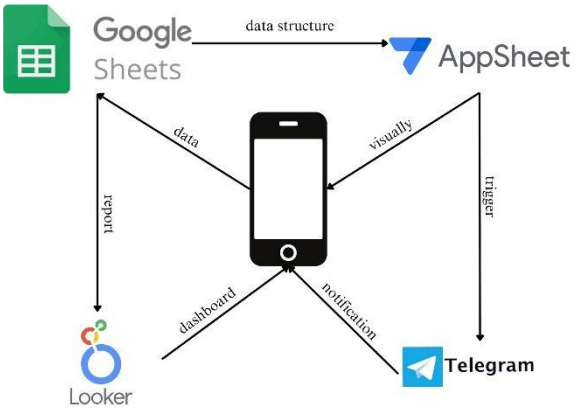

Figure 3. Illustration of architecture of the app

III. RESULTS

A. Results

The implemented digital blood inventory system utilizes internal management analytics to ensure blood availability based on predetermined logic and user interactions. The app enables users to request blood, while the system prepopulates inventory based on hospital needs. The app's features include live tracking of blood suitability for specific patients and situations, reducing the chances of blood wastage. The system also eliminates the need for a dedicated staff member to record and track blood inventory, centralizing data for easy quality assurance checks. Blood usage and activity history are closely monitored through automated reports, ensuring accurate tracking and streamlined decision-making. Additionally, the app enables quick retrieval of blood-related information, reducing inefficiencies in patient care.

We have realized a noteworthy enhancement in the overall efficiency of blood inventory management. This improvement is primarily attributed to the reduction in staff time spent on documentation and reporting, resulting in a remarkable 50% time savings. As a result, staff satisfaction has seen a substantial increase of 65.2%, coupled with enhanced smoothness and readiness of information due to the automation of repetitive tasks. In terms of safety, errors associated with blood management have decreased significantly, now standing at just 4.3%, compared to the initial 14.6% six months after the implementation. Additionally, the percentage of expired blood bags has shown a remarkable decline, reaching a mere 3.3%.

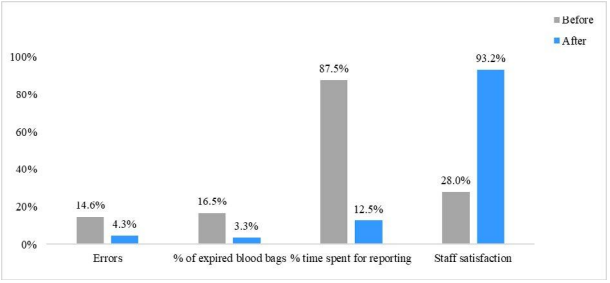

Figure 4. Improvement of blood inventory management before and after digitalization

B. Limitations

Despite its benefits, the digital blood inventory system has limitations. It relies on stable technology infrastructure, risking disruptions. Data security is among the most prominent challenges, due to sensitive patient information, demanding robust protection measures [8]. Sustaining performance requires updates,

and disregarding this could result in potential vulnerabilities. Maintaining user engagement poses a challenge, requiring continuous efforts to promote system benefits. In this project, a significant duration was dedicated to extensive discussions with responsible staff, aiming to collect requirements, ideas, and expectations. This meticulous approach was undertaken to ensure a successful implementation.

IV. CONCLUSION

The digitalization of the blood inventory system at BIH has proven to be effective in enhancing blood management practices. Through the use of IoT and mobile technology, the system reduces wastage, improves data accuracy, and enhances overall operational efficiency. The system's success demonstrates the potential for technology-driven solutions to address longstanding challenges in healthcare inventory management.

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EXPLORING THE RELATIONSHIP BETWEEN NIGHTTIME LIGHT AND PROVINCIAL GRDP IN VIETNAM❁

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Abstract: This study investigates the relationship between nighttime light (NTL) data and provincial Gross Regional Domestic Product (GRDP) in Vietnam from 2010 to 2020, considering spatial effects. The study combines NTL data from the Suomi National Polar-Orbiting Partnership-Visible Infrared Imaging Radiometer Suite (NPP-VIIRS) with GRDP data to identify the intrinsic relationship between NTL and provincial GRDP in Vietnam. The empirical results reveal spatial dependence in explaining economic growth patterns in Vietnam, with increasing spatial dependence over time. Positive and statistically significant coefficients demonstrate the association between NTL data and GRDP, emphasizing the importance of considering spatial relationships. The study highlights the significance of the Spatial Durbin Model (SDM) with fixed effect as the most appropriate choice for fitting the data. This research advances our understanding of economic analysis in developing countries and showcases the potential of satellite-based data for economic research. The findings offer valuable insights for policymakers in formulating regional development strategies and resource allocation to foster balanced economic growth in Vietnam.

Keywords: *economic growth, nighttime light, spatial econometrics, Vietnam*

I. INTRODUCTION

One of the significant challenges encountered in economic analysis, particularly in developing countries like Vietnam, is the lack of reliable economic data. This is especially true when trying to obtain data at the regional level. In recognition of this issue, various alternative methodologies have been proposed to address it. Notably, recent efforts to link nighttime light (NTL) data and economic activity have produced promising results (Elvidge et al., 1997; Keola, 2015; Nguyen et al., 2021; Zhou, 2022). Because it measures the NTL generated by human activity, NTL data is considered as a reliable proxy for economic activity.

In order to gain insights into the economic dynamics of Vietnam's provinces, this study conducts an analysis that combined satellite imagery of NTL with Gross Regional Domestic Product (GRDP) data spanning the time period from 2010 to 2020 of 63 provinces. Vietnam exhibits significant spatial variation in NTL intensity across its provinces. For example, Ho Chi Minh City boasts the highest NTL intensity

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in the country, while certain remote northern mountainous provinces display minimal levels of NTL. This discrepancy in NTL intensity closely mirrors the divergence in GRDP between provinces.

The study contributes to the literature on how to obtain reliable economic data at the regional level in developing countries, with a specific focus on Vietnam. By using satellite-derived NTL data as a proxy for economic activity, the study offers a novel approach to overcome data limitations in regions where conventional economic data may be scarce or inaccessible. NTL data can be particularly useful for identifying clusters of economic activities and understanding the spatial distribution of economic growth. This information is crucial for formulating targeted regional development strategies and allocating resources more efficiently. Moreover, the study emphasizes the importance of understanding the statistical relationship between economic activity and NTL data, taking into account spatial aspects. Spatial econometric estimation plays a vital role in this analysis by allowing the incorporation of spatial effects. This enables a more comprehensive and accurate understanding of the relationship between NTL and provincial GRDP in Vietnam.

This paper is organized as follows: The second section presents a literature review that explores relevant studies focusing on spatial analysis and research related to NTL. The third section provides the description of the data sources and the methodology used in this study. In the fourth section, the estimation results are presented and their implications are analyzed. The study concludes with a final section summarizing the key findings of the study, highlighting their significance and discussing their potential implications for policymakers and researchers.

II. LITERATURE REVIEW

A. Spatial effect

It is widely observed that spatial location is highly associated with economic activities. For example, the special economic zone is featured by high income. Such observation requires using a proxy for location in the economic model. However, various studies examined the determinants of economic growth without considering the importance of spatial effect. This may cause misleading conclusions because of the omitted variable. To this end, many studies have been conducted to analyze the contribution of location in economic modelling. Among the authors, Bernat (1996) and Rey and Montouri (1999) were the first to investigate the spatial effect.

Nguyen (2022) carried out research on the impact of spatial spillover of transport infrastructure on economic growth, using panel data for Vietnam over the period of 2000-2019 and the spatial Durbin model (SDM). Their results revealed a significant contribution of transport infrastructure to the outcome at the national level. However, the authors claimed that the effect of transport infrastructure varied by sub-national regions. In concrete terms, the empirical findings indicated that (1) a positive relationship for the southern region; (2) a negative impact of transport infrastructure on economic growth for the central region; and (3) after 2010, transport infrastructure decreased economic growth in the case of the Mekong delta. Del Bo et al., (2012) analyzed the contribution of infrastructure to growth in a spatial framework with a focus on the European

region. Their empirical results were consistent with the findings of Nguyen (2022). That is, there exists evidence on positive association between infrastructure and economic activity.

Moreover, using the spatial fixed effect and random effect for the SDM, Thang et al., (2016) conduct a study for a panel data for Vietnam from 2000-2005. The primary purpose of their study is to analyze spatial spillover effects from foreign direct investment in Vietnam. Empirical results provided evidence on positive backward spillovers. Besides, the authors claimed that the impact of forward and horizontal spillovers were conditional on distance. In the same vein, Hoang and Goujon (2014) used the spatial-error model and maximum likelihood estimator to investigate the determinants of foreign direct investment (FDI) in Vietnam over the period of 2001-2010. The authors found FDI inflows of a province were affected by that of its neighborhood, suggesting evidence of spatial spillover effect. On the other view, Hoang et al., (2022) identified various key factors of FDI inflows in the Southern Central Coast region of Vietnam over the period of 2007-2016. In particular, the authors claimed that cheap labor cost, legal institution and level of social security were positively associated with FDI inflows.

In addition, Esiyok (2018) analyzed the impact of spatial distance on economic growth for a panel data for Vietnam, spanning from 1999 to 2010. Using the system-GMM estimator together with the spatial lagged-dependent variable model and the spatial-error model, their empirical results revealed that provincial economic growth significantly affected by the GDP of neighboring provinces. Besides, in line with other studies, the authors found positive effects of both human and physical capital on regional income. Torres-Preciado et al., (2014) carried out research on technology innovation-economic growth nexus, using panel data for Mexico over the period of 1995-2007. Using the exploratory spatial data analysis, their results revealed the existence of patterns of spatial interaction. In concrete terms, empirical findings suggested that the Northern states had a higher level of growth rate than the Southern states. Moreover, the local indicator of spatial association exhibited a pattern of local spatial dependence. Bai *et al.,* (2012) investigated the relationship among spatial spillover and regional economic growth in China from 1998-2008. They found positive spatial autocorrelation among provinces in China, implying inter-provincial spillovers.

B. NTL and socio-economic analysis

The lack of reliable economic data poses a significant challenge in economic analysis, particularly for developing countries. To address this issue, various alternative methodologies have been proposed. Motivated by the study of Elvidge et al., (1997), which identified a strong positive relationship between GDP and the NTL observed from space, recent efforts to link NTL data and economic activity have produced promising results.

Regarding the NTL data-urbanization nexus, Zhou (2022) used the NTL data, which is sourced from the Defense Meteorological Satellite Program Operational Linescan System (DMSP/ OLS) and Suomi National Polar-Orbiting Partnership-Visible Infrared Imaging Radiometer Suite (VIIRS/ NPP) NTL dataset to investigate the urban expansion process in Vietnam over the period of 2000-2018. As expected, the authors found the urbanization was highly centralized in the southern Mekong delta and the northern Red River Delta. Besides,

the empirical results highlighted that the size of population and the level of industrialization both gave rise to the urban expansion in Vietnam. Similarly, Zhao et al., (2020) obtained NTL data from DMSP/ OLS and VIIRS/ NPP to analyze the urban dynamics of Southeast Asia over the period of 1992-2018. From their empirical results, the authors confirmed that NTL data was an appropriate measurement of urbanization of the region.

In relation to the relationship between NTL data and income, Keola (2015) conducted a study for a panel data of Cambodia, Lao PDR, Myanmar, Vietnam and Thailand from 1993 to 2009. The primary purpose of their study is to explain changes in economic growth by NTL and land cover data. Empirical findings showed that NTL data significantly explained economic growth for the non-agricultural sector only. A possible explanation for the result is that the NTL observed from space was the result of industrial activities. This finding supports the study of Elvidge et al., (1997), which claimed that DMSP/ OLS NTL dataset was a useful measurement of the spatial distribution of human population at the global basis. The association between GDP and NTL data was confirmed by other scholars. Wu et al., (2013) investigated the main driver of light consumption for a panel data of 169 countries, spanning from 1995 to 2009. Their empirical results revealed that latitude, human activities and gross saving rate, GDP both lead to using light at night. Besides, the authors argued that the relationship between light consumption and income had inverted-U curve shape. Doll et al., (2006) found that there existed correlation between NTL imagery and the level of economic growth for the case of 11 European Union countries and the United States. Similarly, the empirical findings of Dasgupta (2022) for the case of India claimed that NTL data was able to estimate GDP and confirmed short-term effects of economic shocks could be predicted by NTL data.

Although DMSP/ OLS and VIIRS/ NPP NTL dataset are inexpensive and reliable sources of NTL data, there are few studies, which used these sources and others, investigated environmental-economic change with a focus on Vietnam. For example, Giang et al., (2023) used various Landsat satellite images and convolutional-neural-network models to classify coastal landscapes. Quang et al., (2022) used various sources of remote sensing data to measure environmental and economic values in Vietnam. Their findings showed that Sentinel-2 and Landsat 8 were appropriate sensing data for understanding changes in environment quality at national and regional scales. The usefulness of Sentinel-2 and Landsat 8 remote sensing imagery was confirmed by the study of Nguyen et al., (2021), which analyzed the environmental quality in Quang Ninh province, Vietnam. Nguyen et al., (2021) carried out research on assessing salinity intrusion, using a set of 143 samples over the period of 2016-2020 with a focus on Vietnam's Mekong Delta. Their results argued that the combination of satellite images and appropriate machine learning method was a novel approach for measuring salinity intrusion. Ngo et al., (2023) carried out research on environmental quality for Vietnam over the period of 2012-2020. Their aim was to construct the PM2.5 pollution index derived from satellite image, meteorological and land use maps. Their results revealed there existed spatial distribution of PM2.5 and that the level of PM2.5 changed overtime.

On the other view, Vu et al., (2018) highlighted the importance of remote sensing data in assessing the urbanization process in the south of Ho Chi Minh City, Vietnam. Their results exhibited that the land cover changes were mostly explained by satellite imagery. Besides, their findings revealed that over the period of 2000-2010, the lowland area was highly affected by the increase of sea level while the highland area was covered by the urbanization. Using Landsat data, Ha et al., (2020) analyzed urbanization and land use changes in Thai Nguyen province, Vietnam from 2000 to 2016. Based on the empirical findings, the authors argued that there existed structural change in Thai Nguyen over the period.

In the next section, this study will present the materials and methodology utilized to conduct an analysis of the intrinsic relationship between NTL data and GRDP of Vietnamese provinces.

III. DATA AND METHODOLOGY

A. Data

With the aim of exploring the relationship between NTL and provincial GRDP in Vietnam, a balanced panel data from the period of 2010-2020 is constructed, which is sourced from the General Statistics Office of Vietnam (GSO) and data on NTL is drawn from the study of Chen et al., (2020). Table 1 provides the variables used in this study and their corresponding descriptive statistics.

Table 1. Descriptive statistics

Variable	Obs.	Mean	S.D.	Min.	Max.
GRDP	693	62786.39	115604.4	3908.3	990356
NTL	693	15086.7	65533.9	37.8	843126.2

(Source: Author's calculation)

GSO operating under the Vietnamese Ministry of Planning and Investment is tasked with collecting socio-economic data for Vietnam at both the national and provincial levels. Its data collection encompasses various aspects, ranging from administrative, land-related information to climate data, population demographics, labor and socio-economic activities. The GSO compiles and annually publishes these datasets in the Statistical Yearbook, which is accessible online on the GSO website (www.gso.gov.vn). For this study, data on GRDP at constant 2010 prices are collected from the GSO.

The NTL data is primarily obtained from DMSP-OLS and NPP-VIIRS NTL data. These two data sources have their own limitations. On the one hand, the former covers annual data from 1992 to 2013, but it involves saturation issue as well as blooming issue. On the other hand, the latter has better data quality, but timespan is available since 2012. To this end, using DMSP-OLS NTL data, NPP-VIIRS NTL data and DMSP-OLS radiance-calibrated NTL data, Chen et al., (2021) suggested another NTL data, which is so-called NPP-VIIRS-like NTL dataset. This dataset covers NTL data for the period of 2000-2022 and is available at https://shorturl.at/qEO12.

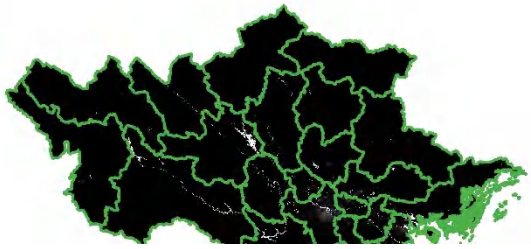

Figure 1. The North region of Vietnam at night

Figure 2. The South region of Vietnam at night

Figures 1 and 2 illustrate nighttime conditions in Vietnam, with white pixels indicating areas of energy consumption for lighting at night, while black pixels represent regions with minimal nighttime lighting. The distribution of these colors follows a discernible pattern. In the northern part of Vietnam, the white pixels are concentrated along the Da River and the Red River. Conversely, in the southern regions, urban areas are prominently covered by white pixels during the nighttime. The figure also highlights significant variations in NTL among different provinces in Vietnam. Specifically, the Southeast region, known for its economic activities, exhibits a high concentration of white pixels, indicating intense energy consumption at night. On the other hand, the Southwest region is characterized by a predominance of black pixels, suggesting lower levels of NTL. The figure implies evidence of divergence in economic activities during nighttime in Vietnam, with discernible spatial associations. The concentration of white pixels in specific regions indicates clusters of economic activities, providing valuable insights into the spatial distribution of nighttime economic dynamics in the country.

B. Methodology

The methodology for this study involves examining the relationship between NTL data and GRDP while accounting for spatial effects. Initially, the presence of spatial autocorrelation is assessed using the Moran's I index, enabling the identification of spatial dependence within the data. The Moran scatter plot is subsequently utilized to visually illustrate the spatial dependence. The study utilizes the spatial weight matrix derived from Vietnamese geospatial data, playing a crucial role in the estimation process by accommodating spatial relationships in the data. Finally, various types of spatial panel econometric models are applied to analyze the relationship between NTL data and GRDP while considering spatial effects over time.

a) Spatial autocorrelation using Moran's I

The Moran's I index is to investigate whether or not spatial dependence exists. The Moran's I index takes the following formula:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{S_0 \sum_{i=1}^{n}(x_j - \bar{x})^2} \quad (1)$$

where $S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}$ and $\bar{x}$ denotes mean value. Based on the Moran's I index, a test statistics z(I) is computed as follows:

$$z(I) = \frac{I - E(I)}{\sqrt{Var\ (I)}} \quad (2)$$

where E(I) denotes mean value of I and *Var(I)* denotes variance of I. The null hypothesis

in this context posits the presence of spatial independence. Thus, rejecting null hypothesis indicates the existence of spatial dependence.

The Moran scatter plot is built on the ground of the Moran's I index (Anselin, 1995). The horizontal axis of the graph presents the variable of interest and its spatial lag is illustrated on the other axis. The graph has 4 quadrants. Each quadrant exhibits different information. For example, at the upper-right of the graph is the so-called high-high quadrant contains the observation, which is featured by high order of correlation between the variable of interest and its spatial lag. On the other hand, at the lower-left of the graph is the so-called low-low quadrant. Besides, the graph involves the regression line, which can be shown as follows:

$$Wz = \alpha z + \mu \quad (3)$$

where W denotes a spatial weight matrix, the term Wz refers to the spatial lag of z, and μ denotes error term. The coefficient α is estimated by the OLS estimator. In this sense, the estimated coefficient α is equivalent to the Moran's I index. The statistical significance of α implies the existence of spatial dependence.

b) Spatial weights matrix

The spatial weight matrix is a key element in spatial econometric analysis. The spatial weight matrix is divided into at least 3 categories on the basis of contiguity weight, distance-based weight and distance-band weight. The general form of spatial weight matrix takes the following forms:

$$W = \begin{bmatrix} 0 & w_{12} & \cdots & w_{1n} \\ w_{21} & 0 & \cdots & w_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n2} & \cdots & 0 \end{bmatrix} \quad (4)$$

where, each entry $w_{ij} \in \boldsymbol{W}$ indicates spatial statistic relating to unit i and j and is assumed to be zero if $i = j$. Depending on the type of spatial weight matrix, the value of w_{ij} may vary. For example, in the case of binary contiguity weight, w_{ij} takes 0 or 1. In the context of Vietnamese geospatial characteristics, the appropriate selection for the spatial weight matrix relies on neighbor-based criteria rather than distance-based criteria. This choice is motivated by the elongated and narrow nature of the Vietnamese landscape.

c) Spatial panel model

To investigate the relationship between NTL and provincial GRDP in Vietnam, we begin the analysis with the OLS model as a benchmark and then proceed with various types of spatial econometric models. The OLS model with fixed-effect takes the form as follows:

$$y_t = x_t\beta + \mu + \varepsilon_t \quad (5)$$

where y_t is an n × 1 column vector of dependent variable, representing provincial GRDP. $\boldsymbol{X_t}$ is a matrix of independent variables including the constant term with dimensions $n \times k$, where k is the number of independent variables. $\boldsymbol{\mu}$ is a vector of estimated parameter in fixed effect model, while assumed as $N(0, \sigma_\mu^2)$ in random effect model. $\boldsymbol{\varepsilon_t}$ is assumed as i.i.d. with $N(0, \sigma_\varepsilon^2)$.

Vega & Elhorst (2013) provides an overview of different spatial econometrics model specification. Figure 3 shows that at the most left-hand side is the general nesting spatial model, which includes three different types of interaction effects among units to account for possible spatial effects. They are: (1) endogenous interaction effects among the dependent variable, (2) exogeneous interaction effects among the explanatory variables and

(3) interaction effects among the error terms. At the most right-hand side of figure 3 is the presence of the OLS model, which assumes no spatial effect. Running from the left-hand side to the right-hand side, it is clear that various spatial effects have been released. For example, the SAC model only considers spatially lag dependent variable and spatially autocorrelated error term; the SAR model takes into account spatially lag dependent variable and ignores other spatial effects.

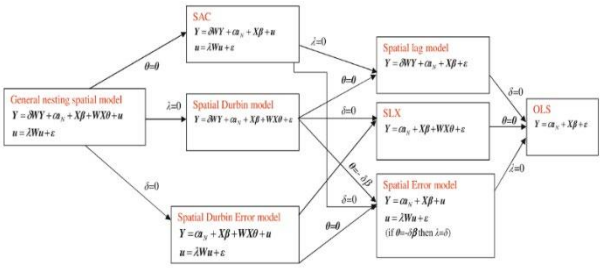

Figure 3. Different spatial econometrics model specification (Vega & Elhorst, 2013)

To include spatial effects in a standard panel model, the weights matrix representing the spatial relationships between provinces needs to be incorporated. The generalized nesting spatial panel model taking into account all types of spatial effects is give as follows (Elhorst, 2014):

$$\boldsymbol{y_t = \rho W y_t + X_t \beta + W X_t \theta + \lambda W \mu + \varepsilon_t} \quad (6)$$

where **W** denotes the cross-sectional weights matrix with $n \times n$ dimensions and each entry $w_{ij} \in \mathbf{W}$ illustrates the spatial weight related to units i and j. The term $\boldsymbol{Wy_t}$ denotes spatial lag of y_t. The term $\boldsymbol{WX_t}$ presents the spatial lag of $\boldsymbol{X_t}$. And the term $W\mu$ demonstrates the spatial lag of $\boldsymbol{\mu}$. ρ explores the spatial autoregressive coefficient, λ represents the spatial autocorrelation, while $\boldsymbol{\beta}$ and $\boldsymbol{\theta}$ are vector of parameters to be estimated, which depend on the model specified.

By imposing restriction on the coefficients of equation 6, other spatial econometrics models are derived. For example, if $\rho = 0$ and $\boldsymbol{\theta} = 0$, the model is so-called SEM; if $\lambda = 0$ and $\boldsymbol{\theta} = 0$, the model is so-called SAR; and if $\lambda = 0$, the model is so-called SDM. In concrete terms, equation 7 indicates the SEM model; equation 8 describes the SAR model; and the SDM model is indicated by equation 9. These models are shown as follows:

$$\boldsymbol{y_t = X_t \beta + \lambda W \mu + \varepsilon_t} \quad (7)$$

$$\boldsymbol{y_t = \rho W y_t + X_t \beta + \varepsilon_t} \quad (8)$$

$$\boldsymbol{y_t = \rho W y_t + X_t \beta + W X_t \theta + \varepsilon_t} \quad (9)$$

In this paper, we aimed to investigate the relationship between NTL and provincial GRDP in Vietnam over the period of 2010-2020. As such, we propose a log-linear model as the empirical analysis model:

$$lnGRDP_{it} = \beta_0 + lnNTL_{it}\beta_1 + \varepsilon_{it} \quad (10)$$

where *lnGRDP* denotes the logarithm of provincial GRDP; *lnNTL* presents the logarithm of NTL; and ε_{it} is the error term. All variables are expressed in logarithmic form to reduce the effect of heteroskedasticity.

Next, we combine (10) with (7) – (9) to present the spatial effect. This yields the following models as follows:

$$ln(GRDP)_{it} = \beta_0 + lnNTL_{it}\beta_1 + \lambda \sum_{j=1}^{n} w_{ij}\mu_{jt} + \varepsilon_{it} \quad (11)$$

$$ln(GRDP)_{it} = \rho \sum_{j=1}^{n} w_{ij} ln(GRDP)_{jt} + \beta_0 + lnNTL_{it}\beta_1 + \varepsilon_{it} \quad (12)$$

$$ln(GRDP)_{it} = \rho \sum_{j=1}^{n} w_{ij} ln(GRDP)_{jt} + \beta_0 + lnNTL_{it}\beta_1 + \theta \sum_{j=1}^{n} w_{ij} ln(NTL)_{jt} + \varepsilon_{it} \quad (13)$$

In this study, (10) and (13) are estimates with the balanced panel data over the period of 2010-2020. Except the model 10, other models involve random effect and individual-fixed effect. Equations 10-12 are estimated by the quasi–maximum likelihood (QML) estimators, which is available via *xsmle* command in Stata. The empirical results are shown in the next section.

IV. RESULTS

This section presents the empirical results of the study. It begins by providing the Moran's I index and displaying the Moran scatter plot, which are used to assess the presence of spatial autocorrelation and visualize spatial dependence. Then, the section focuses on the empirical findings related to the spatial econometric models discussed in the previous section.

A. The Moran's I index and the Moran scatter plot

The statistics of the Moran's I index with a focus on *lnGRDP* are shown in Table 2. The results indicate that the index is statistically significant and differs significantly from zero, providing evidence for the existence of spatial dependence. Furthermore, the figures demonstrate that the magnitude of spatial dependence increases over time, suggesting a strengthening of the spatial relationships.

Table 2. The statistics of the Moran's I index

Year	Moran's I	E(I)	S.D.(I)	Z	p-value
2010	0.234	-0.016	0.085	2.929	0.003
2011	0.236	-0.016	0.085	2.958	0.003
2012	0.237	-0.016	0.085	2.967	0.003
2013	0.240	-0.016	0.085	3.006	0.003
2014	0.260	-0.016	0.085	3.229	0.001
2015	0.287	-0.016	0.085	3.551	0.000
2016	0.297	-0.016	0.085	3.666	0.000
2017	0.297	-0.016	0.085	3.675	0.000
2018	0.302	-0.016	0.085	3.724	0.000
2019	0.298	-0.016	0.086	3.679	0.000
2020	0.307	-0.016	0.085	3.787	0.000

Note: E(I) denotes mean value of I. S.D.(I) denotes standard deviation of I.

To verify the presence of spatial dependence, Figure 4 displays the results of the regression where *lnGRDP* is the independent variable and its spatial lag, *WlnGRDP*, is the dependent variable. Additionally, the Moran scatter plot, utilizing the spatial Queen weight matrix from 2010 to 2020, is presented in the Appendix.

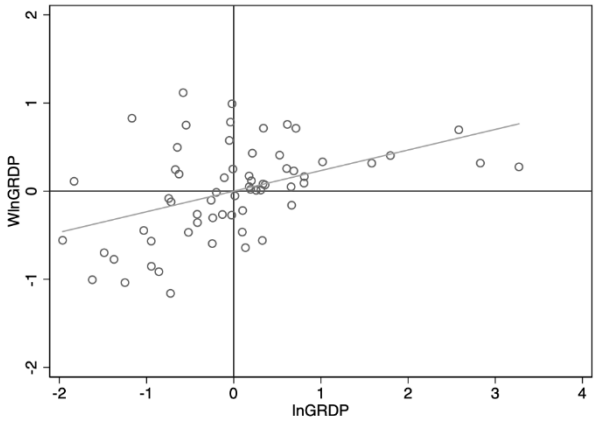

Figure 4. The Moran scatter plot for GRDP in 2020

where, $WlnGRDP = 0.307 \times lnGRDP + \mu$

B. Regression results

The section illustrates empirical results applying equations (10) - (13). Table 3 contain estimates for the OLS, SEM, SAR and SDM models, along with relevant statistical tests. The *Hausman* test is employed to determine the appropriate model, considering the nature of the data, i.e., fixed-effect or random-effect model. Additionally, statistical tests are performed for model selection. The former refers to comparison between the SDM model and the SAR model, while the latter refers to comparison between the SDM model and the SEM model. Besides, we conduct the Akaike's information criterion (AIC) and Bayesian information criterion (BIC) to compare the suggested models fit to the same dataset.

In Table 3, at the most left-hand side is the various variables of interest; the columns 2-3 provide the estimates obtained from the SEM model; the columns 4-5 show the estimates based on the SAR model; and the columns 6-7 illustrate the results estimated from the SDM model. The empirical results are revealed in three different panels. Panel A shows non-spatial estimates. Panel B indicates spatial estimates. And panel C exhibits various tests and statistics. The column 1 shows the OLS estimates with robust standard errors. Table 3 provides the results of estimating equations 11-13 in which the Queen weights is used as spatial weight matrix. Regarding the estimated coefficients, our figures, which are presented in panel A, reveal that the coefficient of *lnNTL* is positive and statistically significant across various models. In panel B, the coefficient *WlnNTL* is positive and statistically significant. Similarly, the spatial autoregressive coefficient (ρ) and the spatial autocorrelation coefficient (λ) are positive and statistically significant.

The statistics indicate that among the suggested models, the SDM model is the most appropriate one to fit the data as the model is correlated with the smallest statistics of AIC/ BIC. These findings are supported by the results derived from *test* and *testnl* command. It is true that the SDM model outweigh both the SAR model and the SEM model because the hypothesis of $\boldsymbol{\theta} = 0$ and that of $\boldsymbol{\theta} = -\rho\boldsymbol{\beta}$ are rejected. In relation to the Hausman test, since the null hypothesis of no correlation between individual-fixed effect and error term is rejected, it turns out that the FE model is better than the RE model in fitting data.

Based on the empirical results and the statistical tests conducted, the SDM model with individual-fixed effect emerges as the most suitable option for fitting the data, taking into account the presence of spatial dependence. The positive and statistically significant coefficients of *lnNTL*, *WlnNTL*, ρ, and λ provide compelling evidence of the existence of spatial relationships and their impact on the relationship between NTL data and GRDP in Vietnam. The findings from this study confirm that the spatial dimension plays a significant role in explaining economic growth dynamics in Vietnam. The positive coefficient of *lnNTL* indicates that an increase in NTL data, which can be interpreted as a proxy for economic activity, is associated with higher GRDP in the provinces. Moreover, the significant coefficients of *WlnNTL*, ρ, and λ underscore the relevance of spatial dependence, suggesting that the economic performance of one province is influenced by the economic activities in neighboring provinces.

These results carry important implications for policymakers and researchers in Vietnam. Understanding the spatial relationships and

the role of NTL data in measuring economic activity can assist policymakers in formulating targeted regional development strategies. By considering spatial effects, decision-makers can identify clusters of economic activities, promote balanced regional growth, and allocate resources more efficiently. Furthermore, this study contributes to the broader literature on economic analysis in developing countries, particularly those facing challenges with data availability at the regional level. By employing spatial econometrics techniques, researchers can extract valuable insights from satellite-based data, such as NTL data, to gain a deeper understanding of economic dynamics in regions with limited access to conventional economic data.

Table 3. The estimation results using the Queen weight

	OLS model	**SEM model**	**SEM model**	**SAR model**	**SAR model**	**SDM model**	**SDM model**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Panel A: Non-spatial estimates							
β_0	6.828***	-	9.964***	-	3.412***	-	4.644***
	(0.000)		(0.000)		(0.000)		(0.000)
lnNTL	0.452***	0.0515*	0.062**	0.095***	0.102***	0.053**	0.060*
	(0.000)	(0.069)	(0.049)	(0.000)	(0.000)	(0.017)	(0.010)
Panel B: Spatial estimates							
WlnNTL	-	-	-	-	-	0.104***	0.102***
						(0.003)	(0.003)
ρ	-	-	-	0.616***	0.595***	0.444***	0.430***
				(0.000)	(0.000)	(0.000)	(0.000)
λ	-	0.799***	0.788***	-	-	-	-
		(0.000)	(0.000)				
Panel C: Test and statistics							
FE	No	Yes	No	Yes	No	Yes	No
RE	No	No	Yes	No	Yes	No	Yes
λ^2	-	6.180**		19.870***		12.0500***	
		(0.045)		(0.000)		(0.007)	
SDM vs. SAR	-	-		-		8.830***	8.940***
						(0.003)	(0.002)
SDM vs. SEM	-	-		-		23.260****	25.010***
						(0.000)	(0.000)
AIC	1280.624	-911.514	-455.849	-1040.839	-588.049	-1103.810	-643.566
BIC	1289.706	-897.891	-433.144	-1027.216	-565.344	-1085.646	-616.320
R_w^2	-	0.676	0.676	0.786	0.784	0.796	0.795
R_b^2	-	0.622	0.622	0.597	0.603	0.487	0.503
R^2	0.578	0.578	0.578	0.481	0.491	0.395	0.408
N	693	693	693	693	693	693	693

V. CONCLUSION

This study investigates the relationship between NTL data and provincial GRDP in Vietnam from 2010 to 2020, with a focus on spatial effects. Data for the analysis were obtained from the GSO and the NTL data sourced from Chen et al. (2021). The empirical results presented in this study offer valuable insights into the intrinsic connection between NTL data and economic growth dynamics at the provincial level in Vietnam.

The empirical findings reveal a statistically significant and increasing level of spatial dependence over time, indicating the existence of spatial relationships influencing the economic growth patterns among provinces. Spatial econometric models, including the OLS, SEM, SAR, and SDM models, were employed to analyze the data. The *Hausman* test was utilized to determine the appropriate model, and statistical tests were conducted for model selection. Consistently, the SDM model with fixed effect was identified as the most suitable choice for fitting the data with spatial dependence

The study highlights the importance of considering spatial dependence when examining economic growth dynamics in Vietnam, as economic activities in neighboring provinces significantly influence one another. This insight is of considerable significance for policymakers and researchers in Vietnam, as understanding spatial relationships and the NTL data in measuring economic activity can inform targeted regional development strategies and resource allocation for balanced regional growth. Furthermore, this research contributes to the broader literature on economic analysis in developing countries, particularly those facing challenges with limited access to conventional economic data at the regional level. By utilizing spatial econometrics techniques and leveraging satellite-based data, such as NTL data, researchers can gain deeper insights into economic dynamics in regions where data availability is constrained.

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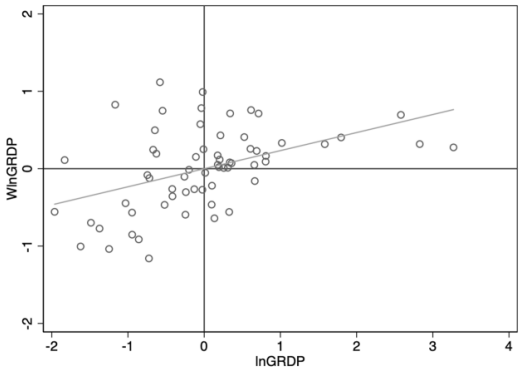
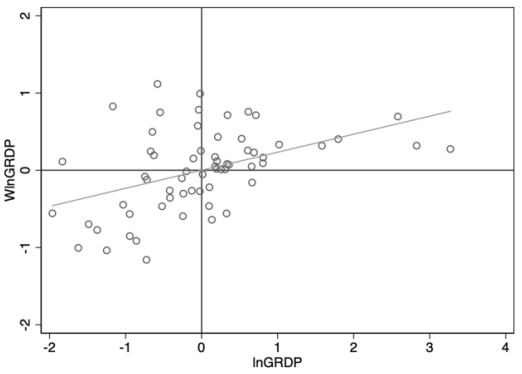
APPENDIX

Panel A: The Moran scatter plot for GRDP in 2010



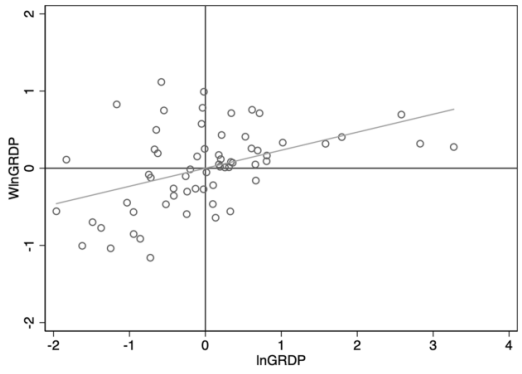
$WlnGRDP = 0.234 \times lnGRDP + \mu$

Panel B: The Moran scatter plot for GRDP in 2011



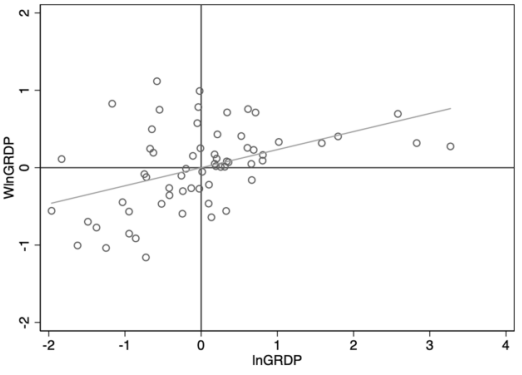
$WlnGRDP = 0.236 \times lnGRDP + \mu$

Panel C: The Moran scatter plot for GRDP in 2012



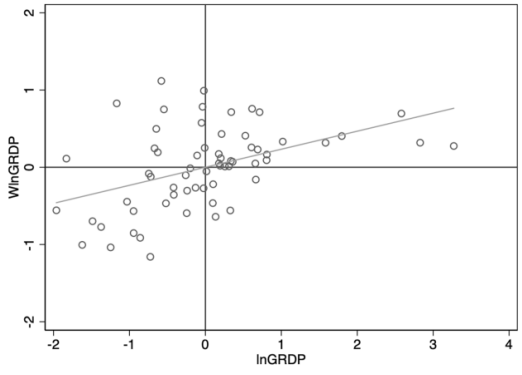
$WlnGRDP = 0.237 \times lnGRDP + \mu$

Panel D: The Moran scatter plot for GRDP in 2013



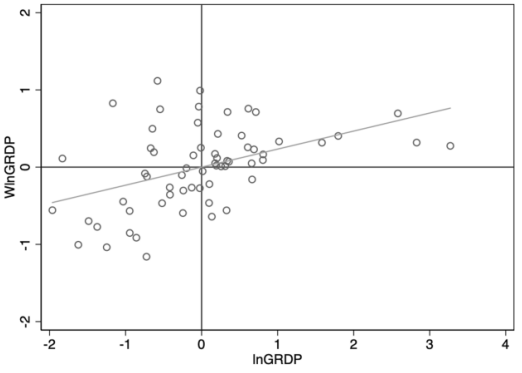
$WlnGRDP = 0.241 \times lnGRDP + \mu$

Panel E: The Moran scatter plot for GRDP in 2014



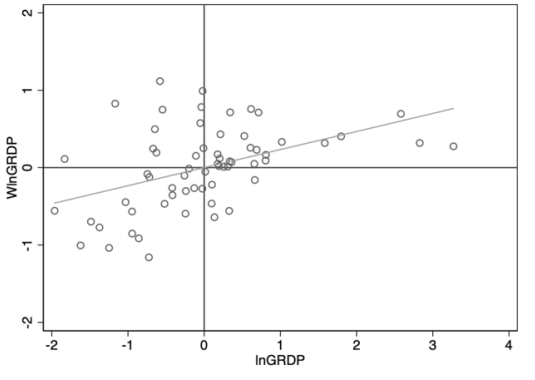
$WlnGRDP = 0.260 \times lnGRDP + \mu$

Panel F: The Moran scatter plot for GRDP in 2015



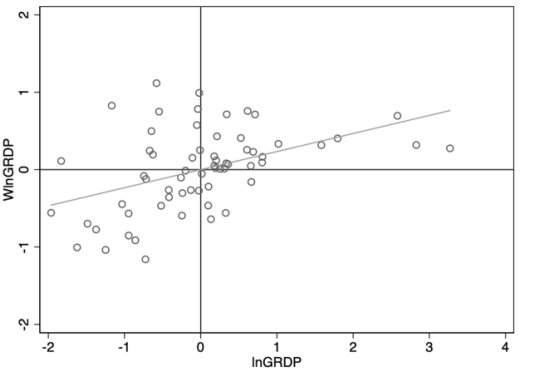
$WlnGRDP = 0.287 \times lnGRDP + \mu$

Panel G: The Moran scatter plot for GRDP in 2016



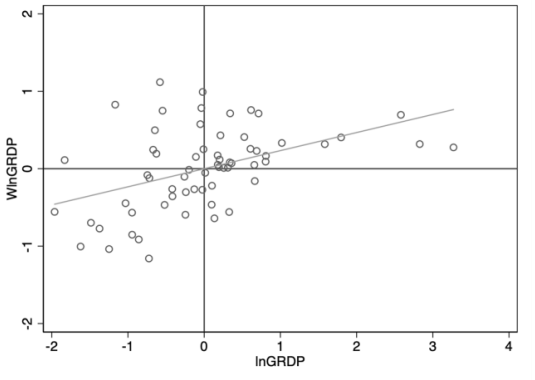
$$WlnGRDP = 0.297 \times lnGRDP + \mu$$

Panel H: The Moran scatter plot for GRDP in 2017



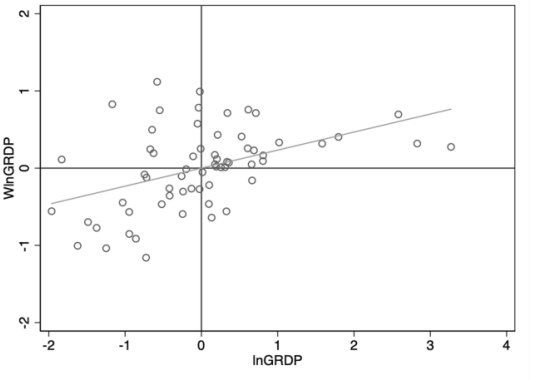
$$WlnGRDP = 0.297 \times lnGRDP + \mu$$

Panel I: The Moran scatter plot for GRDP in 2018



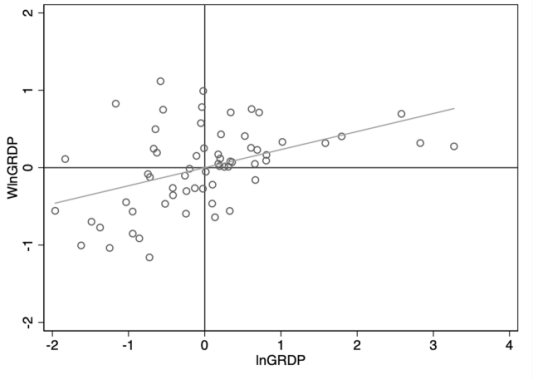
$$WlnGRDP = 0.302 \times lnGRDP + \mu$$

Panel J: The Moran scatter plot for GRDP in 2019



$$WlnGRDP = 0.299 \times lnGRDP + \mu$$

Panel K: The Moran scatter plot for GRDP in 2020



$$WlnGRDP = 0.307 \times lnGRDP + \mu$$

IMPACT OF COVID-19 ON GLOBAL STOCK MARKET VOLATILITY: A COMPARISON BETWEEN DEVELOPED AND EMERGING MARKETS[*]

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Abstract: This study delves into the effects of the COVID-19 pandemic and government policies' stringency level on the volatility of stock markets in 31 developed and emerging economies. Besides, we compare the stock market volatility between these two markets. We found no connection between the rise of COVID-19 cases or death rates and the stock market's volatility in either market. Nonetheless, the stringency index of governments' measures and changes in the exchange rate have a positive and robust relationship with stock market volatility in both. With the same stringency level of government measures, emerging markets are more volatile than developed markets due to their unstable exchange rate. Therefore, our findings imply that investors should develop suitable strategies, while policymakers should create customized plans to tackle crises in different countries.

Keywords: *stock market volatility, COVID-19, government stringency index, cross-country analysis*

I. INTRODUCTION

Since its emergence in December 2019, the novel coronavirus (COVID-19) has infected approximately 452 million people and caused over 6 million deaths in about 240 countries and territories around the globe (Bhatia et al., 2022). The attention of business managers, academic economists, and finance scholars have thus been shifted from traditional business risks to speculative news about COVID-19 and governments' measures, especially after the WHO declared COVID-19 as a global pandemic on March 11, 2020 (Alaoui Mdaghri et al., 2020). In response, governments worldwide have actively adopted measures to halt the spread of the pandemic, such as social distancing, school and workplace closures, virus testing, and restrictions on transportation, public gatherings, and commercial air travel (Phan & Narayan, 2020). According to Chung et al. (2021), government interventions would curb the spread of the pandemic since these policy responses limit social interactions. However, Hunjra et al. (2021) found that such interactions are necessary for commercial activities, and thus these measures have significant economic consequences in both developed and emerging markets. Besides that, policymakers and investors can foresee consequences of government interventions in the future economy through the stock market as it reflects viewpoints of a group of complex and opinionated investors (Ashraf, 2020).

Indeed, the stock markets around the world have experienced severe volatility at that time. For example, the US has suffered from a 14% and

[*] Best poster presentation award

22% average daily increase in COVID-19 cases and deaths respectively from 11 March 2020 to 26 November 2021 (Ritchie et al., 2021). One day after COVID-19 was declared - March 12, 2020 ("Black Thursday"), the US stock market witnessed a decrease of 9.5% in the S&P 500 and 9.4% in the NASDAQ Composite (Imbert & Franck, 2020). The global stock markets also suffered from a sharp decline. The Nikkei 225 (Japan) and the Hang Seng Index (Hong Kong) both plunged by more than 20%, below their 52-week closing highs (Huang, 2020), while the FTSE 100 Index of the UK dropped by 10.87% (Wearden, 2020).

To cope with the pandemic's spread, nations worldwide implemented various measures. The stringency index represents the level of stringency of the governments' responses to the COVID-19 pandemic (Alaoui Mdaghri et al., 2020; Bakry et al., 2022). Various studies have compared the impacts of COVID-19 and the stringency level of governments' measures on stock market volatility in developed and emerging markets. The effect of governments' stringency measures on stock market volatility which has been found in 27 developed and 23 emerging markets (classification of Morgan Stanley Capital International) is different (Bakry et al., 2022; Harjoto et al., 2021). Moreover, according to Mdaghri et al. (2020), while government intervention reduced volatility concerns in developed countries, the situation in developing countries was more complex and diverse. The uncertainty about the economic resilience of developing countries and poor financial growth projections added to the volatility. In terms of the effect of COVID-19 confirmed cases on stock market volatility, Bakry et al. (2022) stated that stock market volatility and COVID-19 confirmed cases have a positive and robust relationship in both developed and emerging markets. This may imply investors perceive higher risk in their investment in stock market when COVID-19 confirmed case growth increases. Hence, they may respond to stock market by withdrawing their investment, which leads to stock market volatility. Furthermore, Uddin et al. (2021) argued that when the death rate rises, investors tend to perceive risk in the stock market, and the government's measures are likely to be more stringent. Investors' concerns about rising death rates may also be amplified by higher uncertainty avoidance in developing market country cultures (Ashraf, 2020).

The growing recent literature discusses stock market volatility in some sectors (Baek et al., 2020; Engelhardt, et al., 2021) and/or in several specific countries: the US (Albulescu, 2021; Baig et al., 2021); Asian countries (Hunjra et al., 2021) during the COVID-19 pandemic as well as the relationship between stock market volatility and government responses (Ibrahim et al., 2020; Uddin et al., 2021; Zaremba et al., 2020). It can be seen that few studies focus on a cross-country analysis of stock market volatility, COVID-19, and governments' measures (Ashraf, 2020; Bakry et al., 2022; Harjoto et al., 2021). Additionally, governments, regulators, business executives, and finance scholars' worries about the effects of government interventions on stock market volatility during COVID-19 necessitate additional research (Hunjra et al., 2021). Accordingly, this study addresses this gap by analyzing the nexus between stock market volatility, the number of COVID-19 cases and death rates, and the stringency level of governments' measures in 19 developed and 12 emerging markets from 11 March 2020 (COVID-19 declaration

date by the WHO) to 31 December 2021. Moreover, this research compares stock market volatility among the two groups of markets during the COVID-19 pandemic. From this study's findings, policymakers in these countries can respond to the pandemic with appropriate measures, and investors can react to such volatile period with proper investment strategies. Therefore, this research focuses on two primary questions, including:

RQ1. How do the COVID-19 pandemic and the stringency level of governments' measures affect stock market volatility?

RQ2. What are the similarities and differences between stock market volatility in developed and emerging markets during the COVID-19 pandemic?

The remainder of the paper is structured as follows. The following section outlines the research design. The third section discusses the results. The last section concludes the study.

II. HYPOTHESIS DEVELOPMENT

This study examines how the COVID-19 case growth and stringency level of governments' measures affect stock market volatility. The results are tested by replacing the COVID-19 case growth by COVID-19 death rate in robustness test. The control variables are trading volume and exchange rate. There is a dummy variable for two types of market.

A. The COVID-19 case growth and stock market volatility

The COVID-19 case growth is the daily growth of the number of COVID-19 confirmed cases in a country (Alaoui Mdaghri et al., 2020; Ashraf, 2020; Uddin et al., 2021). Based on the study of Bakry et al. (2022), in both developed and emerging markets, stock market volatility and confirmed COVID-19 cases have a positive and strong relationship. Harjoto et al. (2021) also found that daily cases rates significantly affect daily volatility in developed and emerging markets. In consistence with these findings, the hypotheses are suggested as follows.

H1a: The COVID-19 case growth has a positive relationship with stock market volatility in developed markets.

H1b: The COVID-19 case growth has a positive relationship with stock market volatility in emerging markets.

B. The stringency index and stock market volatility

The stringency index measures the stringency level of the nations' responses to the pandemic (Alaoui Mdaghri et al., 2020; Bakry et al., 2022). Zaremba et al. (2020) stated that government actions are associated with increasing stock market volatility. Bakry et al. (2022) also pointed out that there is a strong positive link between volatility and the strictness of government interventions in emerging markets, but there is a negative relationship between these factors in developed markets. Furthermore, the institutional theory claims that COVID-19 has a different influence in emerging markets than it does in developed markets (Bakry et al., 2022). In accordance with these findings, the hypotheses are formulated as follows.

H2a: The stringency level of government's measures has a negative relationship with stock market volatility in developed countries.

H2b: The stringency level of government's measures has a positive relationship with stock market volatility in emerging countries.

C. The COVID-19 death rate and stock market volatility

The COVID-19 death rate is the ratio of the number of COVID-19 confirmed deaths over the number of cumulative COVID-19 confirmed cases in a country (Alaoui Mdaghri et al., 2020; Uddin et al., 2021). Harjoto et al. (2021) concluded that an increase in daily deaths from COVID-19 increases the stock market volatility in emerging markets. However, daily fatalities have little impact on stock market volatility in developed markets. In the research of Bakry et al. (2022), the death rate has a positive and substantial effect on volatility only in the emerging markets. It is likely that investors in developed markets place higher emphasis on the information content in confirmed cases than death rates when evaluating the prospects on the economy and businesses. Thus, the hypotheses are introduced as follows.

H3a: The COVID-19 death rate has a negative relationship with stock market volatility in developed markets.

H3b: The COVID-19 death rate has a positive relationship with stock market volatility in emerging markets.

D. Types of markets

To compare the effects of COVID-19 and government measures' stringency level on stock market volatility in two types of markets. This study uses DEV = 1 for a country that is classified as a developed market, and DEV = 0 for a country that is classified as an emerging market. Based on the institutional theory (Khanna & Palepu, 2011), emerging markets frequently experience more stock market volatility due to a lack of financial infrastructure and regulations. In line with this theory, Bakry et al. (2022) found that investors in emerging countries exhibit higher anxiety about the increasing COVID-19 case growth, death rate, and announcement of government measures. Thus, the hypothesis is introduced as follows.

H4: Stock market volatility in emerging markets is greater than that in developed markets.

III. METHODOLOGY

A. Data

This study uses daily data from 31 markets into 2 panels, including 19 developed markets and 12 emerging markets as the classification of Morgan Stanley Capital International. The detailed information of countries, major stock market index of each country is provided in the Table 1. The timeframe is from 11 March 2020 (COVID-19 declaration date by the WHO) to 31 December 2021. All data was collected from Refinitiv. Table 2 summarizes the relevant variables.

B. Empirical model

In other to avoid the heteroskedasticity and autocorrelation problem in panel data, feasible generalized least squares (FGLS) is run. The regression model is proposed to determine the impact of COVID-19 case growth, and governments' stringency responses on stock market volatility in developed and emerging markets.

$$SMV_{i,t} = \alpha + \beta_1 CG_{i,t} + \beta_2 SI_{i,t} + \beta_3 TV_{i,t} + \beta_4 ER_{i,t} + \beta_5 DEV + \varepsilon \quad (1)$$

Where:

$SMV_{i,t}$: The natural logarithm of stock return volatility of country i on day t derived from GARCH (1,1)

$CG_{i,t}$: The daily growth of the number of COVID-19 confirmed cases of country i on day t

$SI_{i,t}$: The natural logarithm of the daily stringency index of country i on day t

$TV_{i,t}$: The natural logarithm of the daily trading volume in USD of stock market of country i on day t

$ER_{i,t}$: The daily percentage change in the exchange rate in terms of USD for a country i on day t

DEV: Dummy variable for types of markets, 0 for developed markets and 1 for emerging markets

α: a constant term

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$: beta coefficients

ε: the residual

To check the robustness of the results, case growth is replaced by the death rate holding all else constant. Repeating the main test, the feasible generalized least squares regression model is proposed to determine the impact of COVID-19 death rate, and governments' stringency responses on stock market volatility in developed and emerging markets.

$$SMV_{i,t} = \alpha + \beta_1 DR_{i,t} + \beta_2 SI_{i,t} + \beta_3 TV_{i,t} + \beta_4 ER_{i,t} + \beta_5 DEV + \varepsilon \quad (2)$$

Where:

$DR_{i,t}$: The ratio of the number of COVID-19 confirmed deaths over the number of cumulative COVID-19 confirmed cases in a country i on day.

Table 1. Country sample

	Developed financial markets		Emerging markets	
No.	**Country**	**Stock market index**	**Country**	**Stock market index**
1	Australia	S&P/ASX 200	Brazil	BOVESPA
2	Austria	ATX	China	Shanghai SE Composite
3	Belgium	BEL 20	Czech Republic	PX
4	Canada	S&P/TSX 300 Composite	Greece	Athex Composite
5	Denmark	OMX Copenhagen 20	Hungary	Budapest SE
6	Finland	OMX Helsinki 25	Mexico	S&P/BMV IPC
7	France	CAC 40	Philippines	PSEi
8	Germany	DAX	Poland	WIG 30
9	Hong Kong	Hang Seng	Russia	MOEX
10	Italy	FTSE MIB	South Korea	KOSPI 200
11	Japan	Nikkei 225	Taiwan	Taiwan SE Weighted Index
12	Netherlands	AEX	Turkey	BIST 100
13	New Zealand	S&P/NZX 50		
14	Norway	OBX		
15	Spain	IBEX 35		
16	Sweden	OMX Stockholm 30		
17	Switzerland	SMI		
18	United Kingdom	FTSE 100		
19	United States	S&P 500		

(Source: MSCI, Refinitiv)

C. Descriptive statistics

Table 3 reports descriptive statistics of variables. Daily stock market volatility (SMV) ranges from -0.1860 to 0.1077. Regarding independent variables, case growth (CG) varies in a wide range from -7.12% to 160.94% with the average of 1.4392% indicating different phases of COVID-19. In response, the stringency index (SI) has the lowest value of 1.022 and largest value of 4.605 with a mean of 4.006. In terms of control variables, trading volume (TV) has a mean of 18.8145 and standard deviation of 2.82, implying a slight fluctuation in trading volume. Change in exchange rate (ER) has a range of -0.2838 to 0.5203 and fluctuates slightly by 0.0084.

Table 2. Variable measurements

Variable	Description/Measurement
Dependent variable: Stock market volatility (SMV)	The daily stock index return volatility of a stock market measured by GARCH (1,1) model
Independent variables: The COVID-19 case growth (CG)	The natural logarithm of the daily growth of the number of COVID-19 confirmed cases in a country
The COVID-19 death rate (DR)	The ratio of the number of COVID-19 confirmed deaths over the number of cumulative COVID-19 confirmed cases in a country
The stringency index (SI)	The natural logarithm of the daily stringency index of a country
Control variables: Trading volume (TV)	The natural logarithm of trading volume in USD of a stock market
Change in exchange rate (ER)	The daily percentage change in the exchange rate for a country
Market Type (DEV)	DEV = 1 for developed market DEV = 0 for emerging market

Table 3. Descriptive Statistics

	SMV	CG	SI	TV	ER
Mean	-4.8E-05	0.014	4.006	18.82	9.5E-05
Median	0.000	0.004	4.098	18.55	0.00
Max.	0.108	1.609	4.605	26.58	0.52
Min.	-0.186	-0.071	1.023	10.71	-0.282
SD	0.015	0.046	0.347	2.82	0.008

IV. RESULTS

To address the effect of heteroskedasticity and autocorrelation on the model, the feasible generalized least squares is run. Table 4 indicates that case growth (CG) is negatively insignificant, while stringency index (SI) is statistically significant and has a positive relationship with stock market volatility (SMV). Furthermore, trading volume (TV) is negatively insignificant. While dummy variable (DEV) and change in

exchange rate (ER) are statistically significant and have a positive relationship with stock market volatility (SMV).

Table 4. Results of Equation 1

Variable	Coefficient	t-Statistic	Prob.
SMV	-0.001769	-1.951250	0.0510
CG	-0.004796	-0.963510	0.3353
SI	0.000500	2.435433	0.0149
TV	-2.10E-05	-0.926353	0.3543
ER	0.069239	5.501296	0.0000
DEV	0.000283	2.148910	0.0317

Table 5 shows that death rate (DR) is positively insignificant, while stringency index (SI) is statistically significant and has a positive relationship with stock market volatility (SMV). In addition, trading volume (TV) is insignificant. Meanwhile, dummy variables (DEV) and change in exchange rate (ER) are statistically significant and have a positive relationship with stock market volatility (SMV).

Table 5. Results of Equation 2

Variable	Coefficient	t-Statistic	Prob.
SMV	-0.001781	-1.965309	0.0494
DR	0.047568	0.460468	0.6452
SI	0.000470	2.290757	0.0220
TV	-1.90E-05	-0.841840	0.3999
ER	0.069196	5.499599	0.0000
DEV	0.000294	2.225095	0.0261

In the main test, there is no relationship between COVID-19 case growth and stock market volatility. This result is inconsistent with the previous literature (Bakry et al., 2022; Harjoto et al., 2021). The difference between this research's findings and others' may be due to difference in time span of the sample. This research analyzes the relationship of stock market volatility until the end of 2021. Meanwhile, most of the previous papers conduct the analysis for several months in 2020. This result may imply that by the end of 2021, investors might not respond as aggressively to negative information about COVID-19 as they did when the pandemic had just started. According to Ashraf (2020), stock markets reacted to the COVID-19 pandemic strongly in the initial period of COVID-19 outbreak, but their reactions have changed over time, depending on the pandemic's stage. Thus, stock market volatility may not be associated with COVID-19 case growth over such a long period.

In the robustness test, case growth is replaced by death rate to confirm the relationship between COVID-19 and stock market volatility. There is also no relationship between death rate and stock market volatility in developed market, which is in line with previous research (Bakry et al., 2022; Harjoto et al., 2021).

The main test indicates that there is a positive and significant relationship between government measures' stringency level and stock market volatility. An increase in the stringency of government is responded an increase of 0.0005 unit in daily stock market volatility. The result is confirmed by the robustness test which indicates that an increase of one index point in the severity of government responses leads to a 0.00047 increase in daily stock market volatility. These results imply that an increase in stringency index may trigger increased uncertainty about how the government assess the severity of the pandemic in the market (Bakry et al., 2022). This finding is consistent with the finding of previous papers, for example Bakry et al. (2022); Harjoto et al. (2021); Uddin et al. (2021).

Regarding control variables, there is no relationship between trading volume and stock market volatility. The robustness test also confirms this finding. This result is not supported by the supply of stock market returns hypothesis (Ibbotson & Chen, 2003), which may be explained by the Ashraf (2020); stock markets reacted aggressively to the COVID-19 pandemic in the early stages of the outbreak, but their reactions have differed over time, depending on the stage of the pandemic. In consistent with Ashraf (2020), this study finding implies that over such a long period of this research, negative news about COVID-19 and government's measures may not prompt investors in both developed and emerging markets to withdraw their money out of the stock market, which results in fewer volatile patterns of trading volume.

Interestingly, there is a positive and significant relationship between exchange rate and stock market volatility. A 1% increase in daily change of exchange rate is associated with about 0.069239% increase in stock market volatility. This is confirmed by the robustness test which reveals a 1% increase in exchange rate return is associated with a 0.069196% increase in stock market volatility. Our finding is consistent with the findings of Mun (2007) and Walid et al. (2011) that returns on foreign exchange rates signal future market risk. This implies that an increase in daily change in exchange rate is associated with increasing stock market volatility.

The main test indicates that the relationship between stock market volatility and independent variables is different between the developed markets and emerging markets because the dummy variable of types of market (DEV) is statistically significant. This is consistent with previous studies (Bakry et al., 2022). The positive coefficient of DEV in Tables 4 and 5 shows that the stock market volatility for emerging markets is greater than that of developed markets if other variables are the same. The institutional theory supports this finding that COVID-19 has different impacts on developed and emerging markets (Khanna & Palepu, 2011). With the same stringency level of government measures, emerging markets would suffer greater stock market volatility than developed markets because of insufficient financial facilities and regulations. Given that, any government measures that restricts the capacity to complete commercial transactions are anticipated to encounter a negative response from investors in emerging markets. Moreover, the existing research proved that the volatility of stock markets in the emerging markets associates with the investors' concern about the death rate rises (Ashraf, 2020 and Uddin et al., 2021) and the lack of confidence in the cases report and the interventions from the government (Uddin et al., 2021).

V. CONCLUSION

This paper studies the relationship between stock market volatility and COVID-19 pandemic and government measures' stringency level using the FGLS on the panel data of 31 markets from March 11, 2020 to December 31, 2021. We found no relationship between stock market volatility and COVID-19 in terms of case growth and death rate. However, there is a positive and robust relationship between government measures' stringency level and stock market volatility in both types of markets. Additionally, stock market volatility in developed and emerging markets are different. With the same stringency level of government measures, emerging markets

would suffer from greater stock market volatility than developed markets because of insufficient financial facilities and regulations (Khanna & Palepu, 2011).

The results have implications for academic research, investment, and policy. First, the result of no association between the pandemic and stock market volatility from 11 March 2020 to 31 December 2021 may imply that COVID-19 case growth and death rate are unrelated to stock market volatility over a long period. Further research may examine investors' behavior during this period closely to evaluate if stock markets are immune to information about COVID-19 over time. Second, this study contributes to the existing literature findings about the relationship of a pandemic (COVID-19) on stock market volatility. It might be used to support further research on stock market volatility during future health crisis and provide information for preparation for them. Third, investors can respond to information related to COVID-19 through findings of the relationship between stock market volatility and the government's stringent measures. An increase in the stringent level of government's response to COVID-19 may lead to greater stock market volatility, which may negatively impact their portfolio returns. In this case, they may consider withdrawing their money from volatile stocks and switching to safe-haven assets including gold, government bonds, and defensive stocks. Fourth, governments should consider tailoring their regulatory responses to pandemics to their specific national contexts to minimize the financial impact. This study demonstrates that as the government's policy to COVID-19 becomes stricter, stock market volatility increases. As a result, it is suggested that policymakers and other associated organizations, such as Securities and Exchange Commission (SEC) authorities analyze the effects of COVID-19 policy measures on stock market volatility to promote a fair, efficient, dynamic, and inclusive stock market.

This paper has some limitations and thus suggests some potential areas for future research. First, this research does not examine how each element of government stringency measures affects stock market volatility. Hence, future studies can consider analyzing the impact of specific government measures, government containment and health, and economic support policy responses on stock market volatility. Second, the study does not analyze country-level factors that cause the difference in the relationship between stock market volatility and COVID-19 in developed and emerging markets, such as quality of governance or trust in government that could explain diverse investment behavior in the different markets.

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THE IMPACT OF SUPPLY CHAIN RISKS ON SUPPLY CHAIN PERFORMANCE: AN EMPIRICAL STUDY FROM THE MANUFACTURING FIRMS IN BINH DUONG, VIETNAM[❁]

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Abstract: Recently, there has been a significant increase in the importance of managing supply chain risks due to the rising levels of risk and disruptions in supply chains. To enhance their competitive advantages, companies are adopting risk-redundancy approaches, which brings about new challenges and risks to the entire supply chain and the economy. Hence, this research aims to identify the factors (supply risk, demand risk, process risk, financial risk, and environmental risk) that affect the supply chain performance of manufacturing companies in Binh Duong, Vietnam. This study utilizes VOSviewer to provide a comprehensive overview of the existing literature on supply chain risk management and SPSS to conduct a quantitative analysis of 199 responses from manufacturing company staff in Binh Duong. The findings indicate that supply risk, demand risk, and process risk have a negative impact on supply chain performance. The study is expected to suggest some insights for further research, contributing to a more holistic understanding of the complexities and dynamics of supply chain risk management and its implications for supply chain performance in the Vietnamese context.

Keywords: *supply chain risk management (SCRM), supply chain performance, supply chain risk (SCR), manufacturing firms, VOSviewer, Vietnam*

I. INTRODUCTION

In the context of globalization, supply chain management (SCM) with stronger firm-supplier-customer integration is becoming more prevalent across all firms (Rangel et al., 2015). Specifically, organizations of all sizes and industries are continuously reevaluating their approaches to achieve effective supply chain management in order to sustain profitability and competitive advantages. Toyota is a typical example of a company that has developed innovative concepts, including judoka and just-in-time (lean techniques). The new strategy is the key to Toyota's success, as it allows for lower-cost production of smaller volumes with greater complexity and shorter lead times (Wee & Simon, 2009). Moreover, outsourcing strategies and global partnerships have become widely adopted trends (Aqlan & Lam, 2015). However, while organizations seek to strengthen their competitive edges and satisfy customers, they bring new dangers and difficulties to the entire supply chain and economy (Christopher et al., 2011).

[❁] Best poster presentation award

Numerous recent events have proved that businesses have encountered significant risks (Jüttner et al., 2003; Norrman & Jansson, 2004). Most seriously, COVID-19 outbreaks and the Russia-Ukraine war have triggered widespread changes in global trade environments (Pournader et al., 2020), financial recession (Casselman, 2020; Jüttner & Maklan, 2011), devastating impacts on the global economy (Smialek & Tankersley, 2020). Those risks eventually make global supply chains more sophisticated and harder to manage than ever before.

Vietnam's manufacturing industry is likewise impacted by supply chain-related risks. The Vietnam Cotton and Spinning Association (2022) reported that 0.87 percent increase in the price of imported cotton from Brazil, the United States, and India, bringing the price per ton to approximately USD 1,625. Consequently, textile and garment producers in Vietnam are unable to pass on the price increase to consumers in the short term, which has a negative impact on their revenue. Additionally, the lockdown in the country has prevented many enterprises from acquiring raw materials and has caused delivery delays with foreign partners (Vietnam Briefing, 2022). Vietnam has recently focused on the growth of its electronic industry, particularly in the semiconductor sector, where Intel and Samsung are active participants. Nevertheless, Samsung Vietnam was concerned that the production of its new models was temporarily halted due to frequent disruptions in the import of components from China through the Lang Son border crossing (Vietnam Briefing, 2022). Meanwhile, Intel predicts that the semiconductor supply bottleneck would persist through 2024. It means electronic companies must face manufacturing difficulties due to low capacity and lead-time of supply of assemblies and components.

From a theoretical perspective, SCRM study has also not been adequate to meet the challenges related to the rising supply chain risks (Khan & Burnes, 2007; Thun & Hoenig, 2011). Extant studies have strongly concentrated on supply risk (Tang & Nurmaya Musa, 2011). Nevertheless, the following researchers have demonstrated that the supply chain is not only vulnerable to risks from the supply side but also from internal production, customer, and collaboration sides (Chen et al., 2013). Chen et al. (2013) noted that the ripple impact of the supply chain makes it imperative to manage supply chain risks in collaboration with other supply chain partners including both company's suppliers and customers. External side risk is subsequently added in the SCRM study field although its research paper is still limited (Shahbaz, Sohu, et al., 2019; Sodhi et al., 2012).

On the other hand, while manufacturing companies in Western nations and the United States have embraced SCRM to mitigate supply chain risks, research on multi-dimensional risk evaluation and its impact on performance is limited in developing Asian countries (Shahbaz, Kazi, et al., 2019). As at an early stage, Vietnamese local companies struggle with risk recognition and classification, hindering their ability to implement SCRM concepts and adapt to global supply chain fluctuations (Vanany et al., 2007). This lack of adaptation can lead to significant losses and even insolvency. Therefore, understanding risk classification and its impact on supply chain performance is crucial for organizations to effectively implement mitigation strategies and improve overall performance.

Given the paucity of empirical research on the impact of SCR on supply chain performance

in developing nations such as Vietnam, Binh Duong province (Vietnam) was selected as the empirical setting for this study. This is because Binh Duong is "the southern industrial hub of Binh Duong with 3,428 newly-established companies" and is also a hub of 29 industrial parks with different manufacturing enterprises and more than 9 industrial clusters that have been operated (Binh Duong Province Portal, 2022). As a result, it needs a considerably higher level of expertise and experience in SCRM management to preserve competitive advantage and profitability. It is anticipated that the findings will provide recommendations to Vietnamese producers.

This study aims to investigate factors of SCR affecting the supply chain performance of manufacturing in Binh Duong. Accordingly, the specific objectives of this research are:

(1) to employ co-occurrence, co-citation and bibliographic coupling techniques to systematically review supply chain risk management literature

(2) to identify SCR factors that affect the supply chain performance of manufacturing companies in Binh Duong, Vietnam.

(3) to assess the impact level of SCR factors on the supply chain performance of manufacturing companies in Binh Duong, Vietnam.

II. METHODOLOGIES

A. Research design

The research design for the paper on Supply Chain Risk Management (SCRM) was carried out systematically and comprehensively. Initially, an extensive literature review was conducted using co-occurrence, co-citation, and bibliographic coupling techniques in VOSviewer. This process helped identify relevant sources and establish the theoretical framework and research questions. A 5-point Likert scale was used, and the collected data were subjected to quantitative analysis using the statistical software SPSS. The choice of a quantitative approach was made to facilitate the analysis of research results, generate reliable descriptions, and enable appropriate comparisons.

This paper follows the research of Gia, et al. (2021) "Risk management and logistical performance: A case of the fishery supply chain north central coast of Vietnam" and Shahbaz, Kazi, et al. (2019) "The impact of supply chain risks on supply chain performance: Empirical evidence from the manufacturing of Malaysia". However, to determine the impact of disruption risk (environmental risk) and several sources of operational risk (supply risk, demand risk, process risk, and financial risk) on manufacturing firms in Vietnam, this paper has modified the interdependent variables to be more inclusive. The adjustments are based on the theoretical frameworks of Wagner and Bode (2008) as well as Chen et al. (2013).

B. Sampling method

The study's target population consists of Vietnam's listed manufacturing companies. This study's sample consists of manufacturing employees from a variety of departments and years of experience at Binh Duong-based firms.

Applying this formula of K value of 5, it can be seen that the minimum sample size should be:

$$n = 5*m = 28*5 = 140$$

The study, therefore, proposes selecting an initial sample of 140 samples. However, if the sample size is increased to 199 respondents, the result is likely to be more reliable. The data is collected via a direct online survey, with survey participants selected using a non-probability method based on their convenience.

III. SYSTEMATIC REVIEW OF SCRM LITERATURE

A. The systematic review process

The primary purpose of this part is to examine the most concerned topics in the supply chain risk management domain in Figure 1.

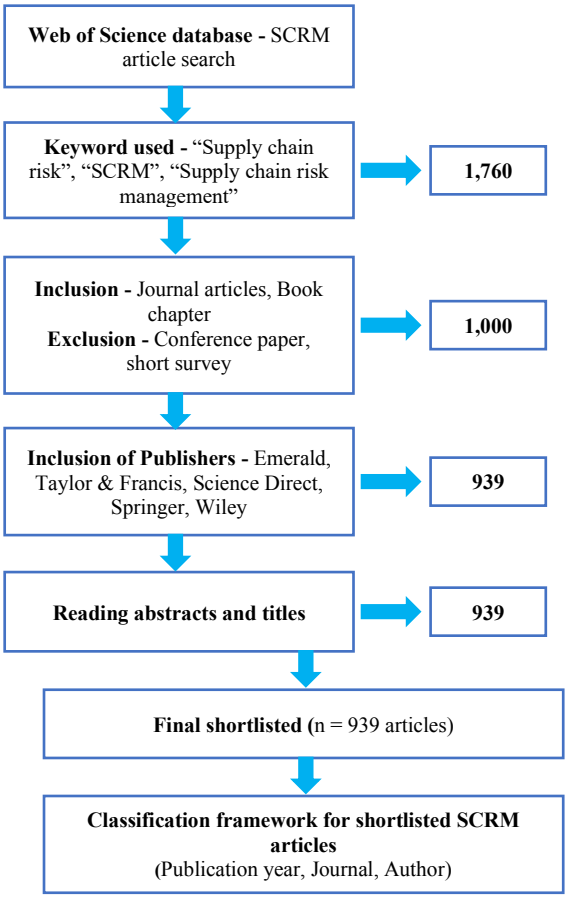

Figure 1. Systematic process of SCRM literature

Based on the classification framework among different aspects, there were 939 articles across 25 journals to review in terms of publication year, journal and author.

B. A classification framework for analysis

1) Articles classification based on publication year

In the early 1990s, SCRM received limited attention from researchers and managers, resulting in an absence of understanding and exploration in this domain. However, since 2007, there has been a steady shift as developed countries started recognizing the importance of SCRM concepts, leading to increased emphasis on SCRM implementation by practitioners and decision-makers. Consequently, the number of published articles in this field has substantially grown. From 2007 to 2022, approximately 94% (883 out of 939) of the articles were published, indicating a notable surge in SCRM research. From 2016 to 2022, researchers have strongly and particularly focused on SCRM due to various unexpected events such as geopolitical issues and the global impact of the COVID-19 pandemic, which caused significant disruptions in supply chains worldwide. Notably, the highest number of articles, 137, was recorded in 2022. Therefore, there is a significance of investigating SCRM in Vietnam, as it remains a consistently prominent and highly relevant topic in the field.

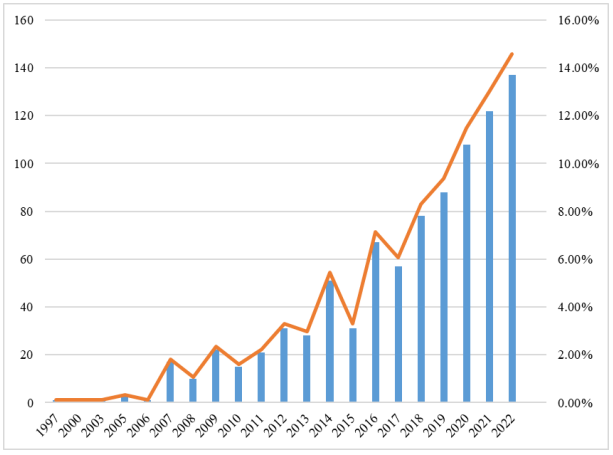

Figure 2. SCRM articles based on publication year

2) Articles classification based on journal

In the SCRM domain, there is a wide range of publication titles covering various research areas such as risk classification, risk mitigation, resilience, and agility. Among these, the International Journal of Production Research has made the highest number of contributions with 84 research papers. The International Journal of Production Economics has also played a significant role in developing a clear understanding of the SCRM domain, publishing 53 articles. The Supply Chain Management: An International Journal ranks third with 34 papers, establishing a strong connection between SCRM and manufacturing and production. Hence, it is important to investigate supply chain risk management, risk classification, and their impact on performance outcomes within the context of Vietnam.

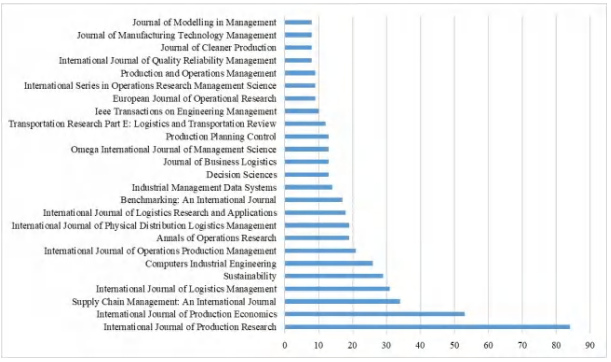

Figure 3. SCRM articles based on journals

3) Articles classification based on author

The analysis of the authors' classification reveals the presence of notable figures in the field of SCRM. Figure 4 provides a comprehensive breakdown of article classification based on authors. Among the 939 shortlisted articles from 25 journals, several authors have made significant contributions to the development of SCRM concepts, theories, and implementations. These authors have each contributed at least six valuable papers that remain relevant today. Notably, Ivanov D. and Wagner Blackhurst J, Ghadge A and Sawik T are recognized as prominent and specialized authors with a particular interest in emerging trends in SCRM domain. As a result, we intend to reference their theoretical knowledge, conceptual frameworks, and research findings.

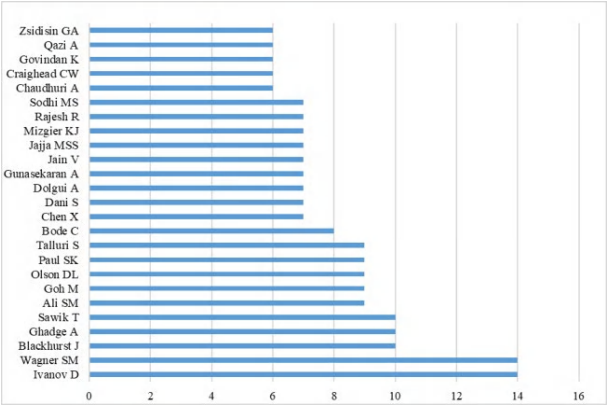

Figure 4. SCRM articles based on authors

C. Co-occurrence of keywords analysis

From the pool of 939 articles, VOSviewer is applied for the analysis of keyword co-occurrence. Specifically, the keywords "Supply chain risk management", "Supply chain risk" and "Supply chain performance" will be examined to identify key research themes in the field. Keyword co-occurrence analysis is a valuable method for uncovering connections between keywords by measuring their frequency of occurrence together (van Eck & Waltman, 2013). Additionally, we will highlight the significant advancements in supply chain performance and supply chain risk from 2016 to 2022. The application of VOSviewer will allow the author to identify trends and key topics in SCRM over the past 6 years. Figure 5 will display a network comprising four clusters, providing insights into the relationships and importance of various themes within SCRM.

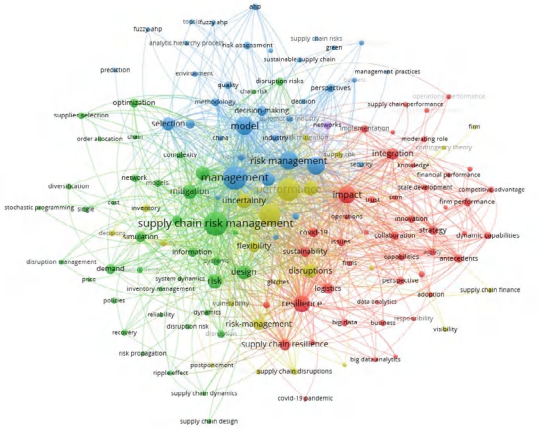

Figure 5. VOSViewer keyword co-occurence clustering view

Feng and Chen (2020) proved that the thicker the connection line between two keywords, the more times they will co-occur. Thus, based on this finding, the visualization map presented in Figure 5 allows us to identify four distinct clusters. Each cluster can be summarized by its separate research themes, and we will assign representative keywords related to these clusters.

Table 1. Keyword co-occurrence result

Cluster	Research themes	Keywords
1 (blue)	Supply chain management	Supply chain resilience, integration, disruption, sustainability, innovation
2 (green)	SCRM process	Supply chain risk management, risk, collaboration, mitigation
3 (red)	SCRM models and strategies	Case study, Fuzzy AHP, framework, management practices
4 (yellow)	SCRM implementation	Risk management, risk mitigation, operations management, performance

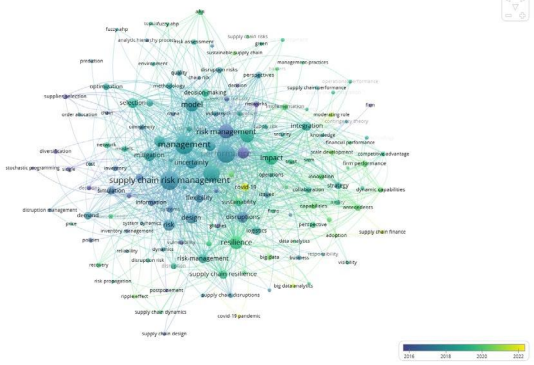

Figure 6. The co-occurrence chronology view of keywords

The analysis of keyword co-occurrence over time reveals a significant trend in the research domain of supply chain management. It became prominent and established itself as a distinct area of study in 2016. Subsequently, due to escalating global uncertainties and disruptions, a new facet of supply chain management emerged known as supply chain risk management. This development prompted a surge of interest among researchers who have been actively involved in advancing implementation theories, conceptual frameworks, models, and strategies on activities and processes within the domain of supply chain risk management.

D. Author analysis

1) Co-citation

The author used co-citation analysis to visualize and identify the foundational research areas that contribute essential knowledge to the SCRM field. This analysis also facilitated the examination of subject similarities between two documents that co-cite the same papers in their reference lists. Furthermore, the "total link strength" signifies the total number of instances in which the two references co-occur in documents (van Eck & Waltman, 2013). In VOSviewer, the author constructed a co-citation network with the top 35 out of 2243 authors meeting the threshold which indicates they are the most frequently cited references.

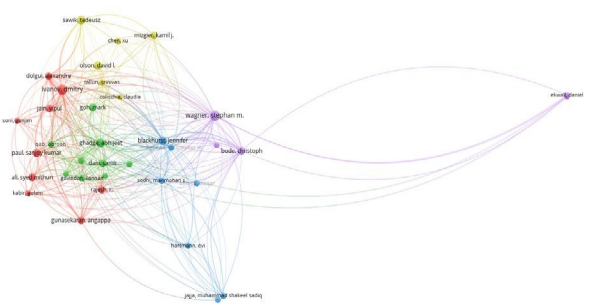

Figure 7. VOSViewer network of co-citation authors

Table 2. Authors' co-citation results

Cluster	Research focus	Citation
1 (purple)	Supply chain networks, supply risk disruption, supply risk identification, supply chain performance	(Wagner & Bode, 2008, 2009), (Jüttner et al., 2003)
2 (blue)	Supply chain resilience, agility, robustness and performance	(Sodhi et al., 2012), (Ahmed & Huma, 2021),
3 (green)	Systematic reviews of supply chain risk management, sustainability, technology	(Ghadge et al., 2012), (Govindan et al., 2014),
4 (red)	Supply chain dynamics, supply chain design, strategies in emerging industries	(Ivanov et al., 2019), (Paul et al., 2016), (Chowdhury et al., 2019)
5 (yellow)	Inbound supply chain risk, supply portfolio approach, risk aversion, review of enterprise risk management in supply chain, Fuzzy multi-objective programming	(Colicchia & Strozzi, 2012), (Sawik, 2016), (Olson & Dash, 2010)

2) Bibliographic coupling

To analyze and visualize the "emerging" research areas contributing to SCRM field, the author will use a method called bibliographic coupling. Bibliographic coupling is a method used to examine the references cited within a set of documents and identifying the overlapping citations. The more references two documents have in common, the stronger the bibliographic coupling is between them (van Eck & Waltman, 2013). This approach provides a quantitative measure of the degree of similarity or connection between scholarly works.

Bibliographic coupling can help researchers discover related works on a particular topic, identify influential papers or authors within a field, or track the development of research over time (van Eck & Waltman, 2013). Additionally, bibliographic coupling can be combined with other methods, such as co-citation analysis, to gain a more comprehensive understanding of scholarly networks and knowledge domains.

The study focuses on analyzing the 36 most frequently cited articles from a dataset containing 939 articles. By using VOSviewer, the author categorizes these articles into five distinct clusters, as indicated in Table 3. Each cluster will show the research front that has been reviewed and used as a foundation for other subsequent articles. So, the bibliographic coupling helps researchers gain a better understanding of the relationships and developments within the SCRM field, guiding their exploration and contributing to further advancements in the area.

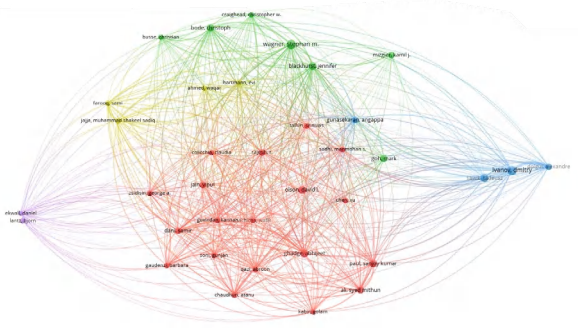

Figure 8. VOS Viewer network of bibliographic coupling authors

Table 3. Authors' bibliographic coupling results

Cluster	Research front	Future research suggestion	Citation
1 (purple)	Cargo theft, transport chain, security	Developing risk analysis of cargo theft, developing an intelligent system to predict risk and costs of cargo thefts in road transport	(Ekwall & Lantz, 2015)
2 (blue)	Supply chain disruption, supply chain risk, ripple effects	Extensions of disruptions, risk models, and redundancy-oriented approaches within global supply networks, as well as the implementation of technology for supply chain risk mitigation	(Ivanov et al., 2019), (Sawik, 2016)
3 (green)	Operational disruptions and business cycles, supply chain vulnerability assessment	Examining the impact of disruptions on operational performance and the evaluation of supply chain vulnerability to mitigate risks; developing supply chain resilience	(Blackhurst et al., 2008), (Wagner & Bode, 2008), (Wagner & Bode, 2009)

Cluster	Research front	Future research suggestion	Citation
4 (red)	Inbound supply chain risk, supply chain design	Extensions of case studies focused on post-supply chain risk (SCR) recovery efforts; integration of sustainability considerations in investment decisions; development of a green investment mechanism that considers supply chain risk aversion and negotiating power	(Colicchia & Strozzi, 2012), (Olson & Dash, 2010), (Zsidisin & Ellram, 2003), (Paul et al., 2016)
5 (yellow)	Supply chain risk assessment, SCRM strategies and approaches (i.e., Fuzzy AHP, Triple-A model)	Expanding and refining the methodologies used; enhancing the accuracy and effectiveness of risk assessment techniques; developing more technology-based SCRM strategies and approaches	(Ahmed & Huma, 2021), (Liao et al., 2017); (Birkel & Hartmann, 2020)

E. Supply chain risk

1) Supply risk

Supply side risks can emerge from various factors such as supplier reliability, moral hazards, purchasing decisions, multiple sourcing, and security issues (Asad et al., 2019); sudden price fluctuations, quality concerns, supplier bankruptcy, conflicting goals, inventory issues, delays, product complexity, and challenges in accessing technology (Asad et al., 2019). It is well known that firms are unable to start production without having access to supplies such as raw materials, components, and information. Furthermore, poor quality of supply sources during purchase is a significant risk and has a bullwhip effect from suppliers to the final customers (Wagner & Bode, 2008, 2009). Supply risk, thus, has prejudicial effects on the costs and competitive advantages of a firm which can ultimately cause a business to fail.

H1: *Supply risk negatively affects the supply chain performance.*

2) Demand risk

Due to demand risk, many firms are in difficulty of overproduction or underproduction, excess inventory, obsolescence, inefficient resource allocation and capacity utilization (Wagner & Bode, 2008). Most seriously, unexpected changes in demand make it more difficult for a firm to estimate and accurately estimate the variation between forecasted demand and actual demand (Chen et al., 2013). The disparity between customers' actual orders and forecasts will reduce the supply chain's effectiveness and efficiency (Sodhi & Lee, 2007). Collectively, demand risk, a failure in satisfying customers, is a vital threat to the supply chain performance (Chen et al., 2013).

H2: *Demand risk negatively affects the supply chain performance.*

3) Process risk

Processes are the sequences of value-adding and managerial operations implemented and executed by firms (Christopher & Peck, 2004). Thus, any quality or timing disturbance (i.e. accidental machinery or software errors, an issue with materials flow) happening in that sequence is related to process risk. Jüttner, (2005) confirmed that "processes can either amplify or absorb the effect of risks in the supply chain". Thereby, disruptions

due to process risk may amplify or absorb causing the bullwhip effect from the upstream to downstream sides of the supply chain (Christopher & Peck, 2004; Jüttner, 2005). From a manufacturing standpoint, process risk can be considered as inefficiencies in the manufacturing process, resulting from a high degree of process changes, material shortages, or the use of outdated technology (Rehman et al., 2018). Moreover, they can severely damage a company's performance in terms of massive financial loss and reputation (Shahbaz, Sohu, et al., 2019; Tran et al., 2016).

H3: *Process risk negatively affects the supply chain performance.*

4) Financial risk

Inflation, belonging to financial risk, is a factor leading to continuous increases in prices which frustrates customers. In turn, customers blame producers or purchase products from other manufacturers. Meanwhile, employees will request higher salaries if the inflation rate is high. So, firms may have problems with raising costs and budget management (Truong Quang & Hara, 2018). Together with inflation, banks charge high-interest rates for loans reduce consumers' purchasing power and businesses' financial strengths (Zhi, 1995). This phenomenon can cause price fluctuations (Zhi, 1995) and affect activities in the entire supply chain.

H4: *Financial risk negatively affects the supply chain performance.*

5) Environmental risk

Environmental risks include extreme issues related to catastrophic events (i.e., pandemics, natural disasters, trade wars, civil unrest, etc.), the negative effects on supply chains are evident (Wagner & Bode, 2008). Obviously, COVID-19 and the Russia-Ukraine conflict have disrupted logistics and purchasing operations (i.e., shortages of containers, increased freight charges, petrol and diesel). These disruptions have had a significant impact on the global supply chain, disrupted businesses for both manufacturers and retailers, and ultimately decreased customer satisfaction due to higher costs, stock shortages, and delayed shipments. Additionally, they have increased operational costs as a result of increased transportation times and decreased revenues as a result of businesses being forced to lower prices or restrict the availability of goods.

H5: *Environmental risk negatively affects the supply chain performance.*

6) Research framework

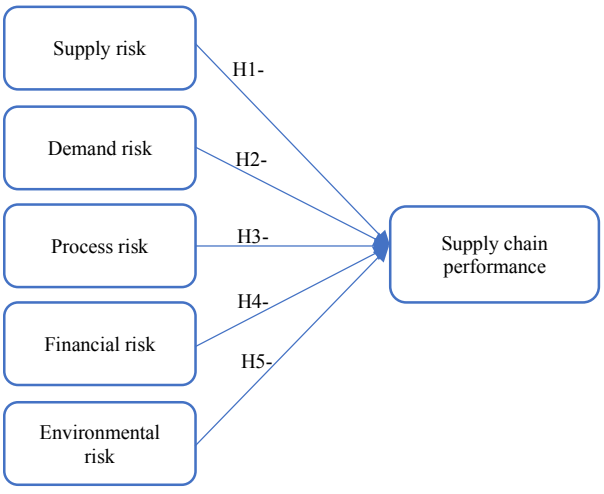

Figure 9. Research framework adapted from Gia, et al. (2021) and Shahbaz, et al. (2019)

IV. FINDINGS AND DISCUSSION

A. Descriptive statistics

Table 4. Respondents' characteristics

Characteristics	Frequency (N=199)	Percent (%)
Company's production field		
Mechanical & Electronic	56	28.1
Processing agricultural products, food	60	30.2
Consumer goods	56	28.1
Wood processing	27	13.6
Respondents' current job position		
Purchasing	43	21.6
Logistics	51	25.6
Production and Operation	56	28.1
Sales and distribution	46	23.1
Others	3	1.5
Respondents' working experience		
Less than 1 year	102	51.3
1 to 5 years	89	44.7
More than 5 years	8	4

Table 4 shows the similarities among three chosen categories: processing agricultural products and food (30.2%), consumer goods (28.1%); and mechanical and electronics (28.1%). Over 75% of respondents directly participate in manufacturing processes encompassing roles such as purchasing (21.6%), logistics (25.6%), production and operations (28.1%).

Additionally, approximately 51% of respondents have less than 1 year of working experience, while around 45% have 1 to 5 years of working experience. Only 4% of the respondents have more than 5 years of experience. As a result, the survey captures insights from employees at different experience levels, contributing to the overall efficiency and effectiveness of the study. These perspectives also help the author in understanding the importance of supply chain risk management perspectives from different levels of working positions.

B. Reliability and validity

Table 5 shows the below results with a total of 23 measurement items.

Table 5. Survey items, CFA factor loadings, Cronbach's alpha

Items	Factor loading
Supply risk (Cronbach's alpha = 0.934)	
Frequent delays in the supply time of materials	0.907
Offer is not flexible	0.917
Depends on a single supplier for important items and has a long product life	0.907
The quality of the supply was poor	0.904

Items	Factor loading
Demand risk (Cronbach's alpha = 0.882)	
The information system does not guarantee security	0.740
Unexpected customers or unstable customers	0.694
Reputation risk	0.666
Broken external / internal infrastructure (i.e., transportation infrastructure, public infrastructure, etc.)	0.919
Error in the demand forecast	0.909
Process risk (Cronbach's alpha = 0.837)	
Production disruption	0.764
Production capacity is not enough	0.725
Inconsistent inventory / inventory handling / maintenance strategy	0.765
Organizational issues	0.725
Not flexible in terms of capacity	0.771
Financial risk (Cronbach's alpha = 0.993)	
Fluctuation in prices	0.973
Fail to reduce cost	0.992
Customer refusing the freight charges	0.989
Increase customs or taxes	0.986
Fluctuation in exchange rates	0.984
Environmental risk (Cronbach's alpha = 0.886)	
Unexpected events of force majeure such as strikes, riots ..., terrorism, wars, natural disasters	0.883
Policy uncertainty	0.794
The leadership of the government is not stable	0.876
Skilled personnel are not available	0.900
Supply chain performance (Cronbach's alpha = 0.964)	
Product quality	0.945
Order fill capacity	0.944
Delivery dependability	0.942
Delivery speed	0.935
Customer satisfaction	0.910

The results revealed that all measurement items have a reliability value higher than 0.8. This indicates that all items are considered as qualified and reliable. The rotated in the table has factor loading higher than 0.5. Thus, the dataset is meaningful and interpretable.

Table 6. Regression analysis – Coefficient

	Standardized Coefficients			Collinearity Statistics		
	B	**Beta**	**t**	**Sig.**	**Tolerance**	**VIF**
(Constant)	0.090			0.829		
SR	0.102	0.131	2.434	0.016	0.964	1.037
DR	0.298	0.257	4.099	0.000	0.707	1.414
PR	0.585	0.468	7.443	0.000	0.701	1.426
FR	0.069	0.082	1.549	0.123	0.993	1.007
ER	-0.063	-0.080	-1.503	0.135	0.982	1.018

**Note: Adjusted R square = 0.450; Sig. = 0.000 <0.05; Durbin -Watson value = 2.060*

The linear regression analysis method was performed with five independent variables (SR, DR, PR, FR, ER) and one dependent variable (SP). The results reveal that within the model, three variables, SR, DR and PR, exhibit Sig. values of less than 0.05. Consequently, "Supply risk", "Demand risk" and "Process risk" have a statistically significant correlation with "Supply chain performance" and vice versa, at a confidence level of 95%. Conversely, the remaining variables, namely FR and ER, show Sig. values greater than 0.05, implying that "Financial risk" and Environmental risk are not correlated with the Supply chain performance.

C. Hypothesis test results

Table 7. Hypothesis test result

Hypothesis test		Sig.	Result
H1	Supply risk negatively affects the supply chain performance	0.016	Supported
H2	Demand risk negatively affects the supply chain performance	0.000	Supported
H3	Process risk negatively affects the supply chain performance	0.000	Supported
H4	Financial risk negatively affects the supply chain performance	0.123	Not Supported
H5	Environmental risk negatively affects the supply chain performance	0.135	Not Supported

V. DISCUSSION

In general, this study provides evidence that supply chain risk negatively impacts the supply chain performance. As illustrated in the study's findings, there are strong relationship between supply risk, demand risk, and process risk towards supply chain performance. Notably, process risk emerges as the most detrimental factor influencing the overall performance of the supply chain. These findings are consistent with previous research conducted by Chen, et al. (2013), Razavian, et al. (2021), Shahbaz, et al. (2019), Wagner & Bode (2008), which also highlighted demand risk as a critical factor contributing to the supply chain performance reduction

Contrary to the initial expectation, financial risk and environmental risk are found to not directly impact on the supply chain performance. Several possible explanations for

this finding are that Vietnamese manufacturers are less likely to suffer the effects of inflation, foreign exchange fluctuation, or market volatility (VCCI, 2021; Vietnam Briefing News, 2022). Additionally, the shortage and scarcity of skilled workers are considered the most significant risk for Vietnam in terms of competitive advantages and supply chain performance (Vu, 2020). However, in the specific context of this study, the respondents predominantly belonged to manufacturing companies that prioritize low labor costs. This focus on cost-efficiency may result in lower demand for highly skilled employees. This aspect could explain the observed limited impact of environmental risk on supply chain performance in the study's findings.

VI. CONCLUSION AND IMPLEMENTATIONS

The study finds that approximately 80% of changes in supply chain performance can be explained by five independent variables: supply risk, demand risk, process risk, financial risk, and environmental risk. Process risk has the most significant impact, while financial and environmental risk show no empirical evidence of a negative relationship. In summary, manufacturing companies in Binh Duong are significantly affected by supply chain risks in terms of their performance.

The study contributes to supply chain risk management by providing a comprehensive literature review and understanding of risk constructs. It emphasizes the negative impact of supply, demand, and process risk on supply chain performance, highlighting the need for effective risk management in manufacturing firms. Implementing such practices can enhance operational efficiency, performance metrics, and competitive advantages. Decision-makers should also focus on managing process risk, such as minimizing production disruptions, ensuring sufficient production capacity, maintaining consistent inventory levels, and implementing effective inventory handling and maintenance strategies

During the study, the constrained adoption of supply chain risk management (SCRM) practices in developing regions, exemplified by Binh Duong, Vietnam, as compared to developed nations, may undermine the broader applicability of our results. Additionally, the sample size of 199 respondents may not fully represent Binh Duong's extensive manufacturing population, potentially impacting result generalizability. Challenges during translation from English to Vietnamese and restricted research information could introduce inaccuracies.

Hence, it is imperative that future research endeavors tackle these acknowledged limitations. We recommend several avenues for future research. Firstly, given the insufficiency of measurement tools for evaluating financial and environmental risks within the predominantly quantitative approach used in this study, we propose exploring qualitative methodologies to delve deeper into the context of SCRM in Vietnam. Secondly, forthcoming research can broaden its scope to encompass additional dimensions of risk, such as collaboration or logistics risk, specific industries, and insights from top management perspectives. This approach will further enhance our understanding of the complexities and the influence of SCRM on overall supply chain performance.

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UNLOCKING THE IMPACT OF SUSTAINABLE SUPPLY CHAIN MANAGEMENT ON CUSTOMER WILLINGNESS TO PAY: THE MEDIATING ROLE OF CUSTOMER SATISFACTION[❁]

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Abstract: This research seeks to explore the effects of sustainable supply chain management practices within the hospitality industry on the willingness of customers to pay a premium. The study reveals that the environmental and social dimensions significantly enhance customer satisfaction, leading to a greater willingness among customers to pay more. Conversely, economic actions do not exert any influence on customer satisfaction. This suggests that customers may not readily perceive tangible economic benefits or advantages associated with economic aspects, leading them to potentially overlook them. Employing structural equation modelling (SEM), the study analyzed data from 171 frequent hotel guests in Binh Duong Province. Furthermore, the results indicate that customer satisfaction acts as a complete mediator in the relationship between the economic dimension and consumers' willingness to pay. This article concludes by offering practical implications and suggesting potential avenues for future research.

Keywords: *sustainability, supply chain management, hospitality industry, customer satisfaction, willingness to pay, triple bottom line*

I. INTRODUCTION

Sustainability concerns have garnered growing attention from both industry practitioners and researchers within the hospitality sector in recent times (Xu & Gursoy, 2014). One contributing factor to this growth is the presence of social intelligence and networking on social media platforms additionally empowers travellers and citizens, enabling them to endorse service innovation and cultivate grassroots entrepreneurship in the realm of sustainable service design (Sigala, 2013). Sustainability practices have emerged as one of the foremost factors shaping customers' perceptions, thereby influencing their decision-making processes (Vargas & Hanandeh, 2018; Rodríguez et al., 2020). Research findings indicate that sustainability practices have become substantial factors influencing customer willingness to pay a premium (Namkung &Yang, 2016).

According to Seuring and Muller (2008), Sustainable Supply Chain Management (SSCM) involves managing the movement of materials, information, and financial resources while promoting collaboration among companies in the supply chain. Joining a sustainable supply chain (SSC) that examines

[❁] Best oral presentation award – Student session

the environmental, social, and economic aspects is crucial for companies, as proposed by the triple bottom line (TBL) approach (Xu & Gursoy, 2014). This approach highlights the importance of these three dimensions in achieving sustainable outcomes in all supply chain activities. In the "smokeless industry", conventional supply chain management primarily focuses on enhancing economic value and ensuring the sustained profitability of operations as its core objectives (Ashby et al., 2012). Consequently, factors related to environmental and social considerations often fail to be noticed. Nevertheless, it necessitates sustained, long-term collaboration among all stakeholders within the hospitality supply chain, encompassing a diverse range of suppliers, retailers, and customers who receive the goods and services (Xu & Gursoy, 2014). This approach underscores the significance of TBL in attaining sustainable outcomes across all activities within the hospitality supply chain. Moreover, an increasing portion of visitors are interested in the sustainability actions of companies (Tena et al., 2019). An increasing number of customers are becoming cognizant of the potential adverse impact their consumption patterns may have on the environment and society (Chen & Tung, 2014). Therefore, adopting sustainability activities has become a determinant factor influencing customer satisfaction (Berezan et al., 2013). This awareness also influences the amount of money customers are willing to pay (DiPietro et al., 2013).

In Vietnam, "the smokeless industry" is on the rise with impressive growth numbers in recent years. According to the latest statistics from the World Tourism Organization in 2017, Vietnam ranked 6th among the 10 fastest-growing tourist destinations in the world and ranked first in Southeast Asia (Hoi, 2020). More specifically, Binh Duong is one of Vietnam's industrial provinces with the fastest economic development (Hung & Laszlo, 2022). Although there are not many famous tourist destinations compared to some other localities in Viet Nam, tourists come to Binh Duong for several reasons such as demand for industrial parks, conferences and events, rich cultural and historical or ecotourism. Therefore, several brand hotels still have strong and sustainable development. This can be because hotels in Binh Duong not only provide basic amenities, but also implement sustainability strategies to provide unique and high-quality hotel services. Customers in this market are increasingly interested in sustainable consumption and demand green products (Chen et al., 2012; Trang et al., 2018). Many tourist and hospitality businesses are increasingly demonstrating a propensity to become proactive in greening their operations and products as a result of this demand and the eco-conscious marketplace (Hopkins, 2019). Therefore, a sustainability strategy has been shown to effectively increase the level of customer satisfaction and a higher amount of money that customers are willing to pay (Namkung & Yang, 2016).

Previous research has primarily examined only one aspect of sustainability, such as environmental management and green practices (Rahman et al., 2012); corporate social responsibility (Paek et al., 2013); corporate sustainability performance (Wolf, 2013); stakeholder pressures (Azam et al., 2021); institutional pressures (Dai et al., 2021); and competitive advantage (Beske et al., 2014). However, hospitality researchers have not given enough consideration to an in-depth understanding of the influence of

the triple bottom line of all three components of sustainable supply chain management on customer willingness to pay. Furthermore, there is a lack of research studies on sustainability aspects in supply chain management (De Brito & Van Der Laan, 2010); they only focus on green supply chain management (GSCM) and the mediating role of customer satisfaction (Karim et al., 2023). This research makes significant contributions on multiple fronts. Firstly, it addresses a notable gap in hospitality research by offering a comprehensive examination of the TBL elements of sustainable supply chain management and their impact on customer willingness to pay with the mediating role of customer satisfaction. This deepens our understanding of this relationship within the hospitality sector, enriching the body of literature. Secondly, the study aligns with the global call for increased sustainability research across industries, particularly pertinent in an era of heightened environmental and social consciousness (Carter & Easton, 2011). Lastly, from a practical standpoint, the research provides valuable insights for hospitality managers and professionals, offering actionable guidance on how sustainable supply chain practices can influence customer willingness to pay, thus contributing to both the academic and managerial dimensions of the field. In the pursuit of these contributions, the current study will make efforts to answer the following research questions:

(1) What is the impact of environmental, social, and economic dimensions of sustainable hospitality supply chain actions on customer satisfaction toward customer willingness to pay in Binh Duong?

(2) Is the relationship between a sustainable hospitality supply chain and customer willingness to pay a premium mediated by customer satisfaction?

II. LITERATURE REVIEW

A. Sustainable supply chain management

According to the World Commission on Environment and Development (1987), SSC characteristics involve integrating the principle of sustainability, as the TBL approach, sustainability has three dimensions: environmental, social, and economic. First, the environmental dimension aims to decrease the negative impact that supply chain operations have on the environment (Hassini et al., 2012). The social dimension is focused on maximizing the benefits for stakeholders involved in supply chain operations. Finally, the economic dimension focuses on achieving long-term profitability (Kleindorfer et al., 2009; Birkel et al., 2019) while minimizing negative environmental and social effects. Adopting sustainable practices within the supply chain can lead to improved survival rates and profitability for all involved parties (Molina-Azorin et al., 2009). Customers are becoming increasingly aware of the impact of their decisions on the environment and society, and they expect businesses to take responsibility for their actions.

By implementing sustainable practices in the hospitality supply chain, businesses can indicate their commitment to environmental and social responsibility, which can lead to increased customer satisfaction toward the higher price that customers are willing to pay (Cronin et al., 2011). As a result, businesses must participate in the triple bottom line-based supply chain that incorporates sustainable practices in all aspects of the environment, society, and economy.

B. Customer willingness to pay

According to Breidert (2007), the willingness to pay is the highest price an individual is willing to accept to pay for a good or service. The amount a person is willing to pay is determined by the perceived financial value as well as the utility of the product. Customer satisfaction is an essential factor to measure the money that customers want to pay (Homburg et al., 2005). Essentially in the hospitality sector, understanding customer satisfaction is becoming increasingly important in their consumption experiences and repeat purchases. In previous research, it is proven that implementing the triple bottom line can have a positive impact on customer satisfaction (Berezan et al., 2013; Xu & Gursoy, 2014). By the same token, according to Taleb et al. (2020), to make people pay a higher price, the impact of sustainable supply chain hospitality plays an important role when measuring the level of customer satisfaction toward the premium price customers want to pay. Also, from the point of view of Xu & Gursoy (2014), customer satisfaction is activated as a mediating role between sustainable supply chain management and customer willingness to pay.

C. Theoretical background

1) Resource-based view (RBV)

In the history of management theory, the resource-based view (RBV) has emerged as one of the most significant and often referenced views. The RBV argues that a firm's persistent competitive advantage is built on its value, scarce, inimitable, and non-substitutable resources (Barney, 1991). Many academics of the resource-based view have stated that competitive advantage is gained by owning and controlling resources and capabilities within a single organization. As a result, internal organizational resources generate a competitive advantage. However, other researchers have broadened the scope of the RBV to concentrate on resources that cross the limits of the organization (Das & Teng, 2000; Sahoo et al., 2022), frequently referred to as the 'extended resource-based view'. From the viewpoint of Dyer and Singh (1998), they propose that organizations might combine resources in new ways across organizational boundaries to gain a competitive edge. By effectively managing connections with external organizations such as suppliers, consumers, government agencies, and organizations, businesses may build important resources. Therefore, a business may achieve and maintain a competitive edge by utilizing its core resources in ways that extend beyond the company's limits. Organizations that make relation-specific investments might combine resources in new ways to produce relational rents and gain a competitive edge over competitors who cannot (Zhao & Morgan, 2017).

D. Hypothesis development

1) Sustainable hospitality supply chain management and customer satisfaction

Research shows that implementing environmentally sustainable practices in the hospitality supply chain can lead to increased customer satisfaction (Berezan et al., 2013) because companies who care about the environment would address the economic and social aspects of the natural environment. More specifically, because the hospitality industry consumes a lot of natural resources and generates a lot of waste, it has always been under pressure to become more ecologically friendly from environmentalists and other community organizations (Cetinel & Yolal,

2009). The adoption of an environmentally-friendly approach has been shown to effectively reduce the industry's environmental impact and increase customer satisfaction (Prud'homme & Raymond, 2013). Customers tend to favor companies that compared to other firms, adopt environmentally friendly methods of service delivery (Gao & Mattila, 2014). Therefore, adopting hotels' green initiatives is a crucial effect in satisfying customers.

The incorporation of social sustainability can also affect customer satisfaction positively. Customer satisfaction may be increased by being socially responsible toward both internal and external stakeholders. Customers are increasingly interested in internal stakeholders, such as the welfare of workers and their working conditions (Costen & Salazar, 2011), improving the health and safety of employees, also providing them with training which can benefit both their job satisfaction and customer satisfaction (De Leaniz & Rodríguez, 2015). In terms of external stakeholders, businesses can also enhance customer satisfaction by building long-term relationships with suppliers to reduce waste and improve sustainability (Closs et al., 2011). These actions can positively impact a company's reputation, brand image, and performance, which in turn can affect customer satisfaction (Lee & Heo, 2009).

The economic sustainability of hospitality businesses plays a key role in keeping customers satisfied. When customers see that a business is doing well financially, they assume the business sells good products and gives good services (Lo et al., 2015) Businesses that are flourishing financially can operate efficiently and offer high-quality goods and services, resulting in satisfied customers (Sanchez-Fernandez & Iniesta-Bonillo, 2009). If a business is doing well financially, it can provide better products and services (Assaf et al., 2012; Loureiro & Kastenholz, 2011), which makes customers more satisfied (Jung & Yoon, 2013). The study put forward the following hypotheses:

H1a: *The environmental dimensions of sustainable hospitality supply chain management have a significant positive impact on customer satisfaction.*

H1b: *The social dimensions of sustainable hospitality supply chain management have a significant positive impact on customer satisfaction.*

H1c: *The economic dimensions of sustainable hospitality supply chain management have a significant positive impact on customer satisfaction.*

2) Sustainable hospitality supply chain management and customer willingness to pay

Several studies indicate that a significant number of customers are willing to pay extra for environmentally friendly products or services (Yoo & Kwak, 2009). Many consumers are becoming conscious of the negative impacts their consumption habits may have on the environment, resulting in a growing demand for eco-friendly alternatives (Chen & Tung, 2014). Moreover, according to Han and Hsu (2009), the positive impact of green initiatives by hospitality businesses can enhance their reputation and encourage customers to spend more money. From the viewpoint of Kang et al. (2012), staying at luxurious and moderately-priced hotels is more willing to pay extra for eco-friendly practices compared to guests staying at budget hotels.

If the sustainable supply chain adopts socially responsible tactics toward internal and external stakeholders, customers may be willing to pay extra. On the internal stakeholder side, customers are willing to pay more for better professional services delivered by well-trained employees (Bechwati, 2011). Corporate Social Responsibility practices in hospitality businesses may boost staff morale and organizational trust, enabling them to provide better customer service and encouraging customers to pay more for their experience (Lee et al., 2013). On the side of the external stakeholders, locally focused businesses purchase and provide local goods and services, enhancing their reputation in the local community. Because they want to support local organizations like family farms, then consumers are willing to pay more for locally produced goods and services (Onozaka & Mcfadden, 2011).

Furthermore, the economic feature of sustainable hospitality supply chain management has a considerable beneficial effect on the willingness of consumers to pay a premium. Strongly profitable hospitality businesses are more likely to provide higher-quality goods and services than struggling ones. Customers' willingness to pay more is expected to rise because these high-quality items and services are likely to exceed consumers' expectations (Campbell et al., 2014). Therefore, this study proposes:

H2a: *The environmental dimensions of sustainable hospitality supply chain management have a significant positive impact on customer willingness to pay a premium.*

H2b: *The social dimensions of sustainable hospitality supply chain management have a significant positive impact on customer willingness to pay a premium.*

H2c: *The economic dimensions of sustainable hospitality supply chain management have a significant positive impact on customer willingness to pay a premium.*

3) The influence of customer satisfaction and customer willingness to pay

Customers are willing to pay extra when they feel satisfied with the products and services they experience. When they have the best experience, they are willing to pay more, buy more, and recommend more (Gursoy et al., 2014). Similarly, when customers are satisfied, they perceive a high outcome of exchange and are willing to pay more. Customer satisfaction with the brand's goods and services contributes to their higher trust in the level of quality of the goods, then willingness to pay at a higher price. Further research revealed that customer satisfaction is one of the most important factors influencing customer loyalty (Akbari, 2019; Pérez & Del Bosque, 2014) and leads to a higher amount of money that customers are willing to pay. Customers are more likely to be satisfied with businesses that adhere to the triple bottom line compared to the company that has not adopted, therefore, is willing to pay more for products and services. As a result, customer satisfaction acts as a mediating role between sustainable supply chain management and customer willingness to pay. According to the above discussion, this study proposes:

H3*: Customer satisfaction has a significant positive impact on customers' willingness to pay*

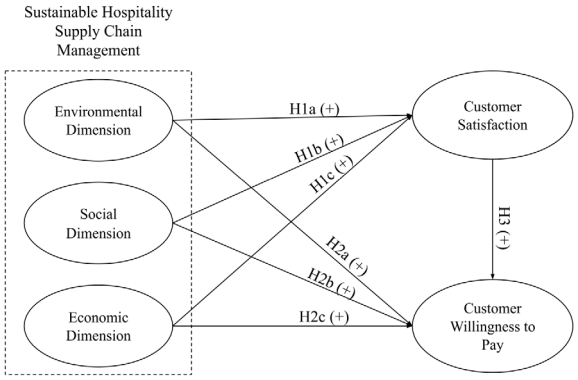

Figure 1. The research framework

III. RESULTS

A. Data collection

The primary data were collected by directly delivering questionnaires to people who frequently stay at hotels in Binh Duong Province. These questionnaires will be delivered to customers through Google Forms for their advantage. The survey will contain a question to select customers who stay at the hotel or not. The question "Have you frequently stayed at a hotel in Binh Duong?" was added to the survey to get information from the right people. A total of 200 initial questionnaires were distributed to customers, however after removing the gathered surveys, there were 171 acceptable responses, and the remaining 29 incorrect responses were eliminated and not used for further study.

B. Measurement of constructs

There are three constructs were measured in this research paper. The measuring scales were created using the sub-dimensions listed in each sustainability dimension of Xu and Gursoy's (2014) conceptual framework of sustainable hospitality supply chain management. Firstly, sustainable supply chain management involved three dimensions of sustainability: environmental, social, and economic. The survey has 17 items in total across the three dimensions, which is a shortened version of Xu and Gursoy (2014). With six items in the environmental dimension, five items in the social dimension, and 6 items in the economic dimension (Xu & Gursoy, 2014). To measure the level of customer satisfaction, the authors use the five items from Caber et al., 2013 and Gursoy et al., 2014. To assess customer willingness to pay, we adopted four items from Christina's (2010). Each item was measured on a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree, and the last part included the demographic questions.

C. Data analysis

To best summarize and present data to the viewer, the authors use tools provided the frequency and descriptive statistics. In this research, the Partial Least Square Structural Equation Modeling (PLS-SEM) technique was used to analyze the data. This approach helps in our understanding of the connections between the three fundamental structures. PLS-SEM is designed to handle data with unusual patterns and limited sample sizes (Hair et al., 2019). There are two steps in the PLS-SEM approach (Hair et al., 2019). In the beginning, this study evaluates the reliability and validity testing, convergent validity, discriminant validity, and model fit. Next, we will do an ordinary least squares regression before looking at the structural model using the bootstrap method for conduction and measurement.

1) Descriptive statistics

Table 1. Characteristics of respondents

Variable	Range	Percentage
Gender	Male	37.4
	Female	62.6
Age	18-34 years old	91.2
	35-55 years old	8.8
Marital status	Single	70.7
	Married	28.1
	Others	1.2
Education	Bachelor degree	89.5
	Master degree	3.5
	Others	7.0
Occupation	Student	12.3
	Worker	0.6
	Officer/Business	31.6
	Others	55.5
Income	Less than 10.000.000 VND	12.3
	Over than 10.000.000 VND	30.4
	Over than 20.000.000 VND	43.3
	Over than 30.000.000 VND	14

Among 171 respondents who took the survey, based on Table 1, the percentage of male customers is 37.4% compared to 62.6% of the proportion of female customers. A significant fraction of respondents were in the age groups of 18–34 (91.2%) and the percentage of people who were 35–54 years old is 8.8%. About 70.7% of the respondents in the current sample were single and 28.1% were married, just only 1.2% of people were in other situations. Similarly, most of the respondents had a bachelor's degree (89.5%), followed by a master's degree accounting for 25.1%, and the rest 7% represent guests who have other degrees. Large of the respondents had officer/business positions (31.6%) compared to 12.3% who were students and 0.6% of respondents who were workers. A significant majority of the respondents who have other jobs constitute about 55.5%. The respondents who have a monthly income of less than 10.000.000 VND are the smallest percentage at 12.3%. Customers who earn over 10.000.0000 VND and over 30.000.000 VND indicated a percentage of 30.4% and 14%, respectively. The rest accounted for the highest number of respondents who have a monthly income of over 20.000.000 VND covering the percentage at 43.

2) Measurement model

Table 2. Latent variables statistics

Construct	Coding	Item	Outer Loading	α - value	CR	AVE
Environmental Dimension (ENV)	ENV1	The hotel uses eco-friendly products in its guest rooms.	0.858	0.899	0.900	0.665
	ENV2	The hotel implements an energy-saving program.	0.778			
	ENV3	The hotel delivers products in environmentally-friendly packaging.	0.839			
	ENV4	The hotel publishes environmental-related newsletters.	0.808			
	ENV5	The hotel uses biodegradable packaging and uses waste disposal practices.	0.795			
	ENV6	The hotel avoids non-recyclable items, they collect and recycle components including paper, glass, aluminum, steel, styrofoam, etc.	0.810			
Social Dimension (SOC)	SOC1	The hotel responds to the complaints of all customers immediately.	0.846	0.869	0.878	0.656
	SOC2	The hotel provides activities for the local community such as selling local woman's handicrafts in a hotel gift shop.	0.758			
	SOC3	The hotel purchases local foods to support local farms.	0.778			
	SOC4	The hotel promotes community involvement and contributes to the development of the local economy.	0.838			
	SOC5	The hotel establishes a long-term relationship with a supplier that provides environmentally friendly products.	0.826			
Economic Dimension (ECO)	ECO1	The hotel improves operating efficiency and risk management.	0.797	0.880	0.897	0.622
	ECO2	The hotel reduces costs through the assessment of housekeeping and maintenance practices.	0.787			
	ECO3	The hotel creates more demand from customers by improving the hotel's reputation.	0.824			
	ECO4	The hotel improves its brand reputation.	0.780			
	ECO5	The hotel ensures financial stability by promoting customer loyalty.	0.802			
	ECO6	The hotel creates marketing opportunities.	0.740			

Construct	Coding	Item	Outer Loading	α - value	CR	AVE
Customer Satisfaction (CS)	CS1	I am interested in staying at this type of hotel.	0.908	0.927	0.931	0.774
	CS2	I will be very happy if I can stay at this type of hotel.	0.840			
	CS3	I will be very satisfied if the hotel can provide such a level of service.	0.921			
	CS4	My choice to stay in the hotel will be a wise one.	0.839			
	CS5	I think it would be the right thing to stay at this type of hotel.	0.888			
Customer Willingness to Pay (CWTP)	CWTP1	I am willing to pay a premium to stay at this type of hotel.	0.914	0.895	0.901	0.761
	CWTP2	I am happy to pay more to stay at this type of hotel.	0.853			
	CWTP3	Most of my friends, family, or relatives would be willing to pay a premium to stay at this type of hotel.	0.886			
	CWTP4	I will pay extra to stay at this type of hotel.	0.834			

According to Table 2, the recommended value of Cronbach's alpha is 0.7 (Reynaldo & Santos, 1999). With a score from 0.869 to 0.927, all the items exceeding the ideal cutting-off value of 0.70 indicate the items have strong reliability. Moreover, the outer loading should be more than 0.708 since the square of that value shows that the construct score accounts for at least 50% of the variation in the variable (Henseler et al., 2015). All the outer loading in the table is over 0.708 which indicates extremely significant. Similarly, the composite reliability (Rho_a) must be between 0 and 1. The higher the test's score, the more reliable. A value of 0.6-0.7 is considered good and a value of 0.7-0.9 is a more advanced phase of research (Nunnally & Bernstein, 1994). All of the CR is greater than 0.878 which represents good reliability. Additionally, convergent validity is measured by calculating the average variance extracted (AVE) from each construct using the outer loadings of the indicators. An AVE of more than 0.50 indicates that more than half of the indicator variation is contained in the construct score (Hair et al., 2017). The AVE values of items were more than 0.50 (0.622 - 0.774), showing all factors have strong convergent validity. As a result, all the items ensure reliability, and no items are removed.

Table 3. Heterotrait-monotrait ratios (HTMT)

	CS	CWTP	ECO	ENV	SOC
CS					
CWTP	**0.686**				
ECO	0.151	**0.425**			
ENV	0.566	0.498	**0.104**		
SOC	0.558	0.414	0.122	**0.092**	

Moreover, we used Heterotrait-Monotrait Ratios (HTMT) criteria, which contrasts the square roots of the AVE values with the correlations of the latent variables, to illustrate discriminant validity. From Table 3, by comparing AVE scores with the squared correlation between the constructs, discriminant validity was evaluated. The measurement model's correlations are all below the threshold of 0.85 (the biggest value is 0.686), indicating desirable discriminant validity.

Table 4. Bootstrap analysis with 5,000 samples

	Original sample (O)	**Sample mean (M)**	**Standard deviation (STDEV)**	**T statistics (|O/STDEV|)**	**p values**	**Results**
CS -> CWTP	0.387	0.384	0.080	4.864	0.000	Supported
ECO -> CS	0.040	0.041	0.050	0.803	**0.422**	**Rejected**
ECO -> CWTP	0.301	0.306	0.060	4.993	0.000	Supported
ENV -> CS	0.542	0.544	0.050	10.829	0.000	Supported
ENV -> CWTP	0.231	0.235	0.069	3.362	0.001	Supported
SOC -> CS	0.530	0.530	0.054	9.865	0.000	Supported
SOC -> CWTP	0.151	0.154	0.071	2.109	0.035	Supported

Looking at given Table 4, by using Bootstrapping with 5,000 samples and assuming a 5% significance level, and a structural model using a covariance matrix was used to analyze the relationships between the constructs as presented in Figure 2. As a result, hypothesis H1a and H1b proposes the paths between the environmental and social actions and customer satisfaction are positive and significant (β1a = 0.542, p < 0.05; β1b = 0.530, p < 0.05), while the path between economic dimension action and customer satisfaction is not significant (β1c = 0.040, p = 0.422) indicating that consumers are not likely to be satisfied if hotels and their suppliers implement economic dimension in sustainable hospitality supply chain management practices. Therefore, hypotheses H1a and H1b are supported while H1c is rejected. However, paths and the effect between the environmental, social, and economic dimensions of actions and customer willingness to pay are significant and positive (β2a = 0.231, p < 0.05; β2b = 0.151, p <0.05; β2c = 0.301, p < 0.05), Therefore, all 3 hypotheses are supported. Lastly, a direct positive relationship between customer satisfaction and customer willingness to pay is identified (β3 = 0.387, p < 0.05), which is supported by the hypotheses. Overall, the findings show that while the economic dimension just only increases consumer willingness to pay directly, the environmental and social dimension actions not only increase customer satisfaction but also increase their willingness to pay a premium.

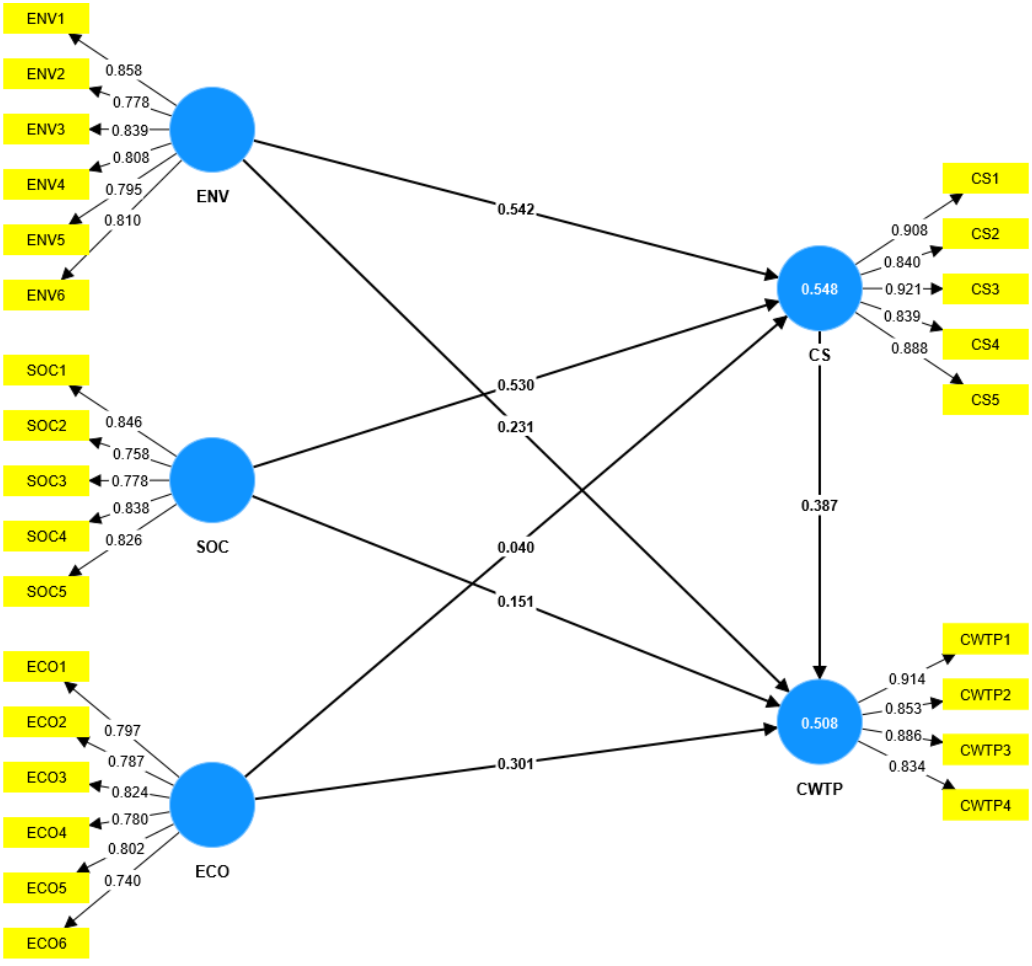

Figure 2. The PLS analysis of the research model

Table 5. Model fit

	Estimated model
Chi-square	356.103
Degrees of freedom	292.000
P value	0.006
ChiSqr/df	1.220
RMSEA	0.036
GFI	0.871
SRMR	0.057
TLI	0.974
CFI	0.977

The structural model produced the following model fit in Table 5: χ^2 =356.103 (df = 292; χ^2/df= 1.220; p<0.01), RMSEA= 0.036; SRMR= 0.057; CFI= 0.977; TLI= 0.974. Moreover, the GFI value is challenging to achieve 0.9 due to the small sample size, and this index is highly dependent on the number of scales, number of observed variables, and sample size. Therefore, GFI is acceptable to employ a threshold of 0.8 (GFI= 0.871) according to Baumgartner and Homburg (1996) and Doll et al. (1994). The model fit shows that the suggested structural model well matches the data. Therefore, it can be inferred that the hypothesis model's constructs are not only valid and reliable but are also distinct from one another (Hair et al., 2019). In addition, the adjusted R square of the dependent variable (customer willingness to pay) R^2 = 0.508. As a result, it indicates 50.8% of the positive variable of the model. For all possible combinations of endogenous constructs, we looked at the f^2 values to determine the effect sizes in Table 6. The environmental, and social have had a strong effect on customer satisfaction, since the f^2 is below 0.15 (0.004), the economic dimension has no effect on customer satisfaction. Moreover, environmental, social, economic, and customer satisfaction have a significant effect on customer willingness to pay. We also examined the collinearity problems by looking at the VIF values of every variable in the structural model. There are no collinearity issues for any of the variables since their VIF values were all below the threshold of 5.

Table 6. F-square value

	CS	CWTP
CS		0.138
CWTP		
ECO	**0.004**	0.185
ENV	0.655	0.067
SOC	0.624	0.029

3) Mediation analysis

Table 7. Indirect effect analysis

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
ECO -> CS -> CWTP	0.016	0.016	0.020	0.778	**0.437**
SOC -> CS -> CWTP	0.205	0.204	0.049	4.213	0.000
ENV -> CS -> CWTP	0.210	0.208	0.046	4.534	0.000

To test for mediation, the indirect effect of sustainable supply chain dimensions on customer willingness to pay through customer satisfaction is examined in Table 7. We discovered that both the direct and indirect effects of the environmental and social dimensions on customer willingness to pay through customer satisfaction are significant ($t= 4.534$, $p<0.001$; $t= 4.213$, $p<0.001$). Besides that, the indirect effect between the economic dimension and customer willingness to pay through customer satisfaction is not significant ($t=0.778$, $p=0.437$) while the direct effect is significant. Therefore, we can conclude that the impact of environmental and social dimensions tends to have a partial mediating role on customer willingness to pay while the economic dimension has a fully mediated effect on customer willingness to pay.

D. Discussion

First, the findings reflect previous findings from studies that environmentally friendly measures by hospitality organizations increase consumer satisfaction (Berezan et al., 2013; Xu & Gursoy, 2014) and willingness to pay a premium for sustainable products and services (Han & Hsu, 2009). This is most likely because a variety of business stakeholders, including customers, shareholders, and investors, place more importance on the environment (Greenberg & Unger, 1991; Makower, 1994). Additionally, companies who report on environmental performance are leading in the industry, more visionary in how they execute their goals, and sensitive to the continuing changes occurring across the world (Dwyer et al., 2009). Respondents who declared a higher level of environmental concern based on their beliefs are more willing to pay a price premium for sustainable products and services (Han & Hsu, 2009) to stay in hotels that employ environmentally friendly activities. Adopting the social dimension of the triple bottom line, which focuses on the impact a company has on the well-being of society, leads to increased customer satisfaction (Lee & Heo, 2009) and their willingness to pay more for products or services. They are willing to support businesses that align with their values and contribute positively to society. This is likely because customers are more considerate about the labour rights, working conditions, human rights problems, and workplace health and safety of employees (Knoepfel, 2001) when they pay money for products and services they experienced. A hotel is more likely to attract customers and investors if it can fulfil its social and environmental responsibilities (Sauvante, 2001).

Despite the argument of Sanchez-Fernandez and Iniesta-Bonillo in 2009, the economic factor does not make clients satisfied with the hotel. This can be because they do not care about the hospitality companies' finances when they decide to stay in a hotel and this leads to the results economic dimension having a minor impact on customer satisfaction. Demands for sustainable business practices that are both socially and environmentally responsible are rising, imposed on corporations by customers, organizations, shareholders, and competitors, making it necessary to focus on more than just the economic sustainability of a supply chain in the modern world (Hassini et al., 2012). Moreover, according to the Cost-Benefit Theory, consumers evaluate products or services based on the comparison between the benefits they receive and the costs they have to bear (Drèze & Stern, 1987; Mishan &

Quah, 2020). This can be because customers do not perceive clear economic value or benefits from the economic dimensions of the business so they may not pay much attention to them. Moreover, the Bounded Rationality Theory suggests that consumers have limitations in gathering and processing information, leading them to simplify decisions and focus only on the most important factors (Simon, 1990) and there are lots of researchers still use this theory in management context (Lejarraga & Pindard-Lejarraga, 2020; Wu et al., 2020). If economic dimensions are not considered critical, customers may overlook them in their purchasing decisions. That the reason why that economic dimension is has no impact on customer satisfaction. Although customers are unsatisfied with the economic dimension of sustainable practices, they are willing to pay a premium for other reasons. It may be explained by the possibility that customers are willing to pay more if they believe the company's sustainability initiatives will improve their experiences with hospitality goods and services (Tarfasa & Brouwer, 2013), increasing the amount that they are willing to pay.

E. Implications

1) Theoretical implications

The three dimensions of sustainable supply chain management action in the hotel sector reflect several important categories. Although adopting the economic dimension of the triple bottom line has no impact on customer satisfaction, the findings of this research reveal that consumer willingness to pay is highly impacted by environmental, social, and economic dimensions. Moreover, customer satisfaction fully plays a mediating role in the relationship between the economic dimension and the customer's willingness to pay. As a consequence, these findings contribute to the RBV theory by demonstrating how the triple bottom line is applied in the hospitality industry to create competitive advantages. Even though the economic dimensions have no impact on customer satisfaction, they still lead to a high amount of money that customers are willing to pay, which gives them a competitive advantage over others in the industry. By using sustainable materials, supporting local businesses, and creating a more positive impact on the community, a company can differentiate itself from its competitors and gain a competitive edge which increases customer satisfaction and leads to consumer willingness to pay a premium. These results will not only enhance future research on sustainable supply chain management in the hotel industry but will also be a source for expanded research on this issue in other industries and areas.

2) Managerial implications

In order to establish a sustainable hospitality supply chain, "sustainable suppliers" must first be identified. A business may either encourage its current suppliers to increase their level of sustainability or limit their supplier group to those that adhere to the firm's sustainability requirements to attain the aim of working with a sustainability-oriented supplier base (Paulraj, 2009). Managers need to be aware that sustainable hospitality supply chain management is a value-driven journey that continues for the entire life of the company, rather than just one action (Tzschentke et al., 2008). The development and implementation of a sustainable hospitality supply chain are likely to be successful if all enterprises included in the chain adhere to a common strategy. Also, the results indicate that not all sustainable

hospitality supply chain initiatives are likely to have the same effect on customer satisfaction and their willingness to pay a premium. Therefore, depending on their indicated effects on future perceptions and behaviours of customers, hospitality organizations may need to assign importance to sustainability activities. Consequently, businesses may need to invest a greater amount in their environmentally friendly initiatives, including green products. In the social dimension, businesses in the hotel industry should try to provide customers with value-added advantages by applying social dimension initiatives. The service quality delivery may also be improved by providing continual training to employees (Kim et al., 2014); it might serve as the primary motivation for businesses to adopt a more advanced level of sustainable supply chain management, which could ultimately increase customer satisfaction and willingness to pay higher (Tarfasa & Brouwer, 2013). Furthermore, implementing environmentally friendly or socially conscious policies that could be expensive often requires financial performance. Because the economic dimension has a minor impact on customer satisfaction, try to increase the effectiveness of its operating system as this may have a big influence on customer willingness to pay more, and as a result, increase firms' financial success (Sun & Kim, 2013). Long-term sustainability initiatives such as environmental, social, and economic practices in supply chain management are expected to provide considerable advantages for businesses as well as for their customers (Goodman, 2000).

IV. CONCLUSION

This study provides an in-depth understandingofhowactionstakenbyhospitality businesses about all aspects of sustainable hospitality supply chain management affect consumers' willingness to pay. While the economic dimension of sustainable hospitality supply chain management has little impact on customer satisfaction, the environmental and social dimensions have a significant positive impact on customer satisfaction toward the customer willingness to pay extra. Additionally, the results show that customer satisfaction fully mediates the connection between economic dimension actions and customer willingness to pay a premium, while environmental and social dimension actions partially mediate customer willingness to pay.

Although this research makes a significant contribution to the theory and practice, there are some limitations. First, this research does not differentiate the possible changes in customer willingness to pay for various kinds of hospitality organizations that use sustainable hospitality supply chain management. The second restriction relates to the gathering of data. Data for this study were gathered from hotels in the hospitality industry within the same cultural context. Even though the sample size was exceeded, a more representative sample is still necessary for findings to be generalized and compared across a more diverse population. Future research should explore a broader framework for the amount of money that customers are willing to pay for a product or service, not only sustainable supply chain management but also other factors that this study does not consider such as tourism, travel agencies, and tour operations.

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ANALYSIS OF RECURRENT EXPENDITURES AND MANAGEMENT OF STATE BUDGET IN NINH THUAN PROVINCE: APPLICATION OF THE PUBLIC EXPENDITURE AND FINANCIAL ACCOUNTABILITY FRAMEWORK (PEFA)

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Abstract: The study analyzed the effectiveness of spending and recurrent expenditure management in Ninh Thuan province, applying the framework of Public Expenditure and Financial Accountability (PEFA) of World Bank. The results show that Ninh Thuan province achieved 8 A, 15 B, 1 C+, 6 C, 3 D. The reliability of the budget is quite well; however, the aggregate revenue outturn is still quite high disparity. At grassroots levels, budget planning is still rather sketchy. Transparency in public finance is still not good. Unreported off-budget expenditures are still high, and allocations from central to local levels are also not clearly mentioned. The budget implementation process has not met the government's process, and the time to complete the construction of the total state budget expenditure estimate is still delayed. The ability to forecast and control the implementation of the budget is not really good, the level of cohesion as well as timely updating of the personnel and salary situation has not been met. In addition, the payroll accounting process is slow and not synchronized with grassroots levels. The accounting and reporting system is not good and needs much improvement.

Keywords: *Public expenditure, public financial management, PEFA, recurrent expenditure management, Ninh Thuan*

I. INTRODUCTION

State budget is an important resource of the government in order to perform its functions and tasks. In order to use the state budget effectively, state budget management is an important task. The reform of the state budget management system was centered in the administrative reform programs for the period 2011-2020, improving the initiative, flexibility, creativity and responsibility of the locality in the management of the state budget.

Literature on the effectiveness of public financial management indicates that effective public financial management is closely related to better perceptions of corruption. PFM reform can be part of an effective fight against corruption (Cathal Long, 2019). In order to improve the effectiveness of public financial management (PFM), the Public Expenditure and Financial Accountability (PEFA) framework was initiated in 2001. PEFA was subsequently established and developed into a standard and widely

accepted method for evaluating public financial management in many countries around the world. Currently, more than 155 countries have adopted this method with nearly 500 public sector assessments out of a total of nearly 800 assessments (PEFA, 2022). Vietnam has also carried out a national assessment of PFM work, despite some difficulties in standardizing the report according to international standards. Evaluation of public financial management at the provincial level was conducted and is also encouraged (Hoang Quoc Tung 2017; Phan Quang Thong, 2017; Ministry of Finance, 2013).

Ninh Thuan province has the revenue of the province's budget mainly from agriculture, small trade and aquaculture. The province's revenue does not meet the annual expenditure tasks, especially education, health care and social security expenses. Therefore, the management of recurrent expenditures from the State Budget of Ninh Thuan Province is important, in order to ensure a reasonable response to the provincial budget expenditure needs. However, this work still has some limitations, such as recurrent expenditures often exceed estimates, regulations on thrift and anti-waste practices have not been strictly followed, causing waste of the state budget; the implementation of the mechanism of autonomy and self-responsibility for administrative and nonbusiness units has not been really effective; qualifications and capacity of financial staff are still weak; the association between the Finance Agency and the State Treasury (State Treasury) in the local financial system has not been synchronized... In this situation, how to manage recurrent expenditures to ensure efficiency of state budget management really matters. The highest efficiency, thorough thrift, and overcoming the situation of spending exceeding the estimate, spending not in accordance with authority, in violation of the provisions of the State Budget Law is a matter of great concern to the Party and local authorities.

To improve issues related to budget expenditure, it is very important to have sufficient information and knowledge on state budget expenditure and management in Ninh Thuan province. However, until now, there have not been many studies on this issue as well as no research on applying PEFA to assess the state budget spending and management in Ninh Thuan province.

II. METHODOLOGY

According to Vu Van Hoa (2009), "Public finance is the creation and use of monetary funds of the State by using the legal power of the State (first of all, political power) to distribute wealth. Social finance (mainly newly created products), to perform economic and social functions of the State... Public finance is the sum total of cash receipts and expenditures conducted by the State. It reflects the system of economic relations arising in the process of creating and using public funds to meet the needs associated with the performance of the State's functions and tasks in terms of economic management, society, national defense – security in each specific period" (p. 13, 14).

A. Classification of public finance in accordance with the organizational system of government

In Vietnam, the public finance system is split into two parts: The State Budget (which includes the budgets of the central government and local governments) and the budgets of institutions or enterprises that are economically and/or financially independent (ADB, 2017).

Central government budget operates under the management and supervision of the National Assembly. It is assigned for national defense, diplomatic work and socioeconomic management at a macro level. Local government budgets can be divided into: Provincial public finance; District public finance; Commune public finance, which is to ensure that local governments have a budget to spend and perform tasks prescribed by the Constitution in their localities (Vu Van Hoa, 2009).

Recurrent expenses in the state budget include those incurred for the governmental apparatus, national security, socio economic development, sociopolitical organizations and others' operations (State Budget Law, 2015).

Managing regular state budget expenditures is a procedure that is rigidly developed from the budget planning stage through the spending stage to guarantee that regular expenditures are used for the proper purpose, economically and efficiently, and in line with practical needs (Ministry of Finance, 2016). One of the principles of State budget recurrent expenditure management is based on budget proposals. Budget proposals are prepared by provincial departments, districts, and communes. Recurring expenditures, once included in the budget proposal and approved by the PPCs, are considered as orders.

All expected recurrent expenditure needs for the plan year must necessarily be identified in the budget proposal from the grassroots level. The local budget at each level is ratified by the relevant people's councils and by the upper-tier provincial people's committees. The final decision on the recurrent expenditure proposal rests with the National Assembly.

Each unit at grassroot levels must base on the approved budget estimates to allocate, spend and account for regular expenses according to the provisions of the State Budget Law. The flexibility in the process of using recurrent expenditures, leading to deviations in expenditure for each item compared with the proposal, can only be accepted by the relevant State financial management authorities. Periodically, as regulated in the prescribed budget final settlement regime, the budget proposal must be taken as a basis for evaluating the spending results of the reporting periods. Accordingly, the expenditure has been estimated according to which items, the expenditure settlement must also be made according to those items.

Other principles of State budget recurrent expenditure management are thrift and efficiency. These are among the most important principles of economic and financial management, because the state budget is always limited but the expenditure needs of the country are not. Therefore, the process of allocating and using these scarce resources must always be calculated in such a way that the lowest cost but still the best efficiency.

Another important principle of State budget recurrent expenditure management is that all state budget expenditures, especially recurrent expenditures are put under the control of the State Treasury. Direct expenditure through the State Treasury is a payment method with the participation of 3 parties: State budget-using units, State Treasury, organizations or individuals receiving payments paid by state budget-using units. All state budget funds using units must open accounts at the State Treasury, subject to inspection and control by the Finance

and State Treasury agencies in the process of making budget proposals, allocating budget, accounting and settlement of the state budget.

B. Public Expenditure Framework and Financial

Accountability (PEFA)

The PEFA Analytical Framework in public finance has shown that the trend of public spending in localities is increasing. That puts pressure on the state budget. Therefore, public financial management is very important and the PEFA Analytical Framework would be useful for local public financial management (Hoang Quoc Tung, 2017). The framework employs quantitative indicators to measure PFM performance. This framework could help to continuously evaluate and report changes in PFM over time and can provide a common basis for comparing PFM performance across countries. From there, it can help reduce transaction costs for countries and help enhance the harmonization of funding benefits among World Bank's fund recipient countries... (World Bank, 2013).

PEFA identifies six effective pillars in a public financial management system and the order in which these goals are achieved (PEFA, 2016).

- Budget reliability is verified by comparing actual revenue and expenses to the approved budget.
- Transparency inn public finances is achieved by making budgets classification transparent, making government revenues and expenditures transparent through disclosing records and intergovernmental transfers, and making budgetary data accessible.
- Asset and liabilities management is associated with whether or not public investments are cost effective, assets are properly managed, financial risks are taken into account, and liabilities and guarantees are carefully structured and audited.
- Policy based fiscal strategy and budget plan: Financial strategy and budget are established in line with the government's fiscal policy, strategic plan, and macroeconomic environment.
- Ability to forecast and control budget execution
- Accounting and reporting are processes that ensure accurate and reliable records are kept. Data is generated and disseminated at the appropriate times to support decision making, management and reporting.

C. Scoring method according to PEFA analysis framework

For each indicator, the score will be calculated in many dimensions, specifically as follows:

Each indicator will be scored in different ways, specifically according to the criteria set out for each dimension. Each dimension will be scored on a scale from A to D. The scoring criteria must be met in all respects; if they are met only partially, the score is low and then a low score indicates low performance.

Most indicators have many separate measured dimensions. Either the average approach (AV) or the weakest link technique (WL) was used to combine the scores for

several dimensions to create the final score. A suitable approach is employed for the relevant indicator.

Weakest link method M1: This scoring method is employed when a multidimensional indicator performs poorly on one dimension, its impact on the other dimensions' performance is likely to be lessened. On the other hand, it is used when a "weakest link" exists between the performance indicators. The indicator's aggregate score is the lowest rating received for any dimension.

M2 average method: Based roughly on the average of the scores for each of an indicator's aspects, the overall indicator score is calculated (Table 1). It is suggested that this scoring technique be applied for specific multifaceted indicators where a low score on one dimension does not always invalidate the value of a high score on another element of the same indicator. Despite the fact that all dimensions of an indicator come under the same room of the PFM system, progress on certain dimensions might be different from the others in a given area.

Table 1. Average scores conversion according to the M2 scoring method

Score			M2 average score
2- For 2 dimensions indicators			
D	D	D	D
D	C	D+	D
D	B	C	D+
D	A	C+	D+
C	C	C	D+
C	B	C+	D+
C	A	B	C
B	B	B	C
B	A	B+	C+
A	A	A	C+
3- For 3 dimensions indicators			
D	D	D	D
D	D	C	D+
D	D	B	D+
D	D	A	C
D	C	C	D+
D	C	B	C
D	C	A	C+
D	B	B	C+
D	B	A	B
D	A	A	B
C	C	C	C
C	C	B	C+
C	C	A	B
C	B	B	B
C	B	A	B
C	A	A	B+
B	B	B	B
B	B	A	B+
B	A	A	A
A	A	A	A

Notes:

Dimension scores can be counted in any order. It is only the quantities of each score that are important for aggregation.

Table 1 is not applicable to indicators using the M1 scoring method (WL).

Score				M2 average score
4- For 4 dimensions indicators				
D	D	D	D	D
D	D	D	C	D
D	D	D	B	D+
D	D	D	A	D+
D	D	C	C	D+
D	D	C	B	D+
D	D	C	A	C
D	D	B	B	C
D	D	B	A	C+
D	D	A	A	C+
D	C	C	C	D+
D	C	C	B	C
D	C	C	A	C+
D	C	B	B	C+
D	C	B	A	C+
D	C	A	A	B+
D	B	B	B	C+
D	B	B	A	B
D	B	A	A	B
D	A	A	A	B+
C	C	C	C	C
C	C	C	B	C+
C	C	C	A	C+
C	C	B	B	C+
C	C	B	A	B
C	C	A	A	B
C	B	B	B	B
C	B	B	A	B
C	B	A	A	B+
C	A	A	A	B+
B	B	B	B	B
B	B	B	A	B+
B	B	A	A	B+
B	A	A	A	B+
B	B	B	A	B
B	B	A	A	B
B	B	A	A	B+
B	A	A	A	A
A	A	A	A	A

(Source: PEFA, 2016)

Aggregate score for the indicator is calculated by using the conversion table, which is solely applicable to indicators employing the M2 scoring. The conversion table cannot be used to calculate aggregate for an entire collection or subset of indicators since it is only intended for usage with individual indices. There is no standardized way to aggregate across indicators because each one measures a distinct issue.

D. Information collection

PEFA is a method to evaluate the effectiveness of public financial management in the world, with 94 dimensions constituting 31 indicators of public financial management in 7 pillars (PEFA 2016). In the PEFA framework, there are 10 indicators corresponding to 5 pillars being appropriate for use in assessing the performance of spending and recurrent expense management of the government budget at provincial level, respectively (I) Budget reliability, (II) Financial transparency public policy, (III) Policy based on financial strategy and budgeting plan, (IV) Ability to forecast and control budget execution, (V) Accounting and reporting. Therefore, this study focuses on analyzing and evaluating these indicators (Table 2).

Secondary and primary information for the research is collected from relevant financial actors such as the provincial Department of Finance, Department of Tax, the provincial State Treasury, District People's Committee and agencies related to the management of budget expenditure management in Ninh Thuan province. The information to assess the management of government budget expenditure at provincial level is listed in Table 2.

Table 2. Source of information and survey content

Institution	Indicators	No of questionnaires
Department of Finance of Ninh Thuan province State Treasury of Ninh Thuan province	Aggregate expenditure outturn for 4 years (2018-2021)	13
	Expenditure composition outturn for 4 years (2018-2021)	
	Budget classification	
	Comprehensiveness of fiscal information	
	Central government operations outside financial reports	
	Transfers to subnational governments	
	Public access to fiscal information	
	Budget preparation process	
	Payroll controls	
	In-year budget reports	
	Annual financial reports	
Department of Finance of Ninh Thuan province State Treasury of Ninh Thuan province Department of Tax of Ninh Thuan province	Revenue outturn for 4 years (2018-2021)	3
	Budget classification (not evaluated)	
	Comprehensiveness of fiscal information	
Department of Finance at districts and city	Budget preparation process	7

III. RESULTS

A. Situation of recurrent expenditures of Ninh Thuan province in the period of 2018 – 2021

Table 3 summarizes the results of the current situation of budget recurrent expenditures from 2018 to 2021, which shows the increase and decrease of the planned and actual spending over the years.

In 2019 and 2020, the province's planned budget increased compared to the previous adjacent year. Each year, localities often add expenditures intended for the year to the amount of the approved budget in the previous year to propose altogether for the year. Therefore, the planned budget for the year is often higher than that of the previous one. For Ninh Thuan province, the increase in annual budget proposals is also explained this way. However, compared to 2020, the budget estimate in 2021 is 285 billion VND lower; it is due to the severe

COVID-19 epidemic which postponed many planned activities of the province. Therefore, based on the actual situation, the province has made appropriate adjustments in the state budget estimate. In terms of the province's actual spending over the years, it can be seen that the actual expenditure tends to increase over the years 20182021.

Comparing the actual expenditure with the planned budget, it is evident that, in 2018, the recurrent spending increased by 102% compared to the plan (Table 3). The expenditures were for (i) security and defense, (ii) payroll increase at grassroots level, (iii) social security. By 2021, total recurrent expenditure continued to increase by 111% compared to the plan due to the medical and healthcare cost increase under the effects of the serious situation of the Covid-19 epidemic.

Table 3. Recurrent expenditures of the state budget of Ninh Thuan province in the period of 2018 – 2021

Year	Original planned Spending (mil. VND)	+/- Planned spending (mil. VND)	Spending (mil. VND)	+/- Spending (mil. VND)	Planned spending/ Spending (%)
2018	3.186.353	-	3.236.758	-	102%
2019	3.595.756	409.403	3.471.663	234.905	97%
2020	3.856.215	260.459	3.779.177	307.514	98%
2021	3.571.071	-285.144	3.954.280	175.103	111%

(Source: Department of Finance, State Treasury of Ninh Thuan province, 2022)

In 2018-2021, the recurrent spending in 2021 was the highest. There are 07/13 expenditure items that require an increase in spending compared to the plan, such as national defense and security, environment protection, economics, and public administration, and other recurrent expenditures.

According to the situation of the whole country, spending in national defense and security, environment protection and social security are all more focused. In Ninh Thuan, the recurrent expenditure for these purposes would be regularly promoted yearly. This is also a challenge for the provincial government in particular and state financial authorities in general in managing recurrent expenditures to ensure the most reasonable and effective revenue collection and expenditure.

The method of budget expenditure management in Vietnam generally and in Ninh Thuan province particularly in the period of 2018-2021 and currently is mainly by input factors. Annually, based on the local budget, additional allocation from the Central government, and the recurrent expenditure proposal of the grassroot units, the Department of Finance, under the assignment of PPC, balances and grants the approved budget to subordinate units. This approach of budget management allows to estimate relatively closely the financial resources that can be obtained. As a result, the spending arrangement is proactively, in accordance with actual revenue, complying with annual recurrent expenditure proposals, that is also convenient for budget beneficiaries. Localities rarely have to adjust the proposals and if there are adjustments, the adjustment is not large compared to the approved budget.

Annually, the State Inspectorate at different levels and related sectors all propose inspection plans regarding budget management and spending, including recurrent expenditures. This shows that the province has focused on inspection and supervision of budget management and spending to avoid errors or omissions in state budget collection and expenditure.

However, the inspection and supervision is still quite stereotyped, so there are still violations that take place.

B. Analyzing the effectiveness of recurrent expenditures and expenditure management in Ninh Thuan province in the period of 2018 – 2021

There are 10 criteria extracted from the PEFA framework to evaluate the effectiveness of recurrent budget expenditure of Ninh Thuan province. These criteria are calculated according to both M1 and M2 scoring methods.

The result of PEFA analysis of Ninh Thuan province in 2022 is 8 A, 15 B, 1 C+, 6 C, 3 D. It shows that Ninh Thuan province is doing quite well in managing recurrent expenditure of the state budget. However, besides the positive results from many efforts of the provincial budget management system, the expenditure and expenditure management assessed according to the PEFA framework still have some problems as follows:

Firstly, the reliability of the budget is quite good: getting 3 A and 3 B. However, the aggregate revenue compared to the approved original budget gets 2 B over 3 dimensions, that still needs to be considered. The difference between the actual budget revenue compared to the original approved budget in the three years 2018-2021 and the difference in revenue according to the revenue target in the years 2018-2021 is still quite high. The planning of budget revenue and expenditure is still heavy formality and stereotypes, that causes difficulties and shortcomings in practice. At the grassroots level, the revenue collection planning is still quite sketchy and counter-productive, which leads to inefficiency.

Table 4. Summarize the evaluation scores of the indicators

Citeria	Score	Scoring method	Brief explanation
PI-1. Aggregate expenditure outturn	A	M1	
(i) Difference between aggregate expenditure outturn and approved aggregate budgeted expenditure	A	M1	It was between 95% and 105% in at least two of the last four years
PI-2. Expenditure composition outturn	A	M2	
(i) Expenditure composition outturn by function	A	M2	In at least two of the previous four years, the variation in spending composition by program, administrative, or functional categorization was less than 5%.
(ii) Expenditure composition outturn by economic type	B	M2	In at least two of the previous four years, the variation in spending composition by economic group was greater than 10%.
(iii) Expenditure from contingency reserves	A	M2	A contingency vote's actual expenses were often less than 3% of the allocated amount.
PI-3. Revenue outturn	B	M2	
(i) Aggregate revenue outturn	B	M2	In two out of the previous four years, the actual revenue was between 94% and 112% of the planned revenue.
(ii) Revenue composition outturn	B	M2	It was less than 10% in two of the last three years.

Citeria	Score	Scoring method	Brief explanation
PI-6. Central government operations outside financial reports	C	M2	
(i) Expenditure outside financial reports	D	M2	Outside of government financial records, spending exceeds 10% of overall BCG expense.
(ii) Revenue outside financial reports	D	M2	It is more than 10% of aggregate BCG revenue.
(iii) Financial reports of extrabudgetary units	A	M2	Detailed financial records of all extra-budgetary units are submitted annually within three months of the end of the fiscal year, together with the final settlement of provincial budget revenues and expenditures according to Circular No. 342/2016/ TT-BTC of the Ministry of Finance
PI-7. Transfers to subnational governments	B	M2	
(i) System for allocating transfers	A	M2	The horizontal allocation of all funds from the central government to subnational governments is determined through transparent, rule-based processes.
(ii) Timeliness of information on transfers	C	M2	The budget processes may be implemented with significant delays. Information on annual grants to subnational governments is released after budget plans are finalized.
PI-9. Public access to fiscal information	C	M1	The government makes available to the public four basic elements, in accordance with the specified time frames.
PI-17. Budget preparation process	C+	M2	
Budget calendar	A	M2	All budgetary units have at least six weeks after receiving the budget circular to significantly finish their detailed estimates on time thanks to a defined yearly budget schedule that exists and is often followed.
Guidance on budget preparation	D	M2	No unit has created a comprehensive budget spending plan for the whole fiscal year before the unit's directing circular has been presented to the superior.
Budget submission to the legislature	C		In two of the previous four years, the government sent the legislature its annual budget plan at least a month before the start of the fiscal year.
PI-23. Payroll controls	B	M2	
Integration of payroll and personnel records	B	M2	The payroll is backed up by detailed documentation for all changes made to personnel records each month, which are then compared to the preceding month's payroll data. A list of approved staff roles governs employee recruiting and promotion.

Citeria	Score	Scoring method	Brief explanation
Management of payroll changes	B	M2	Personnel records and payroll are updated at least quarterly and require a few retroactive adjustments.
Internal control of payroll	B	M2	The authority and rationale for changes to personnel records and payroll are explicit and sufficient to maintain data integrity.
PI-28. In-year budget reports	B	M2	
Coverage and comparability of reports	C	M2	Data coverage and classification allow for direct comparison to the original budget for the key administrative topics.
Timing of in-year budget reports	B	M2	Budget execution reports are prepared quarterly, and issued within four weeks from the end of each quarter.
Accuracy of in-year budget reports	B	M2	There may be doubts about the accuracy of the data. The study highlights data concerns, and the data is consistent and suitable for budget execution analysis. At least once a year, an analysis of budget execution is presented. Expenditure is recorded at the payment step.
PI-29. Annual financial reports	B	M1	
Completeness ofannual financial reports	B	M1	Annual financial reports are generated for the budgetary central government and are compared to the authorized budget. At a minimum, they include data on earnings, expenses, financial assets, financial liabilities, guarantees, and long-term commitments.
Submission of reports for external audit	C	M1	Financial reports for budgetary central government are filed for external audit within 9 months of the fiscal year's completion.
Accounting standards	B	M1	All financial reports are prepared in accordance with accounting standards that are compliant with international law. The vast majority of global norms have been absorbed into national norms. The differences between national and international norms are revealed, and any gaps are clarified. The guidelines used to create yearly financial reports are made public.

Second, transparency in public finance achieved 2 A, 2 C, and 2 D. This result shows that efforts to implement financial transparency have not been really effective. Unreported off-budget expenditures remain high. The allocations from central to local levels are also not clearly mentioned and there are many delays in implementing budget procedures. In addition, the accessibility to budget information of the province and localities is still limited, only via notices and announces of the superior rather than proactively determining the budget according to the actual situation of the province. This impedes financial transparency. It also shows that some spending regimes and quotas are not suitable to reality, difficult to implement.

Besides, the delay in disbursement also makes it difficult to implement and manage the budget. The unspent budget or incomplete spending is still quite large making final settlement difficult. The management of recurrent expenditures is still wasteful, lost and inefficient. The financial and budgetary management regime has not been strictly implemented, and some regimes and spending quotas have been violated.

Fourth, the budget calendar and the guidance on budget implementation have not really met the government's process and there are still many problems to be improved (rated C+). The time to prepare the budget expenditure proposal or the time to submit it to superiors for approval is still delayed. Most of the financial management apparatus in the province is under the management, direction and administration of different actors at each different level: Department of Finance, Department of Tax, and State Treasury at provincial level. These institutions are centrally and vertically managed from the central government to local. The coordination relationship between these agencies is currently loose, limiting the activeness in the budget implementation process.

Fifth, the ability to forecast and control budget implementation with 3 indicators scored B, showing that this dimension requires improvement. The payroll control indicator scores B, which shows the level of cohesion as well as timeliness of changes to the personnel and payroll data has not been met. In addition, the salary settlement process is slow and not synchronized, making the salary management in the province encounter difficult. This affects the provincial budget implementation.

Sixth, the budget accounting and reporting achieved 4 B and 2 C, showing that there is still a need to be improved. Some local units make low-quality finalization reports, with sketchy explanations, and incomplete reports according to prescribed forms and tables. The verification and approval of the final settlement is still stereotype, often slow, and not high quality. The data collected into the final settlement is not timely and accurate. The Financial Inspectorate, the State Inspectorate, and the State Audit have paid attention to and improved the quality of their work, but the detection results are still relatively limited. The handling of violations is not really resolute. The discovery of irrationalities of policies and regimes in order to supplement, amend and perfect policies and regimes has not been frequent.

The results of the evaluation reflect relatively accurately the current actual situation of the management of state recurrent expenditures of Ninh Thuan province. The components that are rated A or B+ are the

ones that are currently being implemented well by the province. However, there are still a number of indicators and dimensions scored C or D showing that these dimensions of the province need to be improved. In fact, the selected criteria of PEFA framework are applicable and useful to assess the performance of provincial recurrent expenditure and budget management. Applicable solutions corresponding and suitable to the actual situation of the province are on improving the quality of state budget expenditure proposal, the quality of management of state budget expenditure, the quality of the settlement of state budget expenditures, the inspection and management of state budget expenditures.

IV. CONCLUSION

Through the systematization of the theoretical basis for recurrent expenditure and the management of state budget expenditures, the regulations in the preparation and implementation of budget proposal, finalization and inspection of budget expenditures in Ninh Thuan province, it can be seen that, in recent years, Ninh Thuan province has made many efforts to make expenditure and State budget recurrent expenditure management becomes more reasonable and effective. The result of PEFA score of Ninh Thuan province reached 8 A, 15 B, 1 C+, 6 C, 3 D.

Ninh Thuan Provincial People's Committee has allocated budget according to the list of expenditures assigned by the Provincial People's Council yearly, approved and appraised in a timely manner according to the right regime and right objects for expenditures for policy beneficiaries. The province also pays attention to implement projects to support the development of production and rural industries, economics, environment and other fields. However, the expenditure and management activities of recurrent expenditures of the province still have many shortcomings, not close to the actual situation; overspending still occurs. The research results show that some composition in recurrent expenditures that have not been cared enough such as budget implementation process, payroll control, annual budget reports.

By using the PEFA assessment framework to find out the shortcomings in recurrent expenditures and management in Ninh Thuan province, the study has proposed a number of solutions (i) to improve the quality the preparation of state budget expenditure proposal; (ii) improve the quality of the management of state budget expenditure; (iii) strengthen the inspection and management of state budget expenditures so as to contribute to the effectiveness of recurrent expenditures and recurrent expenditure management in the province.

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ASPECT-BASED SENTIMENT ANALYSIS FROM HOTEL GUESTS' ONLINE REVIEWS: CASE STUDY OF TWO BRANCH HOTELS IN BINH DUONG, VIETNAM

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Abstract: This study aims to undertake a comprehensive sentiment analysis based on aspect- based sentiment analysis (ABSA) for two branch hotels in Binh Duong province, Vietnam. The ABSA analysis indicates an overall positive sentiment, with notable differences in aspect-based sentiments between the two hotels. The impact of the COVID-19 pandemic on customer expectations is also examined, revealing mixed results in two hotels. The study addresses two research questions, identifying disparities in perceived service qualities and investigating the pandemic's influence. The findings offer practical implications for hotel managers, emphasizing the importance of ABSA in enhancing service quality and adapting to changing customer expectations. By leveraging ABSA, hotels can optimize their services and build lasting customer relationships in the competitive hospitality industry.

Keywords: *aspect-based sentiment analysis, service quality, comparative analysis, COVID-19, hotel management*

I. INTRODUCTION

Hotels must understand their customers' preferences in order to provide a satisfactory experience and succeed in the highly competitive business landscape (Barrows et al., 2011). Online reviews provide a valuable source of information to help hotels tailor their products and services to the needs of their customers. Sentiment analysis is a technique that identifies the emotional tone of a hotel review and classifies it as, for example, negative, neutral, or positive (Bachtiar et al., 2020; Zhuang et al., 2006). Hotels are increasingly using sentiment analysis to better understand customers' feedback and satisfaction. However, conventional sentiment analysis might not adequately capture the intricate nuances of complex customer feedback in online reviews, resulting in the limited usefulness of the analysis (Zhang et al., 2022).

In recent years, ABSA has emerged as a prominent tool, enabling a more comprehensive understanding of customers' satisfaction by decomposing of customers' online reviews into relevant aspects (Ozcan et al., 2022; Brauwers & Frasincar, 2023; Zhang et al., 2022). With the implementation of ABSA, hotels are able to acquire valuable insights into their customers' preferences, allowing them to identify areas that require improvements in

service quality. Consequently, this leads to an enhanced experience for their valued customers (Kim and Kim, 2022). By leveraging ABSA, hotels can make informed decisions based on the analysis of customer sentiments, thus optimizing their services to better align with customer expectations. The comprehensive understanding provided by ABSA allows hotel management to identify specific aspects of their services that require attention, enabling them to implement targeted improvements. Moreover, ABSA's ability to decompose reviews into relevant aspects offers valuable insights into the strengths and weaknesses of a hotel's offerings. This enables hotels to enhance their competitive edge by capitalizing on their strengths and addressing any shortcomings.

This study specifically investigates two branch hotels in Binh Duong province, Vietnam. These hotels are under the same management and brand names and share similar attributes. However, the location and star-rating of each hotel are prominent differences. This study aims to assess how customers perceive and differentiate the service qualities across various aspects in these hotels, utilizing ABSA on online reviews. To achieve this, the Mann-Whitney U test, a nonparametric statistical analysis, is employed to compare service quality perceptions between the two hotels. Additionally, the study is to examine the impact of the COVID-19 pandemic on customers' perceptions of service quality.

From the perspective of hotel managers, this study seeks to provide practical insights by addressing two research questions: (1) Are there any notable disparities in perceived service qualities between the two hotels? (2) How have the perceived service qualities changed before and after the COVID-19 pandemic? The first research question identifies significant variations in customer perceptions of service qualities. The second question specifically investigates the impact of the pandemic on customer expectations. Addressing these research questions will contribute to a comprehensive understanding of customers' perceptions and enable evidence-based decision-making in hotel management.

This study unfolds as follows: The second section provides a literature review, followed by a description of the materials and methodology in the third section. Empirical results, their implications, and relevance to the research questions are discussed in the fourth section. Finally, the conclusion section summarizes the key findings of the study, emphasizing their significance from the perspective of hotel managers.

II. EXPLORING VIETNAM HOSPITALITY INDUSTRY AND THEORETICAL FRAMEWORK

A. Overview of Vietnam hospitality industry

Tourism has been one of the significant contributors to Vietnam's economy. Before the COVID-19 pandemic, in 2019, the tourism sector contributed directly 9.2 % to Vietnam's total GDP (General Statistics Office Vietnam, 2019). The number of international tourists travelling to Vietnam has been affected by the outbreak of COVID- 19, reducing by 79.5 % in 2020, compared to 18 million in 2019 (Tourism Information Technology Center, 2022). When tourism made recovery after the outbreak, other sectors of the hospitality industry such as accommodation, catering and transportation have also been led to returned growth. According to the General Statistics Office Vietnam (2022)

in the first half of 2022, an increase of 20.9 % was recorded in accommodation services' revenue, in comparison with the same period last year. International accommodation standards, especially the luxury rating level, has becoming trickier for Vietnam hotels to adapt, to satisfy international customers. Customer satisfaction has remained a competitive field for hotel managers, where they need to keep improving service quality to gain customer loyalty and retention (Naini et al., 2022).

The characteristic of service 'intangibility' challenges customers' decision to purchase when the quality and performance of product-service are impossible to evaluate before consumption (Bebko, 2000). Therefore, customers are more likely to obtain information from past purchasers before making a purchase (Sparks et al., 2016). This special kind of information could be about opinions, evaluations, feelings, attitudes and comes from under textual or numeric types (Pham & Le, 2018). Online customer reviews which are one type of electronic word-of-mouth (eWoM) have been considered to successfully affect consumer behavior and their decision-making more than traditional marketing methods (Ye et al., 2011; Zhang et al., 2010). Extensive amount of research on online customer review in hospitality industry has been studied thoroughly by decade, but the focuses were on its impact on customers' perception, satisfaction (Li et al., 2013; Liu & Park, 2015; Ye et al., 2011) and business performance (Phillips et al., 2017; Zhang et al., 2010). Along with the growing popularity and practical application of big data, different new methods of data collection and analysis have brought up more valuable insights of online customer reviews on hospitality businesses.

The online hotel business has been growing tremendously in Vietnam, where large hotels reported that 40 - 60 % of their total revenue came from OTA platforms, in just Quarter 1/2023 (Viet Nam News, 2023). Customers started to leave reviews of their stay experience on OTA sites, and this has become a source of useful word-of-mouth for other customers. More customers are considering online opinions from booking channels, when making decisions, as they find these opinions are more objective and trustworthy (Gunasekar & Sudhakar, 2019; Li et al., 2013). Therefore, evaluation of online reviews on those OTA sites is not only important for customers to decide, but also plays a crucial role for hotel managers to understand better the service attributes that matter to their customers (Li et al., 2020; Liu et al., 2017; Thu, 2020; Vo et al., 2022).

Sentiment analysis which has become a research topic by the demand of analyzing opinionated information and classify these opinions into negative, neutral, or positive classes (Pham & Le, 2018). Identifying customer online reviews' sentiment insights regarding service performance could help hotel managers assess customer experience and their satisfaction level to make efficient management strategy.

B. Theoretical framework

ABSA is a natural language processing (NLP) task that aims to extract and classify opinions about specific aspects of a product or service. ABSA has gained significant attention in recent years due to its practical applications in various domains, including customer reviews, social media analysis, and market research (Azhar et al., 2020; Rybakov and Malafeev,

2018; Al-Smadi et al., 2019; Wen et al., 2023; Dcunha, 2019; Le-Minh et al., 2021).

ABSA is commonly classified into three main categories: rule-based approaches, machine learning approaches, and deep learning approaches (Brauwers & Frasincar, 2023; Zhang et al., 2022). Rule-based approaches are based on manually defining rules to extract aspects and classify sentiments. In the early stage of ABSA, Liu (2012) conducted a study on sentiment analysis and opinion mining, which included a rule-based approach for aspect extraction and sentiment classification.

One common approach to ABSA is to use machine learning approaches. Machine learning approaches involve training a model on a dataset of annotated reviews to automatically extract aspects and classify sentiments. These approaches can be broadly classified into supervised, semi-supervised, and unsupervised learning. Various machine learning algorithms, such as Support Vector Machines (Said & Manik, 2022; Sivabharathi & Chitra, 2022), Naïve Bayes (Bhoite & Londhe, 2021), and Random Forests, have been used for ABSA in different contexts (Brauwers & Frasincar, 2023; Zhang et al., 2022). While machine learning approach in ABSA has proven to be effective (Vaswani et al., 2017), it still faces challenging issues such as obtaining quality training data, generalization, feature extraction, interpretability, and computational resources (Wang et al., 2022). In the meantime, deep learning techniques have gained popularity in ABSA for their ability to automatically recognize attributes and determine their polarity by training a neural network on large datasets of labeled instances. Commonly used deep learning architectures in ABSA are Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Transformer-based models (Brauwers & Frasincar, 2023; Zhang et al., 2022).

Transformer-based models have become the dominant approach for ABSA in recent years due to their ability to capture long-range dependencies and contextual information effectively (Vaswani et al., 2017). These approaches are a type of deep learning model that undergo pre-training using large amounts of general language data, such as news articles or Wikipedia. Transformer-based models, such as Bidirectional Encoder Representations from Transformers (BERT) (Devlin et al., 2019) and Robustly Optimized BERT Pretraining Approach (RoBERTa) (Liu et al., 2019), have attained state-of- the-art performance on several benchmark datasets for ABSA. Pre-trained models can be highly effective in reducing the need for extensive labeled data and feature engineering, which can be both time-consuming and expensive.

This pre-trained transformer-based model can be fine-tuned further to address a specific task. Fine- tuning these models on specific ABSA tasks further enhances their accuracy, but this process demands considerable labeled data, computational power, and expertise in machine learning. For small businesses with limited budgets and technical capabilities, this presents a significant challenge. To overcome these limitations, the proposed approach in this study incorporates zero-shot learning using the Python Ktrain library. Zero-shot learning allows the model to perform ABSA without the need for task-specific training data, leveraging semantic relationships learned during pre-training.

By combining transformer-based models and zero-shot learning, small businesses can

use pre- trained models effectively without extensive fine- tuning. This approach provides valuable customer feedback insights without sacrificing accuracy, making ABSA accessible to businesses.

II. DATA AND METHODOLOGY

A. Data

For this study, data were collected from online reviews in various sources of two branch hotels. As shown in Table 1, the data collection period for Hotel A was from April 2016 to the end of March 2023, resulting in a total of 881 reviews. For Hotel B, it was extended from January 2015 to the end of March 2023, encompassing a total of 708 reviews.

Table 1. Data description

	Hotel A	**Hotel B**
Period	2016/04/07 ~ 2023/03/31	2015/01/05 ~ 2023/03/07
Number of Review	881	708
Average of Words per Review	23.7	31.7

Data was sourced from TrustYou (www.trustyou.com, accessed 1 April 2023), an online platform collecting reviews from various online travel agency (OTA) websites.

The distribution of reviews in various languages used in the online reviews is presented in Table 2. It should be noted that the languages used by the online reviewers may not always align with the nationality of the reviewers, especially when English is used. Nevertheless, reviews written in less common languages such as Chinese, Korean, or Japanese are more likely to be authored by individuals from those respective countries. From this perspective, we can infer that the main customer bases of Hotel A and B comprise Chinese, Vietnamese, Korean, and Japanese, along with English-speaking guests.

Table 2. Used languages in the online reviews

Hotel A		**Hotel B**	
Languages	***Reviews***	***Languages***	***Reviews***
Chinese	315	English	283
English	255	Vietnamese	120
Vietnamese	177	Korean	96
Korean	68	Chinese	82
Japanese	47	Japanese	71
German	12	German	16
Italian	3	Dutch	7
Galician	1	French	7
Thai	1	Italian	6
Russian	1	Norwegian	4
Dutch	1	Spanish	4
		Finnish	2
		Thai	2
		Indonesian	1
		Russian	1
		Danish	1

B. Methodology

In conducting ABSA, this study employs a two-stage analysis. In the initial stage, aspects are identified through the implementation of zero-shot learning using the Ktrain Python library (Maiya, 2022). In the second stage, the transformer-based BERT model, provided by Huggingface (Wolf et al., 2019), is applied to extract sentiments associated with each aspect from online reviews.

Zero-shot learning is a methodology that enables a model to perform a given task without requiring specific training data for that task (Pushp and Srivastava, 2017). Instead of fine-tuning the model on a particular task, zero-shot learning leverages the model's ability to

generalize to unseen classes or tasks by utilizing the semantic relationships learned during pre-training. Ktrain, a Python library built on top of TensorFlow and Keras, provides an API that facilitates the application of zero-shot learning to various NLP tasks, including ABSA (Yin et al., 2019). The evaluation metrics of the Ktrain library used in this study are available on the official GitHub repository (github.com/amaiya/ktrain).

There are six aspect categories given to be identified in the first stage as in Table 3. These aspects are essential dimensions for hotel management to gauge service quality and customer satisfaction (Gunasekar & Sudhakar, 2019; Liu et al., 2017). It should mention that customer reviews without specific mentions of aspects like 'good' or 'very good' were excluded from the ABSA extraction and analysis process. It ensured that only reviews containing explicit references to particular aspects were considered.

Table 3. Categories of aspects

Cleanliness and hygiene
Food and beverage
Location and place
Price and value
Room and amenities
Service and staff quality

The BERT based model used in this study (huggingface.co/bert-base-uncased) was introduced by Devlin et al. (2019) and has become one of the most widely used models in NLP tasks, including ABSA. BERT is known for its ability to capture contextual information and long-range dependencies in text, making it well-suited for tasks that require understanding the relationships between words and phrases in a sentence. Huggingface is a popular open- source library that offers pre-trained transformer- based models, including BERT. The performance scores of the BERT base model on different NLP tasks, measured in terms of accuracy and correlation coefficient, can be accessed on the Hugging Face website.

The Mann-Whitney U test, also known as the Wilcoxon rank-sum test, is selected as the appropriate statistical analysis method for this study. The Mann-Whitney U test is a nonparametric alternative to the standard two-sample test (Keller, 2022). It is widely used to compare two independent samples or groups. Unlike parametric tests, the Mann-Whitney U test does not assume a specific distribution for the data and is suitable for analyzing ordinal or skewed data. Its widespread usage stems from its ability to assess significant differences between two groups without relying on strict assumptions about the underlying data distribution (Keller, 2022). Given the ordinal, skewed, and unbalanced features of the sentiments extracted from ABSA in this study, the Mann-Whitney U test is a valid choice. It allows for an accurate assessment and comparison of service quality perceptions between the two hotels, considering the specific characteristics of the data.

In the following section, the results and discussions are presented, providing a comprehensive understanding of customer sentiments and their implications for hotel management.

III. RESULTS AND DISCUSSIONS

A. Results

After ABSA, a total of 1,406 and 1,234 aspects were extracted from the reviews of Hotel A and Hotel B, respectively as in Table 4. On

average, customers mentioned 1.72 aspects per review for Hotel A and 1.88 aspects per review for Hotel B in their online reviews.

Table 4. Extracted aspects description

	Hotel A	**Hotel B**
Number of Reviews	881	708
Average of Words in Review	23.7	31.7
Number of Aspects extracted	1,406	1,234
Average Aspects per Review	1.72	1.88

Table 5 displays the aspect-oriented results of ABSA for Hotel A and Hotel B. The table is divided into six aspects as in Table 5, each evaluated across three sentiment categories: Bad, Neutral, and Good.

Table 5. Aspect-oriented ABSA

		Hotel A		**Hotel B**	
Aspect	***Sentiment***	***Counts***	***%***	***Counts***	***%***
Cleanliness and hygiene	Bad	13	0.9	19	1.7
	Neutral	5	0.4	10	0.8
	Good	91	6.5	68	5.5
	Sub Total	109	7.8	97	7.9
Food and beverage	Bad	29	2.1	37	3.0
	Neutral	34	2.4	44	3.6
	Good	157	11.2	107	8.7
	Sub Total	220	15.6	188	15.2
Location and place	Bad	101	7.2	20	1.6
	Neutral	30	2.1	37	3.0
	Good	49	3.5	141	11.4
	Sub Total	180	12.8	198	16.0
Price and value	Bad	12	0.9	25	2.0
	Neutral	25	1.8	18	1.5
	Good	153	10.9	93	7.5
	Sub Total	190	13.5	136	11.0
Room and amenities	Bad	45	3.2	66	5.3
	Neutral	50	3.6	58	4.7
	Good	339	24.1	238	19.3
	Sub Total	434	30.9	362	29.3
Service and staff quality	Bad	76	5.4	104	8.4
	Neutral	26	1.9	12	1.0
	Good	171	12.7	137	11.1
	Sub Total	273	19.4	253	20.5
Total		**1,406**		**1,234**	

As shown in Table 5, the aspect of 'Room and amenities' received the highest number of reviews, with a total count of 434, accounting for 30.9% of the overall feedback in Hotel A. This indicates that customers provided substantial feedback and opinions specifically related to the rooms and amenities. The aspects of 'Service and staff quality' and 'Food and beverage' received 19.4% and 15.6% of the total reviews, respectively. For Hotel B, out of the total 1,234 extracted aspects, the aspect of 'Room and amenities' received the highest number of reviews, accounting for 29.3% of the total counts. It implies that customers provided significant feedback and opinions specifically related to the rooms and amenities provided by Hotel B. The findings from Table 5 underscore the importance of the aspects related to 'Room and amenities,' 'Service and staff quality,' and 'Food and beverage' in shaping customers' perceptions of both hotels. Moreover, the high number of reviews for the 'Room and amenities' aspect in both hotels highlights the significance customers place on the quality of their accommodations and the amenities provided.

Table 6 presents the results of sentiment-oriented ABSA, focusing on different sentiments associated with various aspects mentioned in customer reviews.

Table 6. Sentiment-oriented ABSA

		Hotel A		Hotel B	
Sentiment	*Aspect*	*Count*	*%*	*Count*	*%*
Bad	Cleanliness and hygiene	13	0.9	19	1.5
	Food and beverage	29	2.1	37	3.0
	Location and place	101	7.2	20	1.6
	Price and value	12	0.9	25	2.0
	Room and amenities	45	3.2	66	5.3
	Service and staff quality	76	5.4	104	8.4
	Sub Total	*276*	*19.6*	*271*	*22.0*
Neutral	Cleanliness and hygiene	5	0.4	10	0.8
	Food and beverage	34	2.4	44	3.6
	Location and place	30	2.1	37	3.0
	Price and value	25	1.8	18	1.5
	Room and amenities	50	3.6	58	4.7
	Service and staff quality	26	1.8	12	1.0
	Sub Total	*170*	*12.1*	*179*	*14.5*
Good	Cleanliness and hygiene	91	6.5	68	5.5
	Food and beverage	157	11.2	107	8.7
	Location and place	49	3.5	141	11.4
	Price and value	153	10.9	93	7.5
	Room and amenities	339	24.1	238	19.3
	Service and staff quality	171	12.2	137	11.1
	Sub Total	*960*	*68.3*	*784*	*63.5*
Total		**1,406**		**1,234**	

Among the analyzed reviews for both hotels, there were a total of 276 and 271 instances (19.6% and 22% of the reviews) for both hotels and where customers expressed a negative sentiment across all aspects.

Additionally, 170 and 179 reviews (12.1% and 14.5% of the total) are neutral. On the other hand, the majority of the analyzed reviews, totaling 960 and 784 (68.3% and 63.5%), expressed positive sentiments towards the various aspects. These results indicate a predominantly positive sentiment among the analyzed reviews.

Table 7 displays the results of the Mann-Whitney U test conducted to compare the results of ABSA between Hotel A and Hotel B addressing the research question 1. The research question 1 focuses on examining whether there are significant disparities in perceived service qualities between the two hotels.

Table 7. Mann-Whitney U test of ABSA

Aspect		Mann-Whitney U Test				H_o: $S_A = S_B$
		Obs.	*Rank sum*	*z-stats*	*p-value*	
Overall	Hotel A	1,406	1896124	2.415	0.016	Reject H_o
	Hotel B	1,234	1589996			
Cleanliness and hygiene	Hotel A	109	11971.5	2.201	0.027	Reject H_o
	Hotel B	97	9349.5			
Food and beverage	Hotel A	220	47969	2.961	0.003	Reject H_o
	Hotel B	188	35467			
Location and place	Hotel A	180	24702.5	-9.706	0.000	Reject H_o
	Hotel B	198	46928.5			
Price and value	Hotel A	190	32838.5	2.808	0.005	Reject H_o
	Hotel B	136	20462.5			
Room and amenities	Hotel A	434	183007	3.974	0.000	Reject H_o
	Hotel B	362	134199			
Service and staff quality	Hotel A	273	75762.5	2.523	0.012	Reject H_o
	Hotel B	253	62838.5			

The results indicate that there are notable differences in aspect-based sentiments between the two hotels for all aspects analyzed, including the overall sentiment. The null hypothesis (H_o), assuming no significant

differences in sentiments, was rejected for each aspect at a significance level of 5%. Regarding the sentiment related to location and place, it is worth highlighting that the observed difference is contrary to the patterns observed in the other aspects. The relatively developed city center where Hotel B is located may provide customers with a more vibrant and convenient environment, leading to a more positive sentiment in that specific aspect. In the meantime, the less developed areas surrounding the Hotel A may contribute to a relatively lower sentiment score in terms of location and place.

The COVID-19 pandemic, which officially began in Vietnam on January 23, 2023, has led to significant shifts in consumer behavior and priorities. The pandemic significantly reduced the number of online customer reviews collected since 2020 as observed in Table A1 and Table A2 in the Appendix. Moreover, Hotel A and B started their operations in 2013 and 2015, respectively, and were in their early stages before the pandemic. After 2020, both hotels transitioned into a more mature stage. Analyzing the periods before and after the pandemic shows changes in the hotels' performance and customer experiences during this transition. Research Question 2, discussed in Section 1, focuses on investigating the impact of the COVID-19 pandemic on customer expectations and its influence on both Hotel A and B, reflecting these factors.

The results of ABSA before and after the COVID- 19 pandemic are presented in the Appendix (Table A1 and Table A2). While it may not be straightforward to conclude that there was a significant shift in customers' service perceptions, some noteworthy changes can be observed.

For Hotel A, regarding the aspect of 'Location and place', there was a significant decrease in negative reviews from 8.8% to 2.9%, along with a slight increase in positive sentiment from 3.4% to 3.6%. These findings are consistent with the ongoing development of the area surrounding Hotel A, which has contributed to an enhanced perception of the location and place aspect. In the same manner, for 'Room and amenities', there was a substantial improvement in negative sentiment, decreasing from 3.8% to 1.6%, and concerning 'Service and staff quality', the number of negative reviews increased from 4.7% to 7.3% (with a decrease of 42% of the negative sentiment count of Before Covid-19), while the number of positive reviews increased significantly from 10.0% to 17.9%. The results demonstrate a positive shift in customer sentiment after the COVID-19 pandemic, characterized by a decrease in negative sentiment and an increase in positive sentiment.

For Hotel B, the analysis reveals improvements in certain aspects. Before COVID-19, negative sentiment regarding 'Cleanliness and hygiene' was 1.7%, which decreased to 0.9% after the pandemic. Similarly, for 'Room and amenities', negative sentiment increased slightly from 5.1% to 6.6%, but positive sentiment also increased from 18.8% to 21.2%. Regarding 'Service and staff quality', there was an slight increase in negative sentiment from 8.3% to 8.8%, while positive sentiment also increased from 10.0% to 15.9%. These findings suggest a mixed response in 'Service and staff quality' aspect.

Table 8 presents the results of the Mann-Whitney U Test conducted for Hotel A, aiming to compare the sentiment before and after the

pandemic across various aspects for research question 2. In terms of the overall sentiment, there is a significant difference between before and after COVID-19, as indicated by the rejection of the null hypothesis. However, when analyzing each aspect individually, the results are mixed. For 'Cleanliness and hygiene', 'Food and beverage', 'Price and value', and 'Service and staff quality', there were no significant differences detected between the before and after periods. This suggests that customers' sentiment scores did not significantly change for these aspects. Conversely, for 'Location and place' and 'Room and amenities' aspects, there were significant differences observed between the before and after periods, as indicated by the rejection of H_o.

Table 8. Hotel A: Mann-Whitney U Test of sentiment before and after COVID-19

Aspect		**Mann-Whitney U Test**				***H_o: Sbefore = Safter***
		Obs.	***Rank sum***	***z- stats***	***p-value***	
Overall	Before	1,021	701079.5	-3.089	0.002	Reject H_o
	After	385	288041.5			
Cleanliness and hygiene	Before	83	4598	0.364	0.716	Fail to reject H_o
	After	26	1397			
Food and beverage	Before	165	17709	-1.613	0.107	Fail to reject H_o
	After	55	6601			
Location and place	Before	149	12846	-2.707	0.007	Reject H_o
	After	31	3444			
Price and value	Before	149	14220	-0.044	0.965	Fail to reject H_o
	After	41	3925			
Room and amenities	Before	312	65851	-2.370	0.018	Reject Ho
	After	122	28544			
Service and staff quality	Before	163	22187.5	-0.262	0.793	Fail to reject H_o
	After	110	15213.5			

In the same manner, Table 9 displays the results of the Mann-Whitney U Test for Hotel B. The results illustrate that there are no significant differences in sentiment ratings between the before and after periods for any of the aspects analyzed. The failure to reject the null hypothesis suggests that there was no substantial shift in customer sentiment for Hotel B following the pandemic. This implies that customers' perceptions of the various aspects analyzed remained relatively consistent before and after the pandemic in Hotel B.

Table 9. Hotel B: Mann-Whitney U Test of sentiment before and after COVID-19

Aspect		Mann-Whitney U Test				H_o: $S_{before} = S_{after}$
		Obs.	*Rank sum*	*z- stats*	*p-value*	
Overall	Before	1,008	620140.5	-0.556	0.578	Fail to reject H_o
	After	226	141854.5			
Cleanliness and hygiene	Before	87	4303	0.590	0.555	Fail to reject H_o
	After	10	450			
Food and beverage	Before	164	15251.5	-1.110	0.267	Fail to reject H_o
	After	24	2514.5			
Location and place	Before	156	15859.5	1.289	0.198	Fail to reject H_o
	After	42	3841.5			
Price and value	Before	115	7789.5	-0.647	0.518	Fail to reject H_o
	After	21	1526.5			
Room and amenities	Before	291	52748.5	-0.102	0.918	Fail to reject H_o
	After	71	12954.5			
Service and staff quality	Before	195	24200	-1.315	0.189	Fail to reject H_o
	After	58	7931			

B. Discussion

The findings of this study have illustrated certain implications that hotel managers could implement to enhance service quality and customer satisfaction based on 'tangibilizing' customer online reviews.

Firstly, the results highlighted the complexity of customer feedback, where multiple aspects were often discussed within a single review. In conventional sentiment analysis, identifying an accurate customer opinion is challenging when several aspects are expressed with a single sentiment. Therefore, it becomes crucial to analyze sentiments with respect to each aspect, as it provides a more nuanced understanding of customer feedback. ABSA enables a more comprehensive and accurate analysis of customer sentiments, catering to the diverse aspects of their experiences. This method could unravel the reality of customer evaluation by the power of words they conveyed (Kim & Kim, 2022). By employing ABSA techniques, hotel managers could gain better knowledge of key aspects that could influence positively or negatively customer experience based on their reviews' expressions. Aspects that were mentioned more times and received higher negative sentiment reviews, would be prioritized to take corrective or preventive actions. As a form of proactive prevention, effective management response to customer online reviews, especially negative ones, has been proven to help improve customer satisfaction and brand trust (Min et al., 2015; Sparks et al., 2016). Even though the number of neutral sentiments was insignificant among the analyzed reviews, it raised various room for improvements that hotel managers could impose to turn into more positive sentiment, when positive reviews were seen to improve the hotels' demand and revenue (Phillips et al., 2017). Furthermore, hotel managers could implement reward programs to motivate customers to post their experience reviews on OTA platforms, which not only helps hotels

gain insights into their service quality but also increases brand exposure for future customers.

Secondly, by using the comparisons of periodic sets of customer online reviews before and after the COVID-19 pandemic, more cogent and scientific information is available to assist hotel managers in strategizing their management activities to maintain service-product standard consistency. Following by customer sentiment response to the COVID-19 pandemic, a notable result suggested that customers would expect more attentive service during and after the pandemic. It was similarly advised that front-line employees should be more proactive and courteous service towards customers during the COVID-19 pandemic (Kim & Kim, 2022). Appropriate employee training programs to maintain positive moment-of-truth are vital to make customers feel satisfied with their experience and have higher intentions to return (Lindsey-Hall et al., 2023).

IV. CONCLUSION

The study employed ABSA to comprehensively understand customers' perceptions of service qualities in two branch hotels located in Binh Duong province, Vietnam. Analyzing online reviews revealed valuable insights into customer sentiments, providing a deeper understanding of their experiences.

The findings emphasized the significance of three aspects, namely 'Room and amenities', 'Service and staff quality', and 'Food and beverage', in shaping customers' perceptions of both hotels. Notably, the 'Room and amenities' aspect received the highest number of reviews, underscoring its importance in customer evaluations. The sentiment-oriented ABSA analysis revealed an overall positive sentiment among the analyzed reviews, indicating high levels of customer satisfaction. However, significant differences in aspect-based sentiments were observed between the two hotels, suggesting varying perceptions of certain service qualities in each establishment. Particularly, the 'Location and place' aspect exhibited contrasting sentiment patterns, influenced by the surrounding environments of the hotels.

Regarding the impact of the COVID-19 pandemic, in Hotel A, there was a positive shift in customer sentiment after the pandemic, with decreases in negative sentiments and increases in positive sentiments across various aspects. In contrast, Hotel B displayed improvements in certain aspects after the pandemic, while others remained relatively consistent. Research Question 1 sought to identify disparities in perceived service qualities between the two hotels, revealing significant differences in aspect-based sentiments. Research Question 2 investigated the impact of the COVID-19 pandemic on customer expectations, revealing notable changes in customer perceptions before and after the pandemic.

This study's findings offer practical implications for hotel managers seeking to enhance service quality and adapt to changing customer expectations. The utilization of ABSA allowed for a nuanced understanding of customer feedback, identifying specific areas for improvement and prioritizing actions based on customer sentiments. ABSA proves to be an invaluable tool in understanding customer feedback and satisfaction, guiding hotels to make informed decisions and continuously improve their services. By "tangibilizing" customer online reviews, hotels can build

stronger customer relationships, enhance brand loyalty, and secure their position as industry leaders. As the hospitality sector evolves, embracing advanced analytical techniques like ABSA becomes imperative for hotels seeking sustainable growth and superior customer experiences.

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APPENDIX

Table A1. Aspect-oriented ABSA: Before and after COVID-19

		Hotel A				Hotel B			
		Before COVID-19		*After COVID-19*		*Before COVID-19*		*After COVID-19*	
Aspect	**Sentiment**	**Counts**	**%**	**Counts**	**%**	**Counts**	**%**	**Counts**	**%**
Cleanliness and hygiene	Bad	10	1.0	3	0.8	17	1.7	2	0.9
	Neutral	3	0.3	2	0.5	8	0.8	2	0.9
	Good	70	6.9	21	5.5	62	6.2	6	2.7
	Sub Total	*83*	*8.1*	*26*	*6.8*	*87*	*8.6*	*10*	*4.4*
Food and beverage	Bad	27	2.6	2	0.5	34	3.4	3	1.3
	Neutral	24	2.4	10	2.6	39	3.9	5	2.2
	Good	114	11.2	43	11.2	91	9.0	16	7.1
	Sub Total	*165*	*16.2*	*55*	*14.3*	*164*	*16.3*	*24*	*10.6*
Location and place	Bad	90	8.8	11	2.9	13	1.3	7	3.1
	Neutral	24	2.4	6	1.6	29	2.9	8	3.5
	Good	35	3.4	14	3.6	114	11.3	27	11.9
	Sub Total	*149*	*14.6*	*31*	*8.1*	*156*	*15.5*	*42*	*18.6*
Price and value	Bad	10	1.0	2	0.5	21	2.1	4	1.8
	Neutral	19	1.9	6	1.6	17	1.7	1	0.4
	Good	120	11.8	33	8.6	77	7.6	16	7.1
	Sub Total	*149*	*14.6*	*41*	*10.7*	*115*	*11.4*	*21*	*9.3*
Room and amenities	Bad	39	3.8	6	1.6	51	5.1	15	6.6
	Neutral	38	3.7	12	3.1	50	5.0	8	3.5
	Good	235	23.0	104	27.0	190	18.8	48	21.2
	Sub Total	*312*	*30.6*	*122*	*31.7*	*291*	*28.9*	*71*	*31.4*
Service and staff quality	Bad	48	4.7	28	7.3	84	8.3	20	8.8
	Neutral	13	1.3	13	3.4	10	1.0	2	0.9
	Good	102	10.0	69	17.9	101	10.0	36	15.9
	Sub Total	*163*	*16.0*	*110*	*28.6*	*195*	*19.3*	*58*	*25.7*
Total		**1021**	**100**	**385**	**100**	**1,008**	**100**	**226**	**100**

Table A2. Sentiment-oriented ABSA: Before and after COVID-19

Sentiment		Hotel A				Hotel B			
		Before COVID-19		*After COVID-19*		*Before COVID-19*		*After COVID-19*	
	Aspect	***Count***	***%***	***Count***	***%***	***Count***	***%***	***Count***	***%***
Bad	Cleanliness and hygiene	10	1.0	3	0.8	17	1.7	2	0.9
	Food and beverage	27	2.6	2	0.5	34	3.4	3	1.3
	Location and place	90	8.8	11	2.9	13	1.3	7	3.1
	Price and value	10	1.0	2	0.5	21	2.1	4	1.8
	Room and amenities	39	3.8	6	1.6	51	5.1	15	6.6
	Service and staff quality	48	4.7	28	7.3	84	8.3	20	8.8
	Sub Total	*224*	*21.9*	*52*	*13.5*	*220*	*21.8*	*51*	*22.6*
Neutral	Cleanliness and hygiene	3	0.3	2	0.5	8	0.8	2	0.9
	Food and beverage	24	2.4	10	2.6	39	3.9	5	2.2
	Location and place	24	2.4	6	1.6	29	2.9	8	3.5
	Price and value	19	1.9	6	1.6	17	1.7	1	0.4
	Room and amenities	38	3.7	12	3.1	50	5.0	8	3.5
	Service and staff quality	13	1.3	13	3.4	10	1.0	2	0.9
	Sub Total	*121*	*11.9*	*49*	*12.7*	*153*	*15.2*	*26*	*11.5*
Good	Cleanliness and hygiene	70	6.9	21	5.5	62	6.2	6	2.7
	Food and beverage	114	11.2	43	11.2	91	9.0	16	7.1
	Location and place	35	3.4	14	3.6	114	11.3	27	11.9
	Price and value	120	11.8	33	8.6	77	7.6	16	7.1
	Room and amenities	235	23.0	104	27.0	190	18.8	48	21.2
	Service and staff quality	102	10.0	69	17.9	101	10.0	36	15.9
	Sub Total	*676*	*66.2*	*284*	*73.8*	*635*	*63.0*	*149*	*65.9*
Total		1021	100	385	100	27.4	1,008	226	100

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CENTRAL BANK DIGITAL CURRENCY AND THE STATE BANK OF VIETNAM: A NEW TOOL FOR FINANCIAL INCLUSION AND FINANCIAL STABILITY

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Abstract: This paper reviews current research on central bank digital currency (CBDC) to assess its application for Vietnam. Adopting the balance sheet approach, this paper shows that CBDC is not distinguished from other forms of currency. CBDC can offer a means to financial inclusion if it targets only households with no access to banks for various reasons. However, CBDC will destabilize the status quo if it incurs a competition among banks to maintain their own current businesses. Therefore, this paper contributes to the CBDC literature with the argument that while CBDC is simply a new form of the current national currency system, the accessibility to CBDC generates different impacts on different groups of currency users. With this argument, this paper suggests that the State Bank of Vietnam should develop its own CBDC system focusing on low-income households that can increase financial inclusion in Vietnam, which results in more financial stability.

Keywords: *central bank digital currency, balance sheet, financial inclusion, State Bank of Vietnam*

I. INTRODUCTION

Central bank digital currency (CBDC) has emerged as an alternative to the traditional forms of currency, both in physical and digital forms, around the world as a counter approach from central banks against the uncontrollable thrive of many cryptocurrencies. Yet, the implementation of CBDC remains unsettled from both academia and policymakers. This is because the potential effects of a CBDC on an economy have not been exhausted due to the fact that CBDC is a general terminology to cover different types of technological setup. Each of these types has its own pros and cons, and there has been no successful case of implementing CBDC although there have been around 140 central banks conducting their own studies and tests[1].

However, digitalization is irreversible to humankind, and CBDC will eventually be the new reality because central banks have already issued their own digital currencies in terms of reserve for commercial banks and chartered financial institutions. Hence, it is necessary for central banks to understand how CBDC affects the current monetary policy transmission, especially when CBDC can guarantee financial inclusion if implemented adequately. With this as one of the goals for the upcoming 4th industrial

[1] Retrieved from https://cbdctracker.org/

revolution, the State Bank of Vietnam (SBV) has conducted its own research since 2021, but there will be no sign of CBDC for Vietnam anytime soon. In the meantime, one of the issues for the SBV is the low financial inclusion of Vietnam. Vietnam ranked the second in the list of world's most unbanked countries 2021[2]. According to the SBV's 2020 statistics, only 70 percent of adults in Vietnam had a bank account, but about half of this number did not have access to credit of any source[3]. These numbers do not account for rural areas and the uses of bank accounts. Simply put, the SBV has to assure that its economy can run as smoothly and fast as its growth in productive activities. Accessing to financial sources is limited to low-income households in Vietnam (Linh et al., 2019), easing this supports low-income households in many aspects of their life (see Lan and Truong, 2022). Hence, financial inclusion becomes more important to the SBV in the age of digitalization.

Therefore, this paper aims to provide a closer look at what can be the adequate choice of CBDC for Vietnam in the search for financial inclusion that can boost our domestic growth in the age of internet of things. To do so, this paper reviews the latest literature on CBDC and applies the balance sheet method to demonstrate possible effects of a CBDC to the current monetary setup in Vietnam.

The remainder of this paper is organized as follows. Section 2 briefly presents CBDC in the current literature. Section 3 outlines common assumptions and methods in using balance sheet approach. Section 4 demonstrates potential impacts of CBDC on the balance sheet of the central bank in relation to other sectors. Section 5 discusses the potential application of CBDC for Vietnam. Section 6 concludes.

II. CENTRAL BANK DIGITAL CURRENCY

This section briefly reviews the current literature on CBDC to establish the general understanding about this topic, including the current definition, designs and their respective pros and cons, and technical requirements of CBDC.

A. Definition

There has not been a universally accepted definition of CBDC due to the ongoing evolution of the taxonomy of digital representations of money (Adrian and Mancini-Griffoli 2021). Nonetheless, CBDC is just a money issued by a central bank as the name already addresses. Hence, IMF defines CBDC "as a digital representation of a sovereign currency issued by and as a liability of a jurisdiction's central bank or other monetary authority" (Kiff et al., 2020). This definition addresses the fact that CBDC is not a new currency, but rather a new form of a currency, issued and controlled by a central bank. This is because there has not been an example that a central bank issues its own CBDC with a new unit of account. Then, CBDC is really a new component in the balance sheet of a central bank. This is why the most vigor argument about CBDC is who can access such the balance sheet of a central bank via using this new format of a currency since it has all functions of currency from medium of exchange, store of value, unit of account, to standard of deferred payments (Lee et al., 2021).

[2] Retrieved from https://www.gfmag.com/global-data/economic-data/worlds-most-unbanked-countries

[3] Retrieved from https://mof.gov.vn/webcenter/portal/tttpen/pages_r/l/detail?dDocName=MOFUCM201181

B. Designs

Lee et al. (2021) summarize that CBDC has two dimensions that shape its structure. They are the business design and the ledger design. The business design defines groups of users for CBDC, i.e., for banks and financial institutions or for business and individuals. The ledger design defines the blockchain technological setup with either token-based or account-based depending on the verification methods. These two dimensions generate four different types of CBDC as summarized in Figure 1.

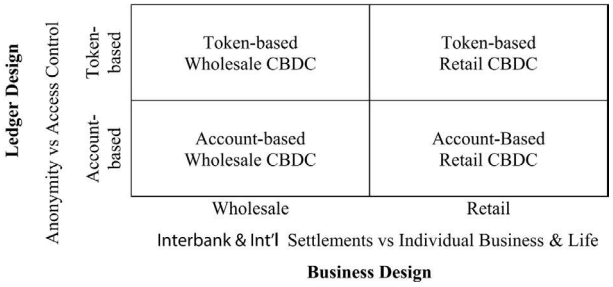

Figure 1. BIS's money flower: A taxonomy of money (Lee et al., 2021)

Figure 1 points out that there are at least four different designs for CBDC and they can share certain features. For example, CBDC is just a new format of a currency and obtains all functions of money. Nonetheless, each of these four designs can serve distinguish purpose.

From the business design, it is generally accepted that CBDC can be either wholesale or retail. Wholesale CBDC (wCBDC) will be used by financial institutions for large-value and high-priority transactions (Bech and Garratt, 2017). At the first look, wCBDC might not be different from the current reserve system that settles transactions between banks. Nonetheless, reserves "are exchanged in a centralized fashion across accounts at the central bank" (ibid., p. 56) while wCBDC allows direct transactions between two parties. Simply put, the role of the central bank is not visible in wCBDC because it does not conduct the settlement as in the reserve system. For this feature, the question comes as should a central bank extend its reserve system for all financial institutions? If yes, what are the requirements for eligibility? And so on. The reserve system has been a tool for the central bank to control the behavior of its banks operating inside its country. If wCBDC becomes available for banks and like-bank institutions, then wCBDC can replace the current reserve system but it does not grant the same control level like the one it replaces. This is not to mention the cross-border transactions that can add more confusion to the implementation of wCBDC because it involves foreign central banks. Discussed in the World Economic Forum 2020, it remains ambiguous that wCBDC can be effectively deployed due to the fact that wCBDC, while it can reduce many layers in the current domestic and international financial system, will replace a very complex system that has operated for a long time (Lannquist, Warren, and Samans, 2020). In other words, wCBDC requires cooperation at the multinational level in order to exhaust its advantages, which is a challenge as central banks will be marginalized both domestically and internationally with such a cooperation. This is because central banks can still observe transactions among institutions, but they cannot intervene when necessary as in the reserve system. Hence, wCBDC has not received much attention from central banks around the world. According to the CBDC tracker website, there have been 44 central banks working on their own wCBDC, but there has been no official launch of this CBDC anywhere nor anytime soon.

Retail CBDC (rCBDC), on the other hand, is designed for low value transactions and available for the general public (Bech and Garratt, 2017). This is why it receives the most attention despite it has yet to materialize anywhere, because it promises to replace the current cash and bank deposits. In short, rCBDC is the conversion of every single unit of cash and bank accounts available right now. rCBDC can be used for personal and business transactions. The only question remaining for rCBDC is whether or not the users obtain direct access to the central bank's balance sheet. This is because the central bank is the only legal entity that can issue rCBDC, unless it assigns this function to a non-state party. In the latter case, rCBDC will be no different from the current setup that allows banks to issue their own digital money. While the direct accessibility is under review by central banks, rCBDC offers more mobility to central banks than wCBDC because it should be available for all. This is why this paper will focus on rCBDC later.

In terms of ledger design, CBDC can be either token-based or account-based depending on the technological setup that a central bank chooses. Token-based CBDC (tCBDC) refers to the use of tokens for transactions among digital wallets through centralized or decentralized systems. The tokens here are symbolic and digital rather than having physical forms. tCBDC requires a verification of the very tokens used in transactions, this will reduce the risk of double-spending the very token (Kahn and Roberds, 2009). This very feature of tCBDC makes it desirable for the authority as there will be no counterfeit issue in issuing tCBDC, unless there is some entity with enough computer power to generate new tCBDC and alter the central book at the central bank. At the same time, tCBDC ensures the anonymity of the users as there are layers of security that cover the actual identification in the digital world. Also, tCBDC can be used without the internet connection as long as digital wallets functions. Hence, the anonymity feature of tCBDC should be considered by the central bank even though a centralized system will erase anonymity as the central bank decides.

CBDC can be account-based (aCBDC), which means that the users must open their accounts at the issuer and the latter will supervise every transaction among its account holders. Unlike tCBDC, aCBDC requires only the verification of the account holder for each transaction. This allows a central entity to observe and control all transactions while it does not have to conduct those transactions as in the current reserve system. Nonetheless, aCBDC inherits a security risk that anyone who can illegally access the central book can tamper and modify any account at will. This is also the current weakness of the digital system.

As discussed in Lee et al. (2021), the four combinations generated by the choices of the business and ledger designs can also be incorporated into either a centralized or decentralized government system. The only difference between these two systems is the existence of a central authority who is responsible for the verification and updating the information regarding the transaction conducted by involved parties. Notwithstanding, a decentralized government system does not mean there is no supervision but rather having a public record system that every user of that CBDC can access to have a knowledge about what happened in the system. Kiff et al. (2020) discuss this design in detail and conclude that there is no clear advantage

between a decentralized system compared to a centralized one. This is understandable due to the fact that, despite the technological advances in security, any digital platform is subject to cyber risk. Then, a decentralized system leaves its users on their own once there are some fraudulent or security issues, such as losing login information, because there is no central authority to discipline the wrongdoer nor maintain the integrity of the system.

Hence, Lee et al. (2021) conclude that the discussion on CBDC will not end soon with the developing technology. And it is the choice of individual central banks to choose its own design and structure of its CBDC. Nonetheless, rCBDC remains promising as it could replace cash in circulation, granting more control to a central bank in implementing its monetary policy. To understand how this occurs, we should understand the basic pros and cons of CBDC at this stage of technology.

C. (Potential) advantages

Until now, it is agreed that the advantages of rCBDC are prominent in (1) promoting financial integration feature, (2) improving financial efficiency and security, and (3) reducing cross-border payment fees (Lee et al., 2021; Kiff et al., 2020; MAS & Bank of Canada, 2019; CPMI, 2018), thanks to its technological setup that reduces layers of third and more parties involved in conducting transaction between the payor and the payee.

Nonetheless, these are potential advantages of rCBDC to the users rather than the issuer. If a central bank wants to have its rCBDC accepted and circulated as its cash, it needs not only a well-developed technological infrastructure but also a well economic growth that altogether grants accessibility to all individuals who wish to use this form of currency. Hence, it depends on the economic foundation of the nation that is able to provide necessary tools and infrastructure for those who want to use this form of currency. Such a system also has to assure the users about their privacy, which is not a priority of a central bank due to the fact that a central bank is not a profit-seeking entity (Kiff et al., 2020).

Indeed, a central bank is responsible for the monetary stability of its economy. For this very duty, the central bank has to pay attention to how digitalization can affect its monetary policy transmission. This is the very reason that central banks around the world study their own version of CBDC. From both Kiff et al. (2020) and Mancini-Griffoli et al. (2018), rCBDC can increase and improve financial inclusion mission of the central bank if implemented, which reduces financial instability. Lee et al. (2021) explain that CBDC can function without internet connection, competing against the complicate internet banking system and banking apps. Moreover, rCBDC offers easier access to rural areas where cash is not alway available for various reasons. And lack of accessibility to cash is a main barrier to financial inclusion (Damodaran, 2013). rCBDC offers a remedy for this issue because the central bank can create rCBDC at its will and distribute it as necessary. This is not to mention the burden of issuing and transporting cash to targeted areas. rCBDC offers the issuer the information regarding how the users spend their money instantly while cash does not reveal any of such information. Williamson (2019) points out how rCBDC can increase the welfare of households, especially the low income ones, as it is the new competitor to the current private banking system.

Again, infrastructure is the very prerequisite for rCBDC, which can be planned accordingly due to the advancement in production nowadays. An adequate investment for such an infrastructure to implement rCBDC should also contribute to the domestic economy in the long run. And the central bank does not operate for profit, but it has to support its economy appropriately. For this, rCBDC with its inclusiveness, assuming that it has suitable infrastructure, can promote financial inclusion better than any current tools of the central bank (Lee and Low, 2018).

For this particular inclusiveness, rCBDC is able to enhance the monetary policy transmission for the central bank once it replaces cash and other forms of currency domestically. This is because the infrastructure of rCBDC generates almost instant updates to the central bank with details about every transaction using this form of currency. This is an accurate statistical source for monetary policy making (see Kiff et al., 2020 for a detailed discussion on this aspect of rCBDC).

D. (Potential) Risks

rCBDC also has its other side. The very first issue of rCBDC is how to get it into the system in the first place as there is no clear discussion on how the central can introduce this new format of its currency into its economy. Instead, current research only pays attention to the case in which the central bank has to offer interest payment if it wants to quickly attract users because issuing rCBDC does not outlaw any form of currency circulating at the moment (see Kiff et al., 2020). Then, if the central bank offers interest-bearing rCBDC, it competes against commercial banks directly. This leads to the second risk of rCBDC that it will obsolete the role of commercial banks because individuals and even business will come to the central bank once rCBDC becomes publicly available. In addition, since rCBDC is just a conversion of cash into an encrypted digital format. Those who want to obtain rCBDC have to withdraw their bank deposits to open their accounts at the central bank's balance sheet. This will render the current two-tier banking system into some direct banking system, in which the central bank is the only bank in existence eventually. There has been no evidence that a one-tier banking system is beneficial for a monetary production economy.

Another infamous issue that rCBDC inherits from the internet infrastructure is the security. There is no panacea for this issue as of now. This is the biggest concern of central banks around the world because any one who can break the firewall and other security measures can wreak havoc for the central bank's balance sheet. Even though all hackings leave their marks and can be reversed with time and resources, the consequences are real and definitely affect the users. This may be the main obstacle to central banks as they do not want to take risk in losing essential information regarding their operation. And, central banks are the last resort of an economy, if they are not trustworthy, it means chaotic.

Finally, the legal system has to be revised to cover the existence of CBDC in any design. This is because the financial market will develop its own derivatives for CBDC (Lee et al., 2021). Once such derivatives emerge, they generate more challenges to the central bank as their information is not visible to central bankers, but their consequences are. Hence, updating the legal system becomes vital to the implementation of CBDC in any design.

III. A BALANCE SHEET ANALYSIS

This section focuses on how rCBDC affects the current implementation of monetary policy. The current literature is limited on how CBDC may influence monetary policy transmission. Meaning et al. (2018) focus on the case of England in relation with the world financial system and conclude that rCBDC does not change the current monetary policy transmission if not strengthen it with the technology application. In contrast, Minesso et al. (2020) apply a DCGE model to the monetary policy with CBDC and find that the issuing country will take advantage from those that do not issue their own CBDC because CBDC with its convenience will soon be accepted outside its jurisdiction. They also warn about the spillover effect of CBDC circulating outside its territory, making countries adopting this CBDC more exposed to financial shocks internationally. For the domestic effects of rCBDC, Barrdear and Kumhof (2016) argue with a DSGE model that rCBDC, extended to banks and financial institutions, can help reduce interest rates across the domestic financial system that will increase long run GDP. Schilling et al. (2020), with a DSGE model, find that rCBDC can help preemptively prevent a bank run scenario at the cost of inflation. Keister and Monnet (2022), however, argue that rCBDC can be designed as a counter-bank-run means without side effects.

Notwithstanding, there is yet any solid proof that rCBDC can enhance the monetary policy transmission due to the fact that there have been only three nations officially launching their own rCBDC since 2017. Theoretical approaches are the only confirmation for the benefits of rCBDC. One of them is the balance sheet analysis, which links the central bank to the banking system and households.

Before setting up the balance sheets of those sectors, it is necessary to set the basic conditions as follows:

- The central bank is the only issuer of this new format. Then, rCBDC belongs to the liability side of the central bank's balance sheet as a new form of currency in circulation, digitally. This also means that rCBDC does not replace any current component in the central bank's balance sheet but rather gets its own sub-category.
- rCBDC only circulates domestically. This follows the fact that not many currencies can circulate outside its jurisdiction.
- Banks neither issue their own version of rCBDC nor hold rCBDC at the central bank. Then, banks automatically receive reserves from the central bank's balance sheet in exchange for any rCBDC they will receive or need in transacting with households and businesses who prefer rCBDC.

We are now ready to look into the balance sheets of the central bank, bank(s), and households with rCBDC as a new format of a currency that requires a new category in balance sheets of all sectors. This visualizes how rCBDC can support the central bank in achieving not only financial inclusion but also monetary stability.

Adopting from the Mishkin (2019), we have the simplified balance sheet of the central bank, banks, and households as below:

Table 1. A simplified balance sheet view of central banks, banks, and household

The central bank	
Assets	Liabilities
1. Securities 2. Loans	1. Currency in circulation: – Coins (if yes) – Notes (paper money) 2. Bank Reserves

Banks	
Assets	Liabilities
1. Cash vault	1. Deposit
2. Reserve balance	2. Others
3. Loans	3. Capital

Households	
Assets	Liabilities
1. Deposit	1. Loans
2. Financial Asset: – Cash – Deposit – Others	2. Credits
3. Non-financial Assets	3. Others
	4. Net Worth

(Source: author)

rCBDC, as it is the liability of the central bank, is the asset of both banks and households and belongs to the financial assets category. This paper puts rCBDC separate from the financial assets for the study purpose. When the central bank issues rCBDC, we will have two basic scenarios.

First, when households exchange x quantity of their cash for an equivalent quantity of rCBDC directly to the central bank. Then, the balance sheet of the central bank remains unchanged in the total value because the amount of rCBDC increases is equal to the amount decreases in notes or coins in circulation. The same happens to balance sheets of households. And they both have a new category for rCBDC but on different sides of the balance sheets because rCBDC is the liability of the central bank while it is the asset for households. However, the banks' balance sheet will not change as they are not involved in this action because households with rCBDC will transact directly with those who accept rCBDC and the central bank is now responsible for such settlements. Then, the overall size of the central bank, banks, and households balance sheets remain unchanged. There will be no change in the monetary policy transmission because the total reserve and money supply are unchanged. Nonetheless, in this scenario, the central bank will obtain more timely information regarding how households behave financially because every transaction using rCBDC will be recorded on time via the system of rCBDC solely controlled by the central bank, as presented below.

Table 2. The changes in balance sheets of central bank, and households when banks are not involved

The central bank		
Assets	Liabilities	
1. Securities 2. Loans	1. Currency in circulation:	
	– Notes (paper money)	-x
	– rCBDC	+ x
	2. Bank Reserves	

Households			
Assets		Liabilities	
1. Deposit		1. Loans	
2. Financial:		2. Credits	
– Cash	-x	3. Others	
– Deposit		4. Net Worth	
– rCBDC	+x		
– Others			
3. Non-financial			

(Source: author)

As long as there is no involvement from banks, the central bank can focus on supervising the financial behavior of households. This is when the central bank can offer its own financial inclusion to households with no access to banks for various reasons. Nonetheless, the central bank has to ensure that it does not compete against its banks because if such a competition happens, banks will soon be out of business due to the fact that they must follow the laws set by the central bank. Then, the central bank can offer its rCBDC to targeted households who cannot access banking services by themselves. If these households transact with those who do not have access to rCBDC, the latter can convert receivable rCBDC to cash or deposits at their selected banks. This will keep the reserve balance intact and cause no major impact to the monetary policy transmission.

Second, when households exchange x quantity of their deposits at banks for an equivalent amount of rCBDC at the central bank. When this happens, banks' balance sheet incurs two reductions of the same amount in their deposits and reserve balance. This is because their customers just transfer a bit of their deposits to the central bank, reducing the reserve requirement quantity for the banks as well. Once there is a change in the reserve balance, there will be changes in the financial system because banks are now holding less reserve than before while they do not extinguish any of their current services that need reserve. For the central bank, its balance sheet only records a change in the components, not in the total value as there is a reduction in its bank reserves countered by an equivalent increase in rCBDC. Then, the balance sheet of households records a reduction in deposits and an increase in rCBDC. All of these changes are illustrated below.

Table 3. The changes in balance sheets of central banks, banks, and household when banks are involved

The central bank			
Assets		Liabilities	
1. Securities 2. Loans		1. Currency in circulation:	
		– Notes (paper money)	
		– rCBDC	+ x
		2. Bank Reserves	- x

Banks			
Assets		Liabilities	
1. Cash vault		1. Deposit	- x
2. Reserve balance	- x	2. Others	
3. Loans		3. Capital	

Households			
Assets		Liabilities	
1. Deposit		1. Loans	
2. Financial:		2. Credits	
– Cash		3. Others	
– Deposit	-x	4. Net Worth	
– rCBDC	+x		
– Others			
3. Non-financial			

(Source: author)

In this second scenario, the total size of banks' balance sheet reduces while the total size of the central bank's and households' balance sheets remain unchanged. In the short run, this might not affect banks as long as they can get support from the central bank. In the long run, however, banks have to recover that decrease in their reserve balance to ensure their current activities. In doing so, banks will either (1) convert their assets into cash, or (2) raise interest rates on deposits to gain back their depositors, or (3) do both.

In the first instance, when banks convert their assets to get cash (which will be converted into reserves at the central bank again), they will bring down the market price for assets of whatever category they sell out. Such a reduction will spill over other assets and bring down the whole price level of assets. This will change the whole course of economic activities as there is no longer profitability in certain assets. While this cannot go on forever, it does cause financial instability with unanticipated results. This instance is undesirable from the central bank's perspective.

In the second instance, banks compete with each other to increase their individual reserve balance. This will drive interest rates up due to the high cost of getting deposits, this increase in interest rates will infect other economic activities and raise prices. Not only will this bank competition affect the price stability target of the central bank, it also reduces the need of rCBDC because households will withdraw their rCBDC for cash to deposit at banks for a higher rate of return on deposits. Again, this is undesirable to the central bank because such a bank competition will erode the very need of rCBDC from households and simultaneously affect the price level.

In the third instance, when banks commit to recover their reserve balance by both selling their assets and raising interest rates on deposits, they certainly destabilize the whole financial system.

The only remedy when either of these instances happens is that the central bank provides a sufficient amount of reserve for its banks. This will steadily enlarge the central bank's balance sheet if its rCBDC gets more and more circulation, reducing the deposits and physical currency in circulation. In other words, the central bank has to issue more reserves once it issues more rCBDC in this second scenario, resulting in a dilemma for this very central bank. Therefore, allowing conversion from deposits to rCBDC appears to be undesirable from the central bank perspective as it destabilizes the banking system with the reduction in the current reserve balance.

IV. CONCLUSION

This paper explains that CBDC is not a new currency but rather just a new form of any currency issued by a central bank. Nonetheless, CBDC can have different designs depending on the choice of the central bank. Each design has its own pros and cons and there is no clear criteria to settle this decision. rCBDC, on the other hand, appears to be the centre of current discussion on how to implement CBDC. This is because rCBDC can circulate among households and businesses. The only barrier to rCBDC is the infrastructure required for such a digital currency, which can be provided by the government and the economic conditions of the users to access such an infrastructure. While these requirements can be achieved gradually, the access to rCBDC can offer a means to financial inclusion as the central

bank can choose to issue this digital currency to households with no access to the banking system for various reasons. Moreover, rCBDC also records all information about its users and the purpose of transactions, allowing the central bank to determine the effectiveness in pursuing its financial targets. The only issue from issuing rCBDC is the involvement of banks when households choose to convert their deposits into rCBDC. Once this happens, financial destabilization is inevitable. Hence, it is the setup of the central bank in limiting who can use rCBDC and for what.

This paper does not deal with other issues, such as the connection from rCBDC to its future derivatives, asset markets, and foreign markets. Also, this paper leaves out the banks' access to rCBDC as it exceeds the scope of this paper to study this matter. Hence, future research can dissect individual limitations of this paper to develop a comprehensive understanding about CBDC. The key takeaway is that CBDC is not a new currency as it still retains the unit as other physical forms of a currency.

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ECONOMIC GROWTH, DEVELOPMENT FINANCE AND ENERGY CONSUMPTION IN ASEAN COUNTRIES: A PANEL GRANGER CAUSALITY ANALYSIS

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Abstract: This study aims to investigate the direction of causality between economic growth, development finance and energy consumption in ASEAN countries. Our empirical findings show that there is evidence of Granger-causality among the variables of interest. Based on the results, we suggested various policy implications toward reducing non-renewable energy consumption and improving financial market for sustainable growth.

Keywords: *economic growth, development finance, energy consumption, Granger-causality*

I. INTRODUCTION

Scholars widely explore the relationship between economic growth, development finance, and energy consumption. Consensus exists on three energy-growth nexus categories: neutrality, one-way causality from energy to growth, one-way causality from growth to energy, and bidirectional causality. Development finance's impact on energy consumption is viewed through direct, business, and wealth effects. Additionally, a robust financial sector is crucial for economic growth (Schumpeter, 1911). Although these above relationships have attracted great attention from scholars, empirical results are mixed. This could be attributed to the time frame used, included variables, modeling philosophy, and methodologies adopted.

ASEAN countries exhibit an interesting setting to study the growth-finance-energy nexus. It is true that this region is characterized by tremendous increase in both GDP, financial sector and energy consumption.

It is true that our study involves the widely investigated literature on the relationship between economic growth, development finance and energy consumption; we fill the gap by focusing on ASEAN countries over the period of 1980-2014, which has been largely ignored.

The rest of the study is structured as follows. Section 2 presents methodology, followed by Section 3 - Data. Section 4 illustrates empirical findings and Section 5 is about conclusion and policy implications for sustainable growth.

II. METHODOLOGY

This research employs the Granger-causality test, originally formulated by Dumitrescu & Hurlin (2012), to investigate the causality direction among the variables of concern. Prior to this analysis, a series of tests are conducted to

identify diverse issues pertaining to extensive panel data, encompassing cross-sectional dependence, non-stationarity, and cointegration. The particulars of these examinations are elaborated upon in subsequent sections.

Cross-sectional dependence test

In this study, we utilize Pesaran's cross-sectional dependence test (Pesaran, 2004, 2015), with its advantages detailed in Tugcu (2018). The Pesaran's CD test statistics are as follows:

$$CD = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \sqrt{T_{ij}}\, \hat{\rho}_{ij} \rightarrow N(0,1)$$

Stationary test

To examine the possibility of non-stationary, we use the test of Pesaran (2006). This test is applicable in the case of panel data with cross-section dependence and heterogeneity. The details of test statistics are given in the following form.

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i$$

The CADF statistics is derived using the following equation.

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \theta_i \bar{y}_{t-1} + \sum_{j=0}^{p} \delta_{ij} \Delta \bar{y}_{t-j} + \sum_{j=0}^{p} \gamma_{ij} \Delta y_{it-j} + \varepsilon_{it}$$

where $\bar{y}_{t-j}$ and $\Delta \bar{y}_{t-j}$ denote the cross-section averages of lagged levels and first-difference, respectively.

Cointegration test

The Westerlund (2015) test is used in this study to investigate whether or not long-run relationship exists among the variables of interest. Compared to other cointegration tests, this test allows cross-sectional dependence.

$$\Delta y_{it} = c_i + \alpha_i (y_{it-1} - \beta_i x_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta y_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta x_{it-m} + \varepsilon_{it}$$

In this study, the following empirical models are estimated by Westerlund cointegration test.

$$\Delta TEC_{it} = c_i + \alpha_i (TEC_{it-1} - \beta_i G_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta TEC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta G_{it-m} + \varepsilon_{it} \quad (1)$$

$$\Delta TEC_{it} = c_i + \alpha_i (TEC_{it-1} - \beta_i FD_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta TEC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta FD_{it-m} + \varepsilon_{it} \quad (2)$$

$$\Delta TEC_{it} = c_i + \alpha_i (TEC_{it-1} - \beta_i EP_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta TEC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta EP_{it-m} + \varepsilon_{it} \quad (3)$$

$$\Delta REC_{it} = c_i + \alpha_i (REC_{it-1} - \beta_i G_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta REC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta G_{it-m} + \varepsilon_{it} \quad (4)$$

$$\Delta REC_{it} = c_i + \alpha_i (REC_{it-1} - \beta_i FD_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta REC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta FD_{it-m} + \varepsilon_{it} \quad (5)$$

$$\Delta REC_{it} = c_i + \alpha_i (REC_{it-1} - \beta_i EP_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta REC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta EP_{it-m} + \varepsilon_{it} \quad (6)$$

$$\Delta NREC_{it} = c_i + \alpha_i(NREC_{it-1} - \beta_i G_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta NREC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta G_{it-m} + \varepsilon_{it} \quad (7)$$

$$\Delta NREC_{it} = c_i + \alpha_i(NREC_{it-1} - \beta_i FD_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta NREC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta FD_{it-m} + \varepsilon_{it} \quad (8)$$

$$\Delta NREC_{it} = c_i + \alpha_i(NREC_{it-1} - \beta_i EP_{it-1}) + \sum_{k=1}^{p} \alpha_{1i} \Delta NREC_{it-k} + \sum_{m=1}^{p} \beta_{1i} \Delta EP_{it-m} + \varepsilon_{it} \quad (9)$$

Granger-causality test

The D-H Granger-causality test is used in this study to investigate the direction of causality among the variables of interest. This test is derived from the Granger's model. Mathematically, it can be shown in the following model.

$$y_{it} = \alpha_i + \sum_{m=1}^{M} \theta_i^m y_{it-m} + \sum_{m=1}^{M} \delta_i^m x_{it-m} + \varepsilon_{it}$$

where x and y are stationary series. The number of lag length can be chosen on various information criterion (AIC, BIC or HQIC). The null hypothesis states that there is no Granger-causality, while the alternative hypothesis is of there is at least one Granger-causality (Dumitrescu and Hurlin, 2012). These hypotheses can be rewritten as follows:

$$H_o: \forall\, m:\ \delta_i^m = 0$$

$$H_a: \exists\, m: \delta_i^m \neq 0$$

The statistics for D-H Granger-causality test is obtained through two steps. The first one is about conducting N individual regressions and the second one performs F-test related to δ_i^m to retrieve individual Wald statistics W_i followed the calculation of the average Wald statistics ($\overline{W}$) as follows:

$$\overline{W} = \frac{1}{N}\sum_{i=1}^{N} W_i$$

On the ground of the Wald statistics, Dumitrescu and Hurlin (2012) proposed the $\bar{Z}$ and $\tilde{Z}$ statistics, which can be shown as follows:

$$\bar{Z} = \sqrt{\frac{N}{2K}} \times (\overline{W} - K) \xrightarrow[N,T\to\infty]{} N(0,1)$$

and

$$\tilde{Z} = \sqrt{\frac{N}{2K} \times \frac{T-3K-5}{T-2K-3}} \times \left(\frac{T-3K-3}{T-3K-1} \times \overline{W} - K\right) \xrightarrow[N,T\to\infty]{} N(0,1)$$

III. DATA

With a primary emphasis on exploring the enduring relationship between economic growth, development finance, and energy consumption in ASEAN countries, we utilize yearly data spanning from 1980 to 2014. Data on economic growth, energy consumption is sourced from World Bank, data on development finance is collected from the International Monetary Fund, and data on energy price is available at the BP Statistical Review of World Energy. TEC is measured by energy use in terms of oil equivalent per capita. REC is a proportion of final energy consumption. NREC is measured by fossil fuel energy consumption. G is measured by annual growth of GDP per capita. FD is a composite index, suggested by IMF. Table 1 shows various statistics of the variables used in this study.

Table 1. Statistics of various vairables used in this study

	Obs	Mean	S.D.	Min	Max
TEC	278	6.902	1.119	5.523	9.194
REC	196	9.533	1.105	4.320	10.780
NREC	264	10.845	1.555	8.168	13.799
G	278	8.080	1.526	5.199	10.909
EP	278	-0.319	1.070	-1.999	4.173
FD	278	-1.278	0.705	-3.649	-0.232

IV. RESULTS

This section presents the empirical findings relating to the various tests shown in section methodology. For convenience, our results are demonstrated from cross-sectional dependence test to Granger-causality test.

Cross-sectional dependence test

Table 2 shows the empirical results relating to cross-sectional dependence test. In Table 2, we present both the statistics of CD test together with its p-value. Based on the findings, we claim that all the variables are cross-sectional dependence.

Table 2. The cross-sectional dependence results

	Pesaran (2004, 2015) test	
	CD test	p-value
TEC	18.279***	(0.000)
REC	-2.627***	(0.000)
NREC	22.462***	(0.000)
G	26.971***	(0.000)
FD	19.921***	(0.000)

*Note: *** significant at 1 percent confidence level. Cross-section independence. Abbreviations: TEC - Total energy consumption, REC - Renewable energy consumption, NREC - Non-renewable energy consumption, G - Economic output, FD - Financial development*

Stationary test

In Table 3, we present $Z\_(\tilde{t}$ bar) statistics and p-values for all variables in both level (Panel A) and first-difference (Panel B) forms. In summary, all variables are non-stationary in the level form but stationary in the first-difference form, indicating they are integrated of order 1 I(1).

Table 3. The stationary result

Panel A: Level		
	Constant	Constant & Trend
TEC	-0.724	1.054
	(0.235)	(0.854)
REC	0.625	0.233
	(0.734)	(0.592)
NREC	-0.894	0.963
	(0.186)	(0.832)
G	0.212	0.520
	(0.584)	(0.698)
FD	-0.230	-0.482
	(0.409)	(0.315)
Panel B: First difference		
	Constant	Constant & Trend
TEC	-10.265***	-9.954**
	(0.000)	(0.000)
REC	-3.939***	-3.511***
	(0.000)	(0.000)
NREC	-10.608***	-10.427**
	(0.000)	(0.000)
G	-10.050***	-8.883***
	(0.000)	(0.000)
FD	-14.319***	-13.991***
	(0.000)	(0.000)

*Note: *** significant at 1 percent confidence level.*

Cointegration test

The results of cointegration test are shown in Table 4. In concrete terms, we report findings for Eq (1) - (3) in panel A, for Eq (4)

- (6) in panel B and for Eq (7) - (9) in panel C. We use the method of Westerlund to consider cointegration between the variables of interest. From the empirical results, it is true that there is evidence of long-run relationship. This is because the null hypothesis is rejected at the normal confidence level. In detail, our findings indicate that total energy consumption, renewable energy consumption, and non-renewable energy consumption are cointegrated with economic growth, development finance, and energy price.

Table 4. The cointegration result

Panel A: The results of cointegration test for Eq (1)-(3)			
	Equation (1)	Equation (2)	Equation (3)
Westerlund test			
Variance ratio	-2.400*** (0.008)	-1.284* (0.099)	2.557*** (0.005)
Panel B: The results of cointegration test for Eq (4)-(6)			
	Equation (4)	Equation (5)	Equation (6)
Westerlund test			
Variance ratio	-2.533*** (0.005)	-1.410* (0.079)	-1.909** (0.028)
Panel C: The results of cointegration test for Eq (7)-(9)			
	Equation (7)	Equation (8)	Equation (9)
Westerlund test			
Variance ratio	-2.582*** (0.004)	-2.397*** (0.008)	-2.789*** (0.002)

Granger-causality test

In this section, we employ DH Granger-causality to showcase our empirical discoveries as seen in Table 5. These figures offer a unified perspective, unveiling a mutual causal relationship between economic growth and total energy consumption. Additionally, our calculations validate that development finance is influenced by total energy consumption, renewable energy consumption is impacted by economic growth, development finance is driven by renewable energy consumption, economic growth is influenced by renewable energy consumption, and development finance is influenced by non-renewable energy consumption.

Table 5. The Granger-causality result

X Granger causes Y	*Statistics* $\bar{Z}$	*Statistics* $\tilde{Z}$	Conclusion
G ⟶ TEC	7.574*** (0.000)	6.811*** (0.000)	Bidirectional causality between G and TEC
TEC ⟶ G	2.072** (0.038)	1.698* (0.089)	
FD ⟶ TEC	1.163 (0.244)	0.902 (0.366)	Unidirectional causality running from TEC to FD
TEC ⟶ FD	4.409*** (0.000)	3.783*** (0.000)	
G ⟶ REC	4.632*** (0.000)	3.678*** (0.000)	Unidirectional causality running from G to REC
REC ⟶ G	1.197 (0.231)	0.812 (0.416)	
FD ⟶ REC	-0.765 (0.443)	-0.825 (0.409)	Unidirectional causality running from REC to FD
REC ⟶ FD	2.6869*** (0.007)	2.055** (0.039)	
G ⟶ NREC	6.811*** (0.000)	6.115*** (0.000)	Unidirectional causality running from G to NREC
NREC ⟶ G	0.675 (0.499)	0.450 (0.652)	
FD ⟶ NREC	-0.038 (0.969)	-0.164 (0.869)	Unidirectional causality running from NREC to FD
NREC ⟶ FD	6.521*** (0.000)	5.658*** (0.000)	

*Note: *** significant at 1 percent confidence level. ** significant at 5 percent confidence level. * significant at 10 percent confidence level. ECT denotes error correction term. D denotes short-term. P-value is reported in parentheses. XšY means X Granger-causes Y.*

V. CONCLUSION

This study investigates the causality direction among economic growth,

development finance, and energy consumption, focusing on ASEAN countries from 1980 to 2014. Data sources include the World Bank, BP Statistical Review of World Energy, and International Monetary Fund.

Our empirical analysis reveals several data issues. Specifically, we identify cross-sectional dependence, non-stationarity in level form but stationarity in first-difference form. Furthermore, our findings suggest cointegration between energy consumption, economic growth, development finance, and energy prices.

Additionally, the DH Granger-causality test results indicate (1) bidirectional causality between economic growth and total energy consumption and (2) evidence of unidirectional causality.

Based on the conclusions drawn from the research paper and focusing on sustainable growth, here are some policy implications for ASEAN countries:

Promoting Energy Efficiency and Conservation: As a result, policymakers should give precedence to energy efficiency and conservation measures. The adoption of energy-efficient technologies and practices must be pursued to curtail energy consumption while bolstering economic growth, ultimately fostering a pathway to achieve greater sustainability.

Incentives for Renewable Energy Adoption: With energy consumption cointegrating with economic growth and energy prices, governments can offer incentives and subsidies to encourage the adoption of renewable energy sources. Supporting investments in renewable energy infrastructure can foster sustainable growth and reduce reliance on fossil fuels.

Enhancing Cross-Border Collaboration: Given the cross-sectional dependence in the data and the interconnectedness of ASEAN countries, regional collaboration on energy and development initiatives can be beneficial. ASEAN member states can work together to share best practices, pool resources, and jointly address sustainable growth challenges.

Investment in Sustainable Infrastructure: Sustainable infrastructure development should be a priority for policymakers. Investing in green and climate-resilient infrastructure can stimulate economic growth while minimizing the environmental impact and ensuring long-term sustainability.

Supporting Research and Innovation: Encouraging research and innovation in sustainable technologies can lead to breakthroughs that drive economic growth and address energy consumption challenges. Governments can allocate funds to support research institutions and startups working on sustainable energy solutions.

Long-Term Policy Planning: Sustainable growth requires long-term planning and commitment. Governments should formulate and implement coherent and stable policies that support sustainable development, energy security, and economic growth over extended periods.

By implementing these policy implications, ASEAN countries can work towards achieving sustainable economic growth while addressing energy consumption challenges and promoting environmental sustainability. Continuous monitoring and evaluation of policy outcomes

will be essential to refine strategies and ensure progress towards long-term sustainable development.

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ENERGY CONSUMPTION ANALYSIS IN HIGHER EDUCATION INSTITUTION BUILDINGS: CASE STUDY, EASTERN INTERNATIONAL UNIVERSITY (EIU)

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Abstract: Energy consumption analysis contributes to the insights of consumption behaviors and allows for the identification of the usage sources. In turn, this enables the suggestion of solutions to enhance efficiency. This paper focuses on investigating energy consumption patterns in higher education institution buildings. A framework is proposed and data from various sources is collected to evaluate the measures of energy usage at a university in Vietnam. A comparison between these measures and those of other institutions around the world is also presented. Besides, data about lighting, air conditioning, and computers are compared between selected buildings in the university. Then, a range of effective practices and solutions are recommended to enhance energy efficiency on the campus.

Keywords: *energy consumption analysis, campus sustainability, energy efficiency*

I. INTRODUCTION

As one of Southeast Asia's fastest developing countries, Vietnam has the most significant energy market in the area as Vietnam's energy power system ranks second after Indonesia in terms of capacity (Le, 2019). In addition, Electricity of Vietnam (EVN) points out that national utility power demand increased by 10.3 - 11.3% each year from 2016 to 2020, and it is expected to increase by 8 - 8.5% per year from 2021 to 2030. Besides, according to a World Watch Institute analysis, buildings consume 40% of global energy (Yuksek & Karadayi, 2017). These facts together stimulate the deployment of effective energy management in the buildings in Vietnamese context to meet stakeholder demand (Almeida et al., 2021 and Batlle et al., 2020).

Based on Finlay and Massey (2012), universities are small societies that may cause a negative impact on the environment through activities such as consumption, operations, waste decomposition, and CO2 emissions. In accordance with Chung and Rhee (2014), universities are a major source of energy consumption. At the same time, universities may also have a positive impact on societal understanding and attitudes

regarding the environment. As a result, green campus has become a worldwide idea in which higher education institutions (HEI) pursue sustainability in education through low-carbon activities (Han et al., 2015). Many universities throughout the world have made steps to conserve energy, including the University of California in Berkeley in the United States (Zhao, 2010), the University of Tokyo in Japan (Sun, 2011), and Tongji University in China (Li, 2009).

Statistics by the Ministry of Education and Training in Vietnam show that there were 237 universities in Vietnam in 2020 with a population of more than 1.8 million students, lecturers, and staff. The Vietnamese Government launched Vietnam National Energy Efficiency Program (VNEEP) period 2019 - 2030. One of the projects in this program is to encourage education on economical and efficient use of energy. Following that plan, a number of universities in Vietnam are also promoting the trend of green campus. In 2022, two universities in Vietnam were in the top 200 most sustainable campuses according to the worldwide recognized ranking of UI Greenmetric.

This research reviews the methodologies for estimating energy consumption in HEI. Then, an examination of energy usage at a university in Vietnam is conducted, particularly in light of the unavailability of independent meters for measuring each building. The investigation utilized indicators such as energy consumption per unit area and energy consumption per capita. Following that, an appropriate methodology for estimating total energy usage in buildings at a university in Vietnam is applied. The framework recommends estimating the usage of electric equipment in each room. Finally, this study proposes solutions for energy saving at the university.

Numerous factors impact the energy consumption for a building such as the design and functions of the buildings or the climate (Ma et al., 2017). In a report by the National Research Council in 2010, the US Energy Information Administration (EIA) classifies buildings into different types based on their functions and education is a separate category. Therefore, the study of energy consumption at HEI should be separated from other types of buildings, especially the residential buildings. However, most of the existing literature on the topic focuses on residential buildings. (Almeida et al., 2021). The methods to analyze energy consumption in buildings can be divided into four streams, including energy audit methods, statistical regression methods, neutral networks and support vector machines (Batlle et al., 2020).

Energy audits are employed by Escobedo, et al. (2014) to suggest the consumption per area and by category of construction as the energy use indicators of buildings in a university in Mexico. In order to analyze and compare the energy consumption at 7 buildings of a university in Guangzhou, Li et al. (2017) also use data from the energy audit. Then, they compare the indicators with other universities in China and suggest solutions for energy saving through the transformation of buildings' design and the end users' energy consumption habits. Han et al. (2015) ran an energy consumption simulation to identify the energy consumption indicators in the library of a university in China. After that, they propose the energy conservation of the technology, management and behavior, and reasonable energy-saving reconstruction.

Battle et al. (2020) developed a framework based on the international standards ISO 50001: 2011 and ISO 50006: 2014 to estimate the energy baselines and energy consumption indicators with a case study of a university in Brazil. They consider a variety of elements, such as activities in the buildings, climate conditions, building materials, and air conditioning systems. Almeida et al. (2021) also conduct a case study in a university in Brazil. They propose a general framework to estimate energy consumption patterns in the buildings by accounting for characteristics of individual rooms in the building. Khoshbakht et al. (2018) also relate the energy consumption of 80 university campus buildings in Australia to the types of room and activities that take place in the space.

Prafitasiwi et al. (2022) assess the awareness of lecturers, staff, and students in achieving efficient electricity consumption by conducting a questionnaire survey and mean analysis. The results suggest that to achieve maximum results in achieving electrical efficiency, awareness should be improved, especially for the student performance. Lastly, the recent trend of forecasting energy consumption has been carried out using multiple methodologies, including monitoring data based bottom-up energy consumption prediction method (Zhao et al., 2021), Particle Swarm Optimization-Stacking Improved Ensemble (PStIE) model (Cao et al., 2023) and Long Short-Term Memory (Faiq et al., 2023).

This paper contributes to a better knowledge of energy use on university campuses in Vietnam. There has been little research on this topic in Vietnam. Following the implementation of the VNEEP by the government, universities in Vietnam have taken steps to promote energy efficiency on campus, such as a power-saving campaign during the hot season and policies to support research on power-saving solutions by Electric Power University, solar panel installation at the University of Technology - The University of Da Nang, and electricity consumption regulations at the University of Transport Technology and Vietnam National University, Hanoi. However, research on energy use in institutions is limited. The findings can be used by the management to better understand the consumption patterns in campus buildings and to decide the effective practices and solutions to reduce the effect of energy used on the environment.

The remaining of this study is organized as follows: Section 2 describes the framework to estimate energy used in a building. Section 3 presents the case study and proposes solutions for energy saving at the university. Section 4 concludes.

II. METHODOLOGY

This analysis requires the annual power consumption per area and the annual power consumption per capita, as suggested by Li et al. (2017), as well as the total consumption of each electrical equipment in each building and the aggregate consumption of each building following Almeida et al. (2021). The first two indicators are simple to monitor because total energy usage records are commonly collected using manually reading metering devices. If the campus does not have an independent meter to measure consumption in each building, the record of consumption in each building may be inaccessible. In that situation, the estimation is completed in four steps: selecting the building, collecting data, analyzing data, and concluding the results. The data collected should be able

to identify the aggregate consumption of each electrical equipment in the university. The equation for energy consumption in each room is presented as below:

$$TEC_{i,j} = \sum_{i=1}^{n} n_{i,j} \times CE_i \times H_{i,j} \ldots \quad (1)$$

Where $TEC_{i,j}$ is the monthly aggregate energy consumption of electrical equipment i in room j, $n_{i,j}$ is the number of equipment i in room j, CE_i is the consumption of equipment i in kWh, and $H_{i,j}$ is the number of hours the equipment i is used in building j monthly.

Then, the total energy consumption in a building is the total consumption of all rooms in that building.

$$TC = \sum_{j=1}^{k} TEC_{i,j} \ldots \quad (2)$$

III. CASE STUDY

A. Campus characteristics

Located in Binh Duong province, Eastern International University (EIU) was established in 2010 with seven Schools and Departments ranging from Business Administration, Engineering, Technology to Healthcare. With the educational philosophy of "Humanity-Community-Creativity-Sustainability", EIU has tried to create not only a professional education institution but also a sustainable studying environment. Consequently, using energy efficiently is necessary to achieve EIU's goals. With high-quality infrastructure including nine buildings (classrooms, laboratories, library, etc…) in 26 hectares, lectures, staff and students can access spacious rooms for their various usage purposes. For example, most of the teaching and learning activities of Business School are organized in the B3 building. This School also attracts the most students and lecturers. Lectures for the seven majors of the School are predominantly organized in B3 leading to high occupancy in this building. Consequently, the B3 building always operates at full capacity all year round. B4 and B5 buildings are the Library and Administration offices, respectively. Usually, these buildings work at full capacity to serve and support students. The B8 building is used for the School of Nursing and B11 is for the School of Engineering and Computer and Information Technology. With 15,000 m^2, B11 is the biggest building in the university with several laboratories, different classrooms and centers such as 4.0 Technology Lab, ERIS Lab and Power Electronics and Renewable Energy Lab. Moreover, there are many activities for students every week so B11 has the potential to consume the highest amount of electricity on the campus.

Further, Binh Duong's climate features are similar to any areas within the Southeast region which are hot, rainy and relatively humid. The average sunshine hours in Binh Duong is about 2,400 hours, with the climax can be up to 2,700 hours (Trần, 2017). Therefore, the demand for electricity is considerable to maintain a high-quality studying environment.

Regarding the electrical system at EIU, the university uses an incoming line of 22kV supplied from the local grid. The university has one meter to measure the total electricity consumption and the record is made every month. There are totally four distribution substations named Subs. A, B, C, and D. The power supply range of each substation is as Figure 1 below:

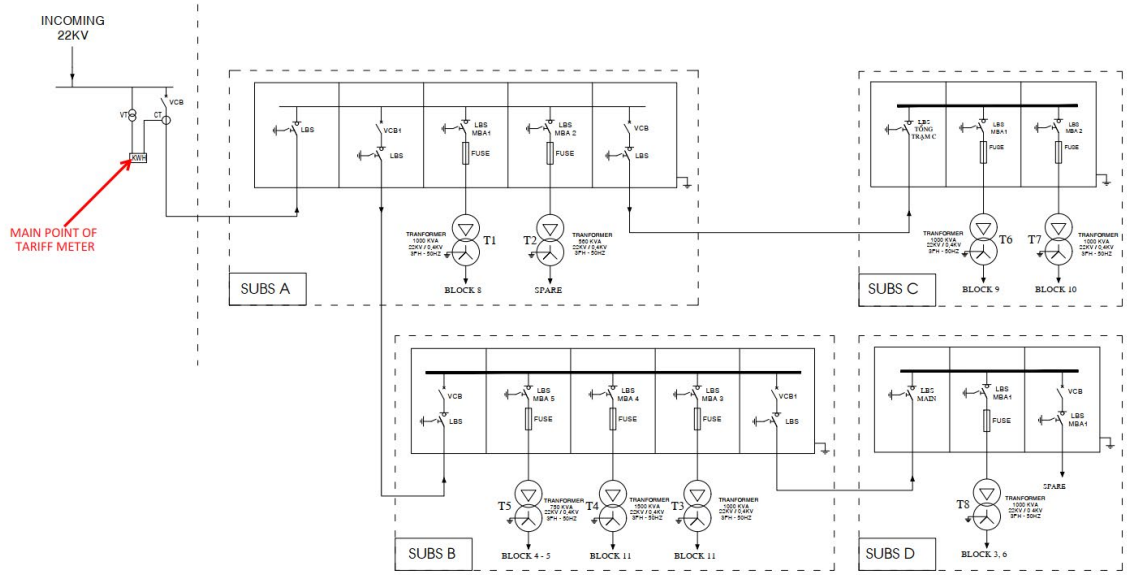


Figure 1. Single line diagram of EIU's electrical system

B. Data collection strategy

The data in this paper was collected via electricity consumption records from the Administration Office. The records from the Administration Office were also required to collect data on the areas in square meters of the buildings on campus, the electrical equipment used in each room and their consumption in Watt (W). Besides, the data on the number of occupants in each building was combined from multiple sources in the published documents on EIU website. In addition, the building's surveys provided information about the main activities in each room and then, the number of hours used of each facility in each room were estimated.

C. Analysis of electricity consumption

Monthly electricity consumption

Figure 2 presents the monthly electricity consumption in EIU from 2019 to 2022. The consumption is low during the Tet Holiday at the end of January and early February and during the summer break in August. The peak period is approximately from March to July because of the hot weather. The early 2020 and from May 2021 to the end of 2021, the pattern does not follow the common trend due to the campus lockdown to deal with the COVID-19 pandemic. Since the campus has only one meter to measure the total electricity consumption, the data in the graph is the aggregate consumption in all buildings and there are no individual records for each building.

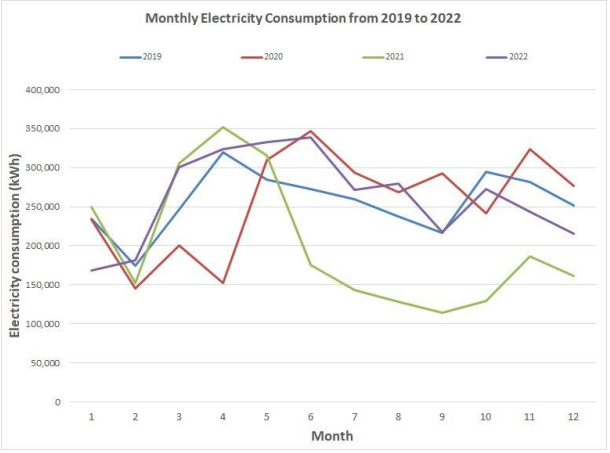


Figure 2. Monthly consumption of electrical energy at EIU from 2019 to 2022

(Source: Authors' estimation)

Table 1 shows the annual consumption of electricity per unit area (kWh/m^2) in EIU from 2019 - 2022. It can be seen that the average annual consumption per unit area is around 35.03 kWh/m^2 in the past four years. However, since 2021 recorded a sudden drop in the amount consumed due to the pandemic, it is necessary to consider the average consumption without the 2021 record. In that case, the average annual consumption per unit area rises to 37.09 kWh/m^2. The electricity used increases slightly after the pandemic.

Table 1. The electricity consumption per unit area in EIU

Construction area/m^2	Year	Annual power consumption (kWh)	Annual power consumption per unit area (kWh/m^2)
83,636	2019	3,075,200	36.77
83,636	2020	3,085,900	36.90
83,636	2021	2,413,600	28.86
83,636	2022	3,144,800	37.60

(Source: Authors' estimation)

Table 2 provides the comparison of annual electricity consumption per unit area in EIU and two educational institutions in Singapore, Nanyang Technology University (NTU) and National University of Singapore (NUS) from 2019 to 2022. Besides those statistics, Campus Paricarana in Brazil recorded an annual consumption of 847.55 kWh/m^2 in 2017 (Almeida et al., 2021) and Jinan University in Guangzhou recorded the amount of 60.83 kWh/m^2, 71.46 kWh/m^2, and 82.14 kWh/m^2 in 2007, 2008, and 2009, respectively (Li et al., 2017). From those statistics, it can be concluded that the annual power consumption per unit area in EIU is much lower than the average consumption of other institutions in Asia.

Table 2. Comparison of EIU annual electricity consumption per unit area with other institutions

Year	Annual Electricity consumption per unit area (kWh/m^2)		
	EIU	Nanyang Technology	National University of Singapore
2019	44.83	566	313
2020	45.00	535	289
2021	35.19	541	289
2022	45.85	Not yet updated	Not yet updated

(Source: Authors' estimation)

Next, the annual electricity consumption per capita in EIU from 2019 - 2022 is summarized in Table 3. Similar to the results in Table 2, except the low amount in 2021 when the campus was under the lockdown for nine months, the average annual electricity consumption per capita is 1,065 kWh/a.p. The amount of consumption increases after the pandemic although the number of population falls compared to 2020 and is similar to the number in 2019. Li et al. (2017) reported that the power consumption per capita in Jinan University in Guangzhou in 2008 is 1,686.38 kWh/a.p. At the same time, they also pointed out the values in the other seven universities in Guangzhou. They range from 707.27 kWh/a.p to 1,415.7 kWh/a.p and average at 1,051.59 kWh/a.p which is close to the record of 1,065 kWh/a.p in EIU.

The rising amount of energy consumption indicators in EIU as mentioned in Tables 2 and 3 might be caused by several reasons. First, more equipment has been installed for teaching and learning and researching purposes. After the pandemic, Blocks B8, B9, B10, and B11 have

been renovated and new equipment such as projectors, smart TVs, computers, and other lab equipment for School of Engineering, School of Computer Science, and School of Nursing have been installed in those buildings. Second, more classes are opened to meet the students' learning path and schedule and to ensure the reasonable class size. Last but not least, the university installs more facilities to take care of the campus greenness such as the automatic watering system.

Comparing the energy consumption indicators in EIU and other institutions, while the consumption per capita is close to the average of other institutions, the consumption per unit area is much lower which can be explained by the wide construction area at EIU. To cope with the rising demand for electricity and the global trend of green campus, a plan for energy-saving renovation is necessary at EIU.

Table 3. EIU's annual electricity consumption per capital

Year	Total population (Lecturers and students)	Annual Electricity consumption (kWh)	Annual Electricity consumption per capita (kWh/a.p)
2019	2822	3,075,200	1,089.72
2020	3115	3,085,900	990.66
2021	3410	2,413,600	707.80
2022	2823	3,144,800	1,113.99

(Source: Authors' estimation)

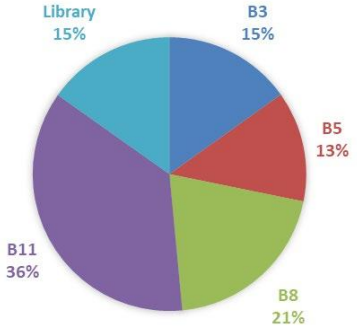
D. Analysis of the power of electrical equipment

Table 4 displays the energy consumption of air conditioning, lighting, and computers in several buildings at EIU. The number of air conditioning and lighting are collected from the diagrams of EIU's electrical system provided by the Administration Office. The number of computers is estimated based on the number of lecturers and staff at the building, one computer each (data is updated up to 2023). The total amount of using hours a month is estimated as daily use from 7:30 AM to 4:30 PM which is the operating hours of the classes at EIU, times 22 days a month (off on weekends) except library which has the operation hours from 7 AM to 8 PM and off on Sunday. We only consider air conditioning, lighting, and computers because they are the main sources of energy consumption in buildings. Other equipment is projectors (have not been installed in all classrooms), printers, telephones, elevators. Blocks B10 and B11 have equipment used for laboratory experiments in the School of Nursing, School of Engineering and Computer and Information Technology. The power consumption in these buildings will be exaggerated compared to other buildings if we take these equipment into consideration. Therefore, we only account for the common facilities in all the buildings. In addition, because of incomplete data, only B3, B5, B8, B11, and B4 (Library) are considered. Since there are different brands of air conditioning, lighting, and computers used in the buildings, the daily consumption rates (kWh) were calculated in an Excel spreadsheet and the aggregate amounts are shown in Table 4. The results in Table 4 are higher than the actual consumption because we assume the maximum usage of these electronic equipment. In reality, the consumption of electronic equipment in the classrooms depends on the class schedule in those rooms which varies every quarter.

Figure 3 presents the comparison of energy consumption at selected buildings in EIU in percentage based on the statistics in Table 4. As can be seen in Panel A, if all the rooms

are operated at full capacity, B11 consumes the most energy at 36% of total consumption. This building has the largest area of 15,000 m^2, in comparison with 2,496 m^2 in B4 (Library), 2,500 m^2 in B5, and 4,581 m^2 in B3. Therefore, B11 also owns the largest number of air conditioning and lighting. At the same time, the Library and B3 have a similar amount of consumption at 15%. B5 has the smallest value at 13%. However, when the indicator of energy consumption per unit area is compared, Panel B shows that the Library has the highest ratio of 44 kWh/m^2, followed by B5 and B3 with the value of 38 kWh/m^2 and 24 kWh/m^2, respectively. B11 ranks fourth place at 17 kWh/m^2. It can be explained that the Library, B5, and B3 have a large number of users. EIU equips the library with modern facilities based on international standards, making substantial contributions to the university's community service goals. Its operation hours are also longer than other buildings. Meanwhile, since B5 is the building of Administrative offices, the electricity equipment must be sufficient to support the operation and they are always consumed at full capacity. Finally, B3 is mainly for Business School students, lecturers, and staff. This is the largest school at EIU in terms of population.

Panel A. The comparison of total consumption



Panel B. The comparison of total consumption per unit area

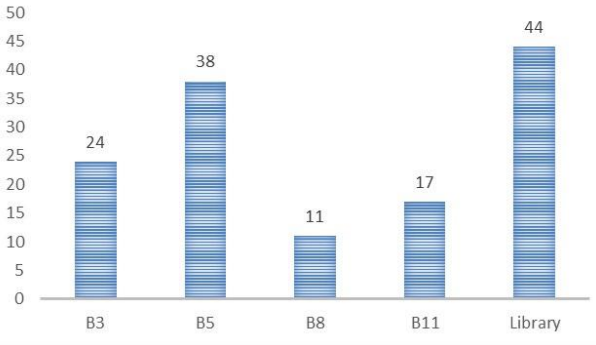


Figure 3. The comparison of energy consumption at selected buildings in EIU

(Source: Authors' estimation)

Lastly, Figure 4 shows the comparison of energy consumption of air conditioning, lighting, and computers at buildings in EIU, also using the statistics in Table 4. The chart shows that air conditioning is the major source of energy consumption as it accounts for 88.5% of consumption while lighting consumes 11.35% and computers consumes less than 0.16%. Therefore, the suggestion for energy-saving renovations should focus on the energy conservation in B11 and especially the consumption of air conditioning.

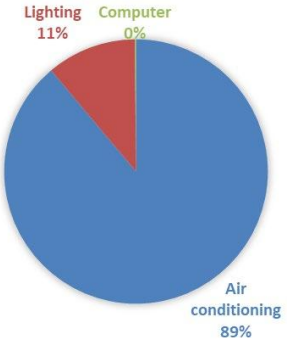


Figure 4. The comparison of energy consumption of different electronic equipment

(Source: Authors' estimation)

E. Suggested actions for energy-saving

In this section, we will propose practices for campus energy conservation. Besides, the application of advanced technology is suggested.

1. Implementing energy-saving practices

Based on the analysis above, students, lecturers, staffs and other people that linked and doing their activity inside the campus are encouraged to follow these practices to save energy in the university:

Lighting system:

- Allow the natural light to lighten up the building and minimize light bulb usage during the day.
- Switch off lights when not used.
- Lighting should be focused on the users only.
- Provide an "Energy Saving" label on the light switch.
- Walls of the buildings should be painted with bright color to avoid light absorption.
- Use LED lights.

Air conditioning and fan:

- Optimize the operating hours of air conditioning.
- Set the temperature to 24^0C to maintain the air conditioning in the most efficiency state.
- Close the door and any gap that allows the cold air inside the room does not come out to the outside.
- Apply scheduled maintenance for the air conditioning.
- Turn off the fan if no one is inside the room.

Electronic Appliances:

- Switch off the electronic appliances if it not been used/
- Set the computer to sleep or hibernate mode instead of using a screen saver so it uses less electricity during periods of inactivity.
- Unplug battery chargers when the batteries are fully charged or the chargers are not in use.
- Improve Heating, Ventilation and Air Conditioning (HVAC) systems to control the temperature and ventilation, keeping it at optimum level whilst saving as much energy as possible.

2. Combining Building Management System and Energy Management System

Building Management System (BMS) is a software solution which automates, monitors, manages, and controls the entire mechanical equipment and electrical gadgets in a building. Energy Management System (EMS) is a software solution used to monitor and control the electrical utilities in an organization thereby optimizing the energy consumption. EMS manages the part of the BMS system where energy is concerned. It includes management of lighting systems, HVAC systems, and much more. BMS and EMS can also provide data visualization dashboards based on which you can monitor the real time data and do the analytics.

3. Application of Renewable Energies Microgrid scheme

A microgrid is a self-contained grid that uses renewable energy, batteries for energy storage and generators to produce power.

Microgrids can complement the national grid or work independently from it, providing communities with access to more sustainable and resilient energy supplies.

IV. CONCLUSION

The analysis on energy consumption at a university in Vietnam was conducted. While the annual electricity consumption per unit area is much lower than other institutions around the world, the average annual electricity consumption per capita of 1,065 kWh/a.p is similar to the average of the selected institutions. It raises the urge to enhance the energy consumption practices to first conserve the energy consumption on campus following the government's VNEEP and second pursue the shift towards the green campus. Moreover, a comparison of electricity consumption of lighting, air-conditioning, and computers among selected buildings in the university was presented. Air-conditioning system is the major source of consumption at almost 89%, followed by lighting at 11%. Therefore, the energy-saving plans should pay attention to these pieces of equipment. Additionally, the library, the administration building, and the Business School building have the highest amount of consumption per area unit as these buildings have the large number of electricity users. Lastly, solutions for energy-saving were also proposed. The further research will be carried out to present the current number of electricity equipment at the university, including those for laboratory experiments and analyze the efficiency of proposed every-saving renovation.

Table 4. Energy consumption of electrical equipment in selected buildings

Building	Equipment	No. of units	Consumption rate/day (kWh)	Estimated no. of using days/ month	Estimated total consumption/ month (kWh)
B3 Floor Area: 4,581 m^2 Orientation: North	Air conditioning	24	4,350	22	95,700
	Lighting	624	606.5	22	13,343
	Computer	61	14.274	22	314.028
B5 Floor Area: 2,500 m^2 Orientation:	Air conditioning	33	3,920.4	22	86,248.8
	Lighting	381	370.332	22	8,147.304
	Computer	N/A	N/A	22	N/A
B8 Floor Area: 13,500 m^2 Orientation: East	Air conditioning	46	5,958.9	22	131,095.8
	Lighting	728	707.616	22	15,567.552
	Computer	N/A	N/A	22	N/A
B11 Floor Area: 15,000 m^2 Orientation: West	Air conditioning	56	10,451.7	22	229,937.4
	Lighting	1494	1,452.168	22	31,947.696
	Computer	59	13.806	22	303.732
Library Floor Area: 2,496 m^2	Air conditioning	21	3,806.4	26	98,966.4
	Lighting	413	401.436	26	10,437.336
	Computer	50	16.9	26	439.4

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ENHANCING BRAND LOYALTY OF MANWAH TAIWANESE HOTPOT IN BINH DUONG: THE MEDIATING ROLE OF CUSTOMER SATISFACTION

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Abstract: This study delved into the integration of self-service technology and Personal Service Attributes as determinants to heighten customer satisfaction and foster brand loyalty in the realm of Manwah Taiwanese Hotpot situated in Binh Duong. The primary objective was to assess how self-service technology and Personal Service Attributes influence customer satisfaction and brand loyalty. Through utilization of statistical methodologies, the gathered data will be subjected to analysis to reveal connections and patterns. The outcomes of this inquiry will enrich the existing knowledge pool by shedding light on the efficacy of self-service technology and Personal Service Attributes within the foodservice sector. Furthermore, the research also provides recommendations and pragmatic approaches for optimizing the implementation of self-service technology and amplifying customer satisfaction and brand loyalty, not only for Manwah Taiwanese Hotpot but also for analogous enterprises. The anticipated ramifications of this study encompass benefits for both academic scholars and hospitality industry practitioners. Ultimately, the core aspiration of this research is to aid businesses in enhancing their customer service strategies and nurturing enduring customer relationships.

Keywords: *customer satisfaction, brand loyalty, self-service technologies, personal service attributes, food service*

I. INTRODUCTION

For centuries, since humans first engaged in trade and commerce, there existed a longstanding interest in studying customer behavior and determining the sources of their satisfaction. The concept of services encompassed products, food, experiences, and satisfaction provided to customers through hospitality personnel and the organizational system (Chen & Xie, 2017). With the development of technology, providers of intangible values became increasingly creative, utilizing products and technological conveniences to optimize customer experiences. Consequently, merchants faced the constant challenge of creating effective Digital Interactive Platforms (DIPs) to generate value (Thomas-Francois & Somogyi, 2022).

Vietnam's F&B industry experienced significant growth over the years, witnessing an increase in the number of restaurants, cafes, and bars in major cities. According to a report by IPOS on the food business market, the F&B industry's revenue reached nearly VND 610,000 billion in 2022, marking a 39% increase

from 2021 (IPOS, 2022). In 2022, the market regained its strength. Alongside this growth, the concern about gaining customer satisfaction surged. Dang's study (2020) identified factors affecting customer satisfaction in the F&B industry, including service quality, price, food quality, atmosphere, and location. Service quality emerged as the most influential factor, suggesting that businesses should prioritize improving it to enhance customer satisfaction and loyalty.

The research problem at hand delves into a rather intriguing paradox within the context of the foodservice industry. Despite the pervasive challenges brought about by a worldwide economic downtrend, the industry as a whole continues to thrive, with many establishments maintaining a robust business performance. This phenomenon has led us to consider a significant contributing factor - the synergy between self-service technology and the quality of service provided by human factors, which collectively elevate guest satisfaction and cultivate brand loyalty.

However, amidst this broader industry resilience, there exists a puzzling case study - Manwah Taiwanese Hotpot in Binh Duong. Despite being equipped with both the self-service technology and a dedicated team of service providers, Manwah has not experienced the same level of success. This anomaly raises the critical question: What might be the underlying problem plaguing Manwah Taiwanese Hotpot, preventing it from reaping the benefits of these seemingly advantageous factors.

The aim was to discern the positive impacts brought about by Self-Service Technologies (SSTs) and Personal Service Attributes on customer satisfaction and brand loyalty. This study addressed a research gap in the Vietnamese market and intended to serve as a foundation for enhancing service quality in Binh Duong's restaurants. It specifically targeted Manwah Taiwanese Hotpot, a chain with branches in Binh Duong, to provide directive insights for service quality improvement.

Despite the challenges posed by the epidemic situation, Binh Duong province made significant strides in digital transformation, as reflected by the Digital Transformation Assessment Index (DTAI) assessed by the Ministry of Information and Communications in 2021. This digital transformation contributed positively to the province's economic shift, leading to an improved ranking of 22/63 among provinces and cities, a nine-rank advancement from 2020 (ranked 31/63). Experts regarded digital transformation as crucial for state management enhancement, fostering favorable conditions for people and businesses. Binh Duong's digital transformation journey served as an exemplary model (VnEconomy, 2023).

High-quality and efficient services became essential for attracting and retaining clients in the modern hospitality landscape, and cutting-edge technology was integral to fulfilling customer needs. Self-service technology emerged as one of these captivating innovations. However, the national technological wave did not entirely revolutionize the local environment. The adoption of digital support by economic entities for self-service models remained relatively limited. Additionally, certain demographic groups, such as the elderly and middle-aged, were not entirely receptive to this new service approach.

Inevitably, prior research also consistently highlighted the influence of service employees'

behavior and attitudes on customer satisfaction, loyalty, and overall service quality (Lovelock & Wirtz, 2011). This research aimed to explore the effects of SST implementation and Personal Service Attributes within the Binh Duong area on client satisfaction and commitment in the realm of foodservice. The study's outcomes aimed to guide local hospitality businesses in making informed decisions about investing in SSTs and optimizing their personnel service training systems.

To fulfill the research objectives, the following questions were posed:

- Does the implementation of SSTs within Manwah Taiwanese Hotpot in Binh Duong lead to positive or negative impacts on local customer satisfaction and brand loyalty?
- Does the implementation of excellent Personal Service Attributes at Manwah Taiwanese Hotpot in Binh Duong lead to positive or negative impacts on local customer satisfaction and brand loyalty?

The scope of the paper encompassed conducting a survey to assess the interest of local hotpot store diners, specifically targeting young local citizens. The research aimed to gather data on preferences, opinions, and behaviors related to hotpot dining options. While the study provided insights into the immediate context, its limited timeframe potentially restricted capturing long-term trends or seasonal variations. Moreover, conducting the survey among a specific demographic group might affect the generalizability of findings.

The research's significance for local hotpot stores and the academic community was multi-fold. It provided insights into consumer preferences and potential market demand, aiding in tailoring offerings. By addressing areas of improvement, such as service quality, businesses could enhance customer satisfaction and drive success. The study also contributed to academic knowledge about consumer behavior in the regional F&B context, serving as a reference for future research and supporting decision-making for local establishments.

II. LITERATURE REVIEW

A. Brand loyalty in foodservice business

Brand loyalty is pivotal for foodservice business success. In a competitive market, a loyal customer base offers a significant edge. It signifies customers' commitment to a brand, leading to repeated visits and positive referrals. Building brand loyalty begins with consistently delivering high-quality products and services. Customers develop trust and confidence in a foodservice brand when they consistently experience delicious, well-prepared meals, attentive service, and a pleasant dining atmosphere. This consistent delivery of quality fosters a sense of reliability and reliability, which are important factors in creating brand loyalty. Creating a memorable and personalized experience is another important aspect of building brand loyalty. When customers feel valued and appreciated, they are more likely to develop an emotional connection with a foodservice brand. This can be achieved through attentive customer service, personalized recommendations, and special promotions or rewards for loyal customers. Such gestures contribute to a positive brand image and encourage customers to choose the brand over competitors.

B. Customer satisfaction

In the realm of the hospitality industry, guest satisfaction reigns supreme as the ultimate measure of success. It is the culmination of numerous factors carefully orchestrated to create an experience that leaves a lasting impression. From the moment guests step foot into a hotel lobby or dine at a restaurant, their expectations are on-set, and it is the duty of the hospitality professionals to surpass those expectations. Service quality serves as the cornerstone of guest satisfaction. A warm smile, a genuine greeting, and a willingness to go the extra mile can create a sense of comfort and assurance. Attentive staff members anticipate guests' needs, ensuring that their stay is as seamless and enjoyable as possible. Whether it's providing timely assistance or offering personalized recommendations, every interaction plays a pivotal role in shaping overall satisfaction.

The pursuit of guest satisfaction extends beyond impeccable service. It encompasses the physical aspects of the establishment as well. Cleanliness, comfort, and attention to detail are vital ingredients in creating a welcoming environment. A well-maintained restaurant with fresh linens, cozy furnishings, and a soothing ambiance sets the stage for a restful retreat. Guests seek solace in the knowledge that their accommodations provide a sanctuary away from the hustle and bustle of daily life. Efficiency is another key factor in enhancing guest satisfaction. Long queues or administrative hiccups can mar an otherwise pleasant experience. By implementing technology and adopting efficient procedures, hospitality providers can create a seamless transition for guests, leaving them with a sense of satisfaction from the very beginning to the end of their experience.

C. Hypothese development

Self-service technologies (SSTs) became increasingly common in the service industry, including the food and beverage (F&B) sector. SSTs were defined as "technological interfaces that enabled customers to produce a service independent of direct service employee involvement" (Meuter et al., 2003). While SSTs were designed to increase efficiency and reduce costs for businesses, their impact on customer satisfaction was also considered. Research literature consistently demonstrated that self-service technology (SST) attributes had a positive impact on overall customer satisfaction. Studies by Meuter et al. (2000), Dabholkar et al. (2000), Collier and Sherrell (2010), and Verhoef et al. (2009) provided valuable insights into the relationship between SST and customer satisfaction.

Notably, SST's positive impact on satisfaction extended to various industries, including retail, banking, and hospitality. By offering self-service options, organizations could meet the evolving needs and preferences of customers, leading to improved overall satisfaction levels. Furthermore, the convenience and positive evaluations associated with SST usage contributed to enhanced post-purchase satisfaction and fostered long-term customer loyalty. Based on above discussions, the first hypothesis was formed:

H1: *SSTs attributes have positive impacts on overall satisfaction.*

Many studies have shown that personal service attributes had a significant positive impact on overall satisfaction in the F&B industry. Customers who received personalized attention and a high level of service were more likely to be satisfied with their experience and to return to the business in the future.

Businesses that prioritized personalized attention, expertise and professionalism, and comfort and convenience were more likely to create loyal customers and achieve long-term success. Extensive research supported the notion that Personal Service Attributes had positive impacts on overall satisfaction. Studies conducted by Bitner, Brown, and Meuter (2000), Parasuraman, Zeithaml, and Berry (1985), Maxham III and Netemeyer (2002), and Mattila and Enz (2002) shed light on the significance of service providers' Personal Service Attributes in shaping customer satisfaction.

In addition, Mattila and Enz (2002) examined the influence of hotel employees' service attributes on guest satisfaction. They revealed that positive Personal Service Attributes displayed by service providers, such as friendliness, willingness to help, and knowledge, contributed to higher levels of overall guest satisfaction. Therefore, the second hypothesis was constructed:

H2: *Personal service attributes have positive impacts on overall satisfaction.*

If an SST was easy to use, efficient, and reliable, it led to a positive customer experience, which strengthened the customer's emotional attachment to the brand or service provider. Conversely, if an SST was difficult to use, unreliable, or frustrating, it led to a negative customer experience, which weakened the customer's emotional attachment. Meuter et al. (2003) emphasized that positive experiences with SST, characterized by attributes such as reliability, convenience, and ease of use, contributed to increased brand loyalty among customers. They highlighted the importance of understanding customer satisfaction with technology-based service encounters and their implications for building loyalty. Meanwhile, Verhoef et al. (2009) explored the role of technology-based self-service in driving customer loyalty. Their findings indicated that SST attributes, including customization options, responsiveness, and personalization, positively influenced brand loyalty by enhancing customer satisfaction and perceived value. They emphasized the importance of these attributes in building brand attachment and fostering repeat business. Kim and Kim (2017) examined the airline industry and highlighted the impact of SST attributes on brand loyalty. They asserted that attributes such as system availability, transaction speed, and user-friendliness played a crucial role in shaping customer loyalty and fostering positive brand attitudes. Those discussions has led to build the next hypothesis:

H3: *SSTs attributes have positive impacts on brand loyalty.*

Research had shown that employees who possessed certain personal service attributes, such as empathy, emotional intelligence, and proactive problem-solving skills, were more likely to develop strong relationships with customers. These strong relationships led to increased customer satisfaction and loyalty, which, in turn, increased the employee's brand loyalty to the organization (Beatson et al., 2006). In addition, Kim and Kim (2020) highlighted the importance of personal service attributes, such as competence, friendliness, and responsiveness, in shaping customer perceptions and fostering loyalty. Their research revealed that customers who experienced positive interactions with service providers were more likely to develop strong brand loyalty. Auh et al. (2005) investigated the impact of personal service attributes on customer loyalty

in the business-to-business context. Their findings demonstrated that service providers' attributes, including expertise, reliability, and trustworthiness, significantly influenced customer satisfaction and long-term loyalty. Therefore, the fourth hypothesis was built as:

H4: *Personal service attributes have positive impacts on brand loyalty.*

Lastly, customer satisfaction could have a significant impact on brand loyalty in the food and beverage industry. When customers were satisfied with their experience at a restaurant or other F&B establishment, they were likely to feel more positively about the establishment and develop a stronger emotional connection to it. This could lead to increased loyalty and repeat business, as well as positive word-of-mouth marketing from satisfied customers (Bughin et al., 2010). Anderson and Sullivan (1993) emphasized the crucial role of customer satisfaction in driving brand loyalty. Their research revealed that satisfied customers were more likely to repurchase products or services from a particular brand, resulting in increased brand loyalty. These studies collectively suggested that overall satisfaction played a critical role in building brand loyalty. Customers who experienced high levels of satisfaction were more likely to develop strong attachments to a brand, exhibit repeat purchase behavior, and engage in positive brand advocacy. From these points of view, the last hypothesis was formed:

H5: *Overall satisfaction has positive impacts on brand loyalty.*

D. Research model

Based on the above discussions, the following Figure 1 depicts the essential dimensions of the conceptual framework created and explored in this research. This framework diagrammatically depicts the theories made in the next sections of the literature (Beatson et al., 2006).

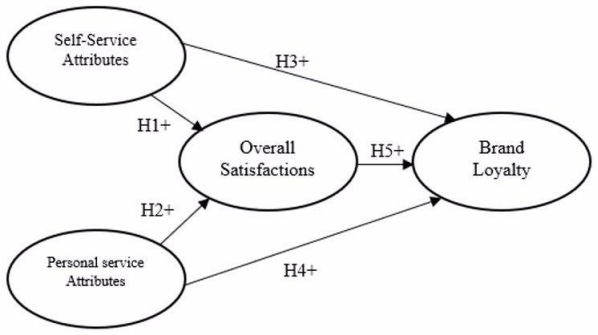

Figure 1. Research model

(Source: Moderated from the study of Beatson)

III. METHODOLOGY

A. Research process

Formal quantitative research is conducted to test hypotheses and traditional research models. The study used survey data from 250 participants to test the theoretical model with a convenient sampling method. The data analysis technique analyzes a linear structural model based on partial least squares (PLS-SEM). Regarding the proposed research model and a reflective measurement model, PLS-SEM is more suitable than CB-SEM (Hair et al., 2020). The steps to perform structural equation model analysis include evaluating the measurement and structural models to test hypotheses and research models (Sarstedt et al., 2020). Finally, the research results will be discussed based on a comparison with previous studies to explain the results from practice, thereby giving some management implications based on the results achieved.

B. Sampling method

The sample was drawn from the pool of young diners of Binh Duong Manwah

Taiwanese Hotpot in Bình Dương by using the snowball sampling method. This is because of the applicability as well as the practical result this candidate could process, both in terms of age group, interests, and geographical Concerns. Totally 24 questionnaires were completed and usable for 15 organisations. Each of the organizations (high schools, universities, etc.) would have at least 9 participants to join and complete the forms, which resulted in a total of 250 participants. The results of descriptive statistics about the survey subjects are presented in Table 1.

Table 1. Demographic description

		Frequency	Percent
Gender	Male	125	64.1
	Female	70	35.9
Education Level	High school	34	17.4
	First/Second year university student	42	21.5
	Third/Fourth year university student	58	29.7
	Fifth year university student and above	29	14.9
	Post-graduated	32	16.4
Income Level	Under 5 million	73	37.4
	5-15 million	77	39.5
	Above 15 million	45	23.1
Total		**250**	**100.0**

(Source: Author's data analysis)

As presented in Table 1, out of the total of 250 respondents, there were 125 answerers who were male students along with other 70 female participants, accounting for 64.1% and 35.9% respectively. Since the age range collected was on the scale of from high school pupils to fresh post-graduates, aged from 14 to 25, most of the answerers belong to the middle group of first/second year and third/fourth year students who aged from 18 to 22, as the sum result of these 2 groups was 51.2%. Correlating to the most frequent age level recorded, most of the recorded interviewees have their monthly income of 5 to 15 million, with the proportion of 39.5% out of the 3 selected income range.

C. Data analysis

To estimate the parameters of the measurement and structural models, SmartPLS was used to conduct the data analysis of the next stage. The measurement model to test the relevance of the sample and the structural model to test the relationships between variables to each other (Wong, 2013).

The first step was analysing Standardised Root Mean Square Residual (SRMR) to test the suitability of the model with the sample which the result of the samples smaller than 0.08 is the best result (Henseler, 2017). Table 2 showed that the SRMR of the model was 0.058 < 0.08 which meant the model was perfectly satisfied with the sample area.

Table 2. Standardised Root Mean Square Residual (SRMR)

	Saturated Model	Estimated Model
SRMR	0.058	0.058

(Source: Author's data analysis)

The next step was evaluating the factor loading helped to identify how effectively the item represents the underlying construct. The outer loading larger 0.7 is accepted (Sarstedt et al., 2020). The outer loadings of all items were greater than 0.07 which meant the items were significant.

The AVE was used to evaluate the convergent validity of the measuring model, which was based on the average correlation between variables with the result was greater

than 0.50 was accepted (Fornell et al., 1996). As shown in the report, all the figures recorded were greater than 0.5, indicating that more than 50% of the variance in the latent construct, from the attributes of self-service technology and personal service to customer overall satisfaction and brand loyalty, is accounted for by its indicators, supporting convergent validity. Since the data for Brand Loyalty (BRA) had the highest AVE value of 0.879, indicating that the observed indicators associated with the "BRA" latent construct capture a large proportion of its variance relative to measurement error. This suggests strong convergent validity for the "BRA" construct. Meanwhile, the figure for Personal Service Attributes, PER has the lowest AVE value of 0.791 among the four constructs. While it is slightly lower compared to the other constructs, it still exceeds the threshold of 0.5 for convergent validity.

Table 3. Average Variance Extracted (AVE)

	Average Variance Extracted (AVE)
BRA	0.775
OVE	0.758
PER	0.803
STT	0.806

(Source: Author's data analysis)

The study used Cronbach's Alpha (CA) and Composite Reliability (CR) to assess the reliability of variables in a survey. CA values ranged from 0.70-0.95 (Gupta et al., 2019), while CR values greater than 0.70 were considered satisfactory (Netemeyer et al., 2003). The study found that all variables were reliable, with CA values exceeding 0.9 and CR values exceeding 0.90.

Table 4. The reliability test

	Cronbach's Alpha	Composite Reliability
BRA	0.903	0.932
OVE	0.920	0.940
PER	0.939	0.953
STT	0.940	0.954

(Source: Author's data analysis)

Henseler (2015) developed the Heterotrait-Monotrait Ratio of Correlations (HTMT) to test factor correlations, requiring a significant difference between factors for discrimination which meant that the HTMT needed to be less than one, as all discrimination values were accepted.

Table 5. The heterotrait–monotrait ratio

	BRA	OVE	PER	STT
BRA	**0.880**			
OVE	0.649	**0.871**		
PER	0.566	0.440	**0.896**	
STT	0.629	0.470	0.421	**0.898**

(Source: Author's data analysis)

The regression analysis tests the relationship between variables using the Coefficient of Determination (R^2) in the complex model. The results showed that brand loyalty (BRA) was influenced by Overall Satisfaction, Personal Service Attributes and Self-service Technologies, while Overall Satisfaction (OVE) were influenced by transformational relationships, learning orientation, autonomy, and creative self-efficacy.

Table 6. Coefficient of determination

	R Square	R Square Adjusted
BRA	0.605	0.600
OVE	0.292	0.286

(Source: Author's data analysis)

The path coefficient is crucial in regression coefficient analysis. SmartPLS software results indicate significant relationships between variables, with p-values less than 0.05, <0.05, or t-values larger than 1.96 (Purwanto et al., 2021). Table 7 shows all variables had a significant positive relationship, with p-values less than 0.05 and t-values larger than 1.96.

Table 7. Path coefficient

	T Statistics	P Values
OVE -> BRA	7.154	0.000
PER -> BRA	5.201	0.000
PER -> OVE	6.206	0.000
STT -> BRA	6.444	0.000
STT -> OVE	6.041	0.000
OVE -> BRA	7.154	0.000

(Source: Author's data analysis)

Effect size (f^2) is a measure of the proportion of variance in the dependent variable that can be explained by the independent variable(s) in a regression analysis. To make sense of the substantial significant effects, the effect size (f^2) would be a useful tool. The value of effect size greater than 0.15, 0.02 or 0.35 could be considered as weak, moderate, or strong respectively (Sarstedt et al., 2020). Brand loyalty (BRA) has a moderate effect on overall satisfaction (OVE) with an effect size of 0.252, indicating that approximately 25.2% of the variance in overall satisfaction can be explained by brand loyalty.

Overall satisfaction (OVE) has a small effect on brand loyalty (BRA) with an effect size of 0.100, suggesting that approximately 10% of the variance in brand loyalty can be explained by overall satisfaction. Personal Service Attributes (PER) have a small effect on brand loyalty (BRA) with an effect size of 0.124, indicating that around 12.4% of the variance in brand loyalty can be explained by perceived factors. Personal Service Attributes (PER) have a moderate effect on overall satisfaction (OVE) with an effect size of 0.218, suggesting that approximately 21.8% of the variance in overall satisfaction can be explained by perceived factors. Self-Serviced Technology (SST) has a small effect on brand loyalty (BRA) with an effect size of 0.139, indicating that around 13.9% of the variance in brand loyalty can be explained by stated factors. Self-Serviced Technology (STT) has a moderate effect on overall satisfaction (OVE) with an effect size of 0.218, suggesting that approximately 21.8% of the variance in overall satisfaction can be explained by stated factors.

Table 8. Effect size (f^2)

	BRA	OVE
BRA		
OVE	0.252	
PER	0.124	0.100
STT	0.218	0.139

(Source: Author's data analysis)

Although the effect sizes between the variables were not strong, they still have the effect which could conclude that the model was significant.

IV. RESEARCH FINDINGS AND DISCUSSION

A. Research findings

The culmination of the statistical analysis reveals compelling insights into the dynamics of the hotpot dining experience and its relationship with various factors. The data establishes a significant positive association among these factors, underscoring their profound impact on overall customer satisfaction. The data yielded remarkable outcomes, reflecting a substantial

correlation between overall satisfaction and the quality of the dining experience. The statistical measures paint a vivid picture: a high T statistic of 7.154, coupled with an exceptionally low p-value of 0.000, attests to the substantial influence of the survey-examined factors on respondents' satisfaction levels. This robust relationship between the components of the dining experience and overall satisfaction is indicative of the critical role these factors play in shaping diners' contentment. Brand loyalty, denoted as BRA, emerges as a pivotal determinant in the hotpot industry's landscape. The analysis pinpoints a substantial impact, as evidenced by the considerable T statistic of 5.201 and a p-value of 0.000. The findings illuminate the profound influence of customers' allegiance to a specific hotpot brand on their overarching satisfaction with the entire dining endeavor. This emphasizes the significance of fostering brand loyalty to enhance customer contentment. The survey's exploration of Self-Service Technology (STT) unearths an intriguing connection between technological interfaces and overall satisfaction.

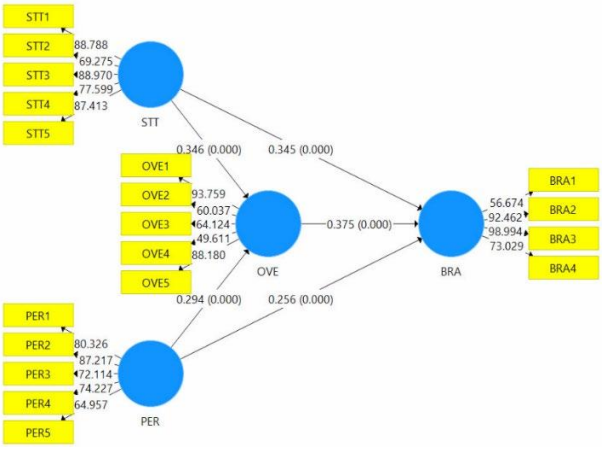

Figure 2. Research findings

(Source: Results from the SEM Analysis by SmartPLS 3.0)

A resounding correlation is evident through the high T statistic of 6.444 and an impressively low p-value of 0.000. The outcome underscores the pivotal role of self-service technology within the hotpot restaurant setting, revealing its substantial sway on respondents' holistic satisfaction. In summation, the synthesis of these analytical outcomes crystallizes a comprehensive understanding of the interplay between diverse factors and customer satisfaction in the realm of hotpot dining.

Table 9. Findings results based on structural model

	T Statistics	P Values	Findings
OVE -> BRA	7.154	0.000	Significant
PER -> BRA	5.201	0.000	Significant
PER -> OVE	6.206	0.000	Significant
STT -> BRA	6.444	0.000	Significant
STT -> OVE	6.041	0.000	Significant
PER -> OVE -> BRA	4.370	0.000	Significant
STT -> OVE -> BRA	4.266	0.000	Significant

(Source: Author's data analysis)

Our research on food service and customer satisfaction has yielded overwhelmingly positive results, aligning closely with their practical implications from the very outset. The data collected throughout this study consistently demonstrates a strong correlation between enhanced customer satisfaction and the successful implementation of various service improvements within the food industry. As our findings have shown, investments in areas such as staff training, menu diversification, and personalized customer experiences have not only boosted satisfaction levels but also translated into increased customer loyalty and repeat business. These outcomes underline the critical importance of attentiveness to

customer preferences and the continuous pursuit of excellence in service delivery for any food service establishment aiming to thrive in today's competitive market. This research provides valuable insights that can serve as a foundation for strategic decision-making and guide the industry towards sustained success and growth.

B. Discussions

The research findings from the Taiwanese hotpot survey revealed several significant insights into the relationship between Customer Satisfaction, Brand Loyalty, Self-service Technology, and Personal Service Attributes. These findings highlighted the importance of understanding and addressing these factors to create a positive dining experience and foster customer loyalty in the competitive hotpot market.

The high T statistics and low p-values for overall satisfaction (OVE), brand loyalty (BRA), and self-service technology (STT) indicated strong associations with customer satisfaction. This suggested that these factors significantly contributed to customers' overall experience and their likelihood of becoming loyal to a hotpot brand.

In recent years, self-service technology has gained increasing popularity in the foodservice industry. The research findings underscored the importance of implementing effective self-service technology to enhance customer satisfaction. By providing customers with control over their ordering process, enabling customization options, and ensuring seamless and user-friendly interfaces, hotpot restaurants streamlined operations, reduced wait times, and enhanced the overall dining experience.

Additionally, the impact of Personal Service Attributes on customer satisfaction and brand loyalty should not have been overlooked. While the specific findings regarding Personal Service Attributes were not provided in the given data, previous research suggested that factors such as age, gender, income level, and cultural background influenced customers' preferences, expectations, and loyalty. Understanding these demographic variables and tailoring services and marketing efforts to specific customer segments helped hotpot businesses better meet customer needs and enhance brand loyalty.

Customer satisfaction and brand loyalty were crucial factors in the competitive food service industry. Understanding the drivers of customer satisfaction and loyalty was essential for businesses to thrive. This essay explored the relationship between customer satisfaction, brand loyalty, self-service technology, and Personal Service Attributes, drawing insights from research studies conducted in the field.

One area of focus in the foodservice industry was the impact of self-service technology on customer satisfaction. Chen and Xie (2017) conducted a case study on Starbucks and found that customers who used self-service kiosks reported higher satisfaction levels compared to those who interacted with staff. This highlighted the significance of self-service technology in streamlining service processes and enhancing customer satisfaction (Chen & Xie, 2017).

Gounaris and Stathakopoulos (2004) investigated the antecedents and consequences of brand loyalty across industries. They identified customer satisfaction as a key factor influencing brand loyalty. When customers were satisfied with their experience, including

aspects like service quality, food quality, ambiance, and perceived value, they were more likely to exhibit loyalty towards a brand (Gounaris & Stathakopoulos, 2004). Kim and Kim (2017) further supported this notion, emphasizing the importance of these factors in full-service restaurants (Kim & Kim, 2017).

Personal Service Attributes, such as age, gender, income level, and cultural background, could also play a role in shaping customer satisfaction and brand loyalty. Nguyen et al. (2020) examined the effects of Personal Service Attributes in Vietnamese coffee shops. They found that these attributes had varying effects on customer satisfaction and loyalty, highlighting the importance of understanding and catering to the diverse needs and preferences of different customer segments (Nguyen et al., 2020).

The research findings suggested several implications for businesses aiming to enhance customer satisfaction and foster brand loyalty. Firstly, leveraging self-service technology could improve the overall customer experience, streamline processes, and contribute to higher satisfaction levels. Implementing user-friendly interfaces, customization options, and efficient self-service systems could positively influence customer perceptions. Secondly, businesses should prioritize factors that drive customer satisfaction, such as service quality, food quality, ambiance, and perceived value. By focusing on these aspects, brands could create positive experiences that contributed to customer satisfaction and loyalty. Lastly, understanding and catering to the Personal Service Attributes of customers could further enhance satisfaction and loyalty. Tailoring services and marketing efforts to specific demographic segments helped businesses meet customer needs more effectively.

Otherwise, this research stands as a testament to its applicability and innovation, as it delves beyond the conventional boundaries of customer service analysis. Notably, it not only explores the amalgamation of self-service technology and personal service attributes but also provides a profound insight into the intricacies of the foodservice industry, with a particular focus on the local market of Binh Duong, Vietnam. This dual-pronged approach not only extends the boundaries of existing research but also addresses the unique dynamics of a specific locale, making it inherently adaptable to various contexts within the global foodservice landscape.

By studying the interplay between cutting-edge technological advancements and the timeless nuances of human interaction, this research offers a comprehensive understanding of how these elements can be harnessed to elevate customer satisfaction levels. Moreover, its specific examination of the Binh Duong market provides a localized perspective, allowing businesses in this region to apply our findings directly to their operations. This dual-layered approach empowers local food service providers to make informed decisions tailored to their unique circumstances, thus fostering innovation and growth within the industry. In essence, this research bridges the gap between the global and the local, offering a versatile and groundbreaking perspective that can be embraced by a wide spectrum of stakeholders in the foodservice sector.

V. CONCLUSION

The purpose of this study was to understand and evaluate the factors that affected customer satisfaction, consequently influencing brand loyalty among diners at Manwah Taiwanese

Hotpot Binh Duong restaurant. The study analyzed two main factors in detail: self-service technology products and human factors. The results confirmed a positive relationship between self-service technology, waitstaff, customer satisfaction, and the decision to return. The research revealed that the implementation of online ordering platforms significantly improved the customer experience in the foodservice industry. Customers benefited from the convenience of placing orders, customizing meals, and making payments without direct staff interaction, resulting in enhanced control, reduced wait times, and improved convenience. The integration of self-service technology streamlined operations, minimized errors, and increased efficiency within foodservice businesses.

Moreover, Personal Service Attributes played a significant role in delivering exceptional customer service. Attributes such as communication skills, empathy, and a positive attitude were essential for creating a welcoming environment and building lasting relationships with patrons. Leadership and management attributes were crucial for owners and managers, contributing to a positive work environment and continuous improvement. However, despite the positive impact of self-service technology, the research indicated that customer feedback at Manwah Taiwanese Hotpot Binh Duong was not highly impressive. The average customer perception ratings for services related to self-service technology and human factors were relatively moderate, leading to perceptions of overall satisfaction and loyalty decisions after multiple experiences at the restaurant.

The study's implications highlighted the challenges faced by Manwah Taiwanese Hotpot Binh Duong in building brand loyalty and implementing efficient self-service technology. The restaurant's lack of investment in maintaining a distinct brand image, outdated POS systems, and disengaged staff contributed to a lackluster customer experience. The absence of innovative menu offerings, inconsistency in food quality, and insufficient marketing efforts further hindered the establishment's ability to foster brand loyalty.

The correlation between our research results, which demonstrate the positive impacts of integrating self-service technology and enhancing personal service attributes on customer satisfaction and brand loyalty, holds profound implications for businesses in the hotpot restaurant industry, particularly those that have not yet invested significantly in technology and staff training. For a hotpot as Manwah Taiwanese Hotpot Binh Duong restaurant that has been hesitant to embrace technological advancements and has perhaps been overlooking the importance of staff training, our findings offer a promising path forward. By recognizing that customers increasingly value efficiency, convenience, and personalized experiences, this restaurant can reevaluate its strategies and initiate changes to stay competitive in today's dynamic market.

Firstly, implementing self-service technology, such as interactive tabletops for ordering or payment kiosks, can streamline the dining experience, reducing wait times and enhancing customer control. Our research demonstrates that such enhancements lead to increased satisfaction and, ultimately, greater brand loyalty. Secondly, investing in staff training to improve personal service attributes is equally critical. A well-trained and attentive staff can elevate the dining experience by providing warm, knowledgeable, and personalized service. This, in turn, fosters a

deeper connection with customers, reinforcing brand loyalty.

In conclusion, the study revealed that a combination of self-service technology and brand loyalty significantly impacted customer satisfaction in the foodservice industry. Effective implementation of self-service technology enhanced the overall customer experience and contributed to the success of the brand.

However, the study still acknowledged its limitations, such as the specific focus on self-service technology and service staff and the potential bias in customer perceptions. Future research was recommended to adopt a more comprehensive approach, considering a wider range of factors that contribute to customer satisfaction. Conducting longitudinal and comparative studies, employing qualitative research methods, and exploring cultural differences were suggested to gain deeper insights into customer satisfaction and its driving factors. Addressing these limitations would provide more actionable insights into the foodservice industry.

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ENHANCING INNOVATIVE ACTIVITIES AMONG FRONTLINE EMPLOYEES: THE MEDIATING ROLE OF CREATIVE SELF-EFFICACY

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Abstract: This paper aims to identify the influence of three determinants of creative self-efficacy on innovative activities. By using snowball sampling method to collect the data; 207 employees, who work directly with customers in different style of organisation in Binh Duong, have completed the survey questionnaire as valid participants. The research method employed was partial least squared structure equation modelling (PLS-SEM) with Smart PLS software for data analysis. The findings indicate that creative self-efficacy mediated the relationship between three determinants (transformational leadership, leaning orientation and autonomy) with innovative activities. The research acknowledges the limitation of the limited sample size and encourages further exploration of these relationships in other contexts. In addition, this study provides valuable insights for the management board on how to enhance the innovative activities among the frontline employees at service organizations in the future.

Keywords: *creative self-efficacy, transformational leadership, learning orientation, autonomy, innovative activities*

I. INTRODUCTION

In modern days, with the development of economics, the potential of the market and also the demand of customers has become largely in national and international sides that make the firms have to recognise their strengths, weaknesses, opportunities or threats to help their firms compete with others, survive or progress. Following that creativity and innovation have become the key factors to accomplish these changes in the difficult situation that requires the activity to catch up with others. The companies need to evaluate their employees' creativity due to the differences between their minds from each other and how they can apply their thinking to the innovative activities of the companies. According to Coelho et al. (2011, p. 31), "firms need creative employees to initiate organisational innovation" because of their different minds. Another quote showed that the creativity of employees increases the opportunities for others to follow, adapt and create their own ideas for developing themselves in an organisation (Shalley et al., 2004, p. 933).

Recently, the concept of creative self-efficacy and its effects in the explanation of employees' participation in innovation-related activities has attracted a lot of interest from many researchers. Tierney et al. (2002, p. 1137) suggested that "creative self-efficacy, that may

be a key personal attribute for creativity in the workplace" as a "self-constructs". In another research, they showed that the most important factor in predicting performance in a given activity domain is self-efficacy relevant to that domain (Tierney & Farmer, 2011, p. 277).

One critical issue of interest would be the research of creative self-efficacy because it relates especially to the front-line employees in not only the hospitality firms but also other types. Cambra-Fierro et al. (2014, p. 68) have supported in the point of view that the engagement of customers in the service, product or activities of the firm is the result of their feeling sufficiently satisfied and also from the relationship between company-customers itself. There is one reason that front-line employees' assignments are to do unstructured tasks which means that the staff who work at those positions usually face customers before other positions and they also have to deal with difficult customers who have different problems. These varied customers make the service employees need to be creative and can perform innovative activities to make their customers feel satisfied in many cases. It is very interesting that the creativity which is related to the tasks can perform the characteristics that have inside the service employees naturally. Therefore, it is very reasonable to assume that these employees need a certain level of creativity which can help them perform innovative activities. According to Tierney and Farmer (2011, p. 277) one of the important steps in organisation' effort to innovate was to understand the way to create employee creative-efficacy.

Frontline employees are the backbone of many organizations, and their performance is integral to organizational success, especially in regions characterized by rapid growth and development, such as Binh Duong. Understanding the factors that influence their self-efficacy and how these factors impact their ability to engage in innovative activities is crucial. However, there is a notable gap in the existing literature that requires comprehensive exploration. The primary problem addressed by this research is the limited knowledge regarding the determinants of self-efficacy among frontline employees in Binh Duong and the subsequent influence on their capacity for innovative activities.

Despite the critical importance of self-efficacy in employee motivation, performance, and overall organizational success, there is a lack of research specific to this dynamic region, which has its unique economic, social, and cultural contexts.

To effectively support and empower frontline employees in Binh Duong, it is imperative to identify and analyse the most significant determinants of their self-efficacy. Furthermore, understanding how these determinants influence their capacity for innovative activities is essential for organizations striving to remain competitive and adaptive in today's rapidly changing business environment. Therefore, this research aims to answer the following critical research questions:

- What are the most significant determinants of self-efficacy among frontline employees in Binh Duong?
- How do these determinants enhance innovative activities of frontline employees in Binh Duong?

Addressing these critical research questions will contribute to bridging the existing gaps in our understanding of self-efficacy among frontline employees in dynamic regions like Binh Duong. Furthermore, it will offer practical

insights for organizations, policymakers, and researchers aiming to create a supportive and innovative work environment. Ultimately, the outcomes of this research will not only benefit organizations by improving employee performance but also promote the region's economic development and competitiveness on a global scale.

II. LITERATURE

The selection of self-efficacy influencing factors in this research is guided by the Social Cognitive Theory, particularly the works of Albert Bandura, who developed the theory (Tierney & Farmer, 2002). Bandura's Social Cognitive Theory emphasizes the role of self-efficacy in human behavior, suggesting that an individual's belief in their ability to perform a task significantly influences their actions, motivation, and overall performance.

A. Creative self-efficacy

Firstly, self-efficacy included the beliefs of people about their capabilities to practise overcoming challenging demands and their own functioning (Schwarzer & Luszczynska, 2008). Second, self-efficacy was dynamic because it could motivate people to adopt the higher level of tasks over time which resulted in contribution in performance (Seo & Ilies, 2009, p. 121). Third self-efficacy component demonstrated how individuals' mobilisation impacted on their choice, determination, attempt, ultimately, the attainment of a particular outcome (Beghetto, 2006). According to Bandura (1997), the self-efficacy should not range as "general" or "specific", they needed to understand that they fall somewhere continuing between these two extremities. Bandura' theory in 1997 suggested that people who had high self-efficacy more often viewed challenging tasks as something that they could control and could not avoid. Then, creative self-efficacy was represented as an expansion of content and intrinsic characteristics of a particular type of self-efficacy of the broader one construct. Consequently, creative self-efficacy had an inherent nature and depended on the person's judgement about the resources and limits in a specific area.

In the previous study of Tierney and Farmer (2002, p. 1,138), this construct was explained as "the belief of one has the ability to produce creative outcomes". This explanation was very crucial for narrowing the concept of self-efficacy into creativity to the assignments which related to specific work roles and consequently made the concept of it different from the general self-efficacy. This referred to the individual's overview beliefs on himself or herself across a number of situations, contexts and assignments.

B. Determinants of creative self-efficacy

Based on the study of Tierney and Farmer (2002, p. 1,137), creative self-efficacy could be defined as the "key personal attribute for creativity in the workplace". As a result, it is important that we examine the determinants of creative self-efficacy. There are many factors that relate to creative self-efficacy reasonably. However, in this paper, we just focus on three of them which are leader-related, self-related and job-related. Although the factors are limited, we attempt to focus and carefully select the representatives of each of them based on the level of difference in employees' creative self-efficacy, especially the frontline office aspects.

Creative self-efficacy, the belief in one's ability to generate and implement novel ideas and solutions, is influenced by several key determinants. Transformational leadership,

characterized by inspirational and visionary leadership practices, can inspire employees to believe in their creative capabilities. Leaders who foster a culture of continuous learning orientation, where employees are encouraged to explore and experiment, can enhance creative self-efficacy by emphasizing that failures are opportunities for growth. Additionally, autonomy, granting employees the freedom to make decisions and take ownership of their work, can empower individuals to trust in their creative potential, as they have the independence to pursue innovative ideas. These determinants collectively contribute to bolstering creative self-efficacy, enabling individuals to harness their creative skills effectively within the organization.

C. Hypotheses development

1. Leader-related factor: Transformational leadership

In this paper, transformational leadership is chosen as the representative factor influencing creative self-efficacy. The decision is supported by three compelling reasons. Firstly, transformational leadership has been a subject of significant research interest in the realm of leadership for over three decades (Hay, 2006, p. 3). Secondly, it is considered an ideal leadership style for fostering sustainable development in today's competitive global market (Ghasabeh et al., 2015, p. 460). The pivotal reason lies in transformational leadership's focus on individual empowerment and motivation, creating a reciprocal relationship with followers that elevates motivation and ethical standards for both the leader and followers (Díaz-Sáenz, 2011, p. 300), ultimately nurturing effective leaders within the team.

Previous studies have highlighted the importance of transformational leadership in enhancing employees' performance, especially frontline employees. Mittal and Dhar (2015, p. 897) observed that transformational leadership promotes employees' creative self-efficacy, enabling them to think independently at work. When employees trust their leader and feel empowered, they experience reduced anxiety and concerns about their leader's behavior, leading to the generation of new and efficient ideas (Afsar & Masood, 2017, p. 37). Hansan et al. (2015, p. 254) identified four key components of transformational leadership: inspirational motivation, idealized influence, intellectual stimulation, and individualized consideration. These components significantly impact employees' creative self-efficacy by addressing their needs, appreciating their ideas, and influencing their motivation, encouraging them to be more creative on their own.

The hypothesis formulated to predict the relationship between transformational leadership and creative self-efficacy is as follows:

H1: *Transformational leadership is positively related to creative self-efficacy.*

2. Self-related factor: Learning orientation

This paper selects learning orientation as the representative self-related factor for creative self-efficacy. Firstly, learning is acknowledged as a fundamental source of self-efficacy (Bandura, 1997), encompassing enactive learning (learning from practical experience) and vicarious learning (learning through observation and modelling) (Weiss, 1990). Secondly, learning orientation is recognized as a crucial catalyst for both creativity and innovation (Hirst et al, 2009), and it plays a central role in developing learning capacities within organizations (Alerasoul et al, 2021, p.3). Consequently, individual learning orientation serves as a

compelling representative for the self-related determinants of creative self-efficacy.

According to Azka et al (2011), learning orientation had the greater desire to help employees to enhance their knowledge and ability to learn new things which improved their creative self-efficacy and therefore improved their performance at work. Based on the models of learning orientation, Kong et al (2018, p.446) showed that employees could learn from their experience especially when they got the failures, they could use them as materials to improve. In the study of Khattak and Khan (2017, p.435) stated that learning orientation could help employees to build their skills by combining their current and new ideas together to adapt with different situations. Moreover, they also showed that those who had learning orientations were the people who had curiosity which were attracted by challenging tasks. For that reason, learning orientation has had the effect on employees' creative self-efficacy which helped to develop the hypothesis prediction is:

H2: *Learning orientation is positively related to creative self-efficacy.*

3. Job-related factor: Autonomy

In addition, autonomy is chosen as the representative for the job-related factor determinant of creative self-efficacy. There is an important reason that made me choose it. According to Hackman and Oldman (1980), this was one of five dimensions of job-characteristics that could influence employees' motivation at work. From the viewpoint of the job-characteristics dimension, we could see that autonomy played an important role in human basic needs at job situations. Furthermore, in the study of Morgeson et al. (2005, p. 400) stated that, autonomy was more likely a unique role in job-related factors because it was the characteristic that showed how well employees could control and had the responsibility in their job situation.

In Naotunna and Zhou's point of view (2018, p. 301), jobs with lots of autonomy could enhance creativity because it helped employees to accept the risks and alternative thinking in different job situations. For instance, frontline office employees need to have the job autonomy to deal with many situations in terms of customer service. Job autonomy made employees feel freedom and could be discretionary in their tasks which helped them to have more ideals and confidence to speak up their creativity (Brandmo, 2019, p. 4). In these studies, researchers focused more on employees in general. From those reasons, the paper could develop the prediction that job-related factors can affect creative self-efficacy.

H3: *Job autonomy is positively related to creative self-efficacy.*

4. The effect of creative self-efficacy as mediator on innovation activities

Individuals who have high creative self-efficacy can deal with the challenge easier to compare with others. They have more ideas and mobilise in their behaviour or actions to solve different situations. This is because they spend more time on creative thinking processes and effort to exchange them to become the solutions. According to Hu and Zhao (2016, p. 819), employees who had high creative self-efficacy would be more curious, risk takers and creative thinkers which motivated them to engage in innovative activities. In the previous study of Newman et al. (2018, p. 2), it stated creative self-efficacy could affect innovative activities for two reasons which were the engagement of creative ideas that employees are willing to

contribute to the innovation of organisation due to the freedom feeling and they would feel better equipped to deal with uncertain tasks or sudden challenges in the new developing which needed innovative activities at workplace. Moreover, in the previous study of Michael et al. (2011, p. 261), it suggested that high creative self-efficacy "successfully copes with failures and uncertainties when they are confident and implement innovative tasks". These studies researched individuals who had high creative self-efficacy effect on the innovative activities, however, they did not mention the particular department in them. From these discussions, the next hypothesis is constructed as:

H4: *Creative self-efficacy is positively related to innovative activities.*

5. Transformational leadership with innovative activities

Liv et al. (2016) stated that "leaders encourage the development of advanced skills, they build followers' intrinsic motivation to move beyond accepted practice, which has been consistently linked to individual innovation". Transformational leadership provides a driving force for employees to motivate them to be more creative and confident in their work which can help them exceed their basic requirements and contribute more to innovative performance. In the previous study, Afriyie et al. (2019, p. 7) stated that transformational leadership empowered their employees to make them more focus on the service, quality and profit return which resulted in the significant impact on innovative activities of individuals. For example, in the study Weng (2013) surveyed about 439 nurses from hospitals in Taiwan about how transformational leadership affected them on innovative behaviour which made their victims feel satisfied with service. Along with these reasons, transformational leadership could affect the innovative performance of frontline employees who usually deal with many unexpected situations. From that, the hypothesis of the relation between transformational leadership and innovative activities was developed for prediction.

H5: *Transformational leadership is positively related to innovative activities.*

6. Learning orientation with innovative activities

Learning orientation was expected as the development of innovative behaviour by creating the enhancing domain-relevant skills and creative-related skills in particular areas which became the fundamental background for generating something new (Atitumpong & Badir, 2018, p. 11). In the study of Chatchawan et al. (2017, p. 155) about the learning orientation affected innovative work behaviour of employees of Local Administrative Organisation in South Thailand suggested that learning orientation motivated people to learning new things in long period of long time which accepted them to share knowledge and experience to each other to develop innovative activities to enhance the competitive of an organisation. Mahmoud et al. (2016, p. 632) survey among senior manager of 28 banks in Ghana about the learning orientation effect on innovative activities and suggested that learning orientation was the process that employees collected and shared customers' needs information, market changes, and competitor actions to have the appropriated innovative activities to provide the new service or products superior to competitors. With the information above, the hypothesis about learning orientation with innovative activities has been developed.

H6: *Learning orientation is positively related with innovative activities.*

7. Job autonomy and innovative activities

Autonomy led to proactive behaviour and personal initiative which played the key role in the context of outbound openness that required more effort of employees which led to the result in encouraging the innovative activities (Burcharth, 2017, p. 1251). Lee et al. (2021) suggested that the increasing in job autonomy of employees could have a positive impact on innovative behaviour because it improved the internal motivation of employees which encouraged them to provide more ideals and created various problem solutions in their specific tasks. For instance, the previous study of Shakil et al. (2021) surveyed employees from 15 private healthcare institutions operating in Bangladesh about the direct role of job autonomy with innovative activities. Based on the basis above, the hypothesis of job autonomy of frontline employees with innovative activities has been developed.

H7: *Job autonomy is positively related with innovative activities.*

D. Research model

Figure 1 shows the conceptual model and provided the summary of the variables and the hypotheses which are guided for this paper of studying. As could be seen in the model, transformational leadership, learning orientation and autonomy represented three different determinants of creative self-efficacy. Moreover, this paper also showed the creative self-efficacy affects employees' innovative activities as the mediator role. Besides that, the determinants of creative self-efficacy have had the effect on innovative activities at the individual level of employees.

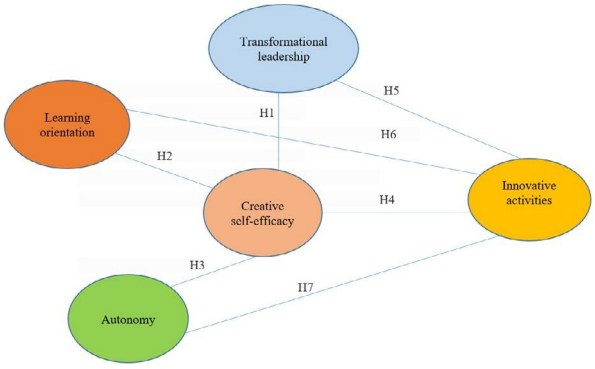

Figure 1. The reseach model

III. METHODOLOGY

A. Research process

Formal quantitative research is conducted to test hypotheses and traditional research models. The study used survey data from 207 participants to test the theoretical model with a convenient sampling method. The data analysis technique analyses a linear structural model based on partial least squares (PLS-SEM). PLS-SEM is advantageous when dealing with smaller sample sizes. This study involves a limited number of participants, so PLS-SEM is more robust and provides reliable results with fewer observations compared to CB-SEM, which typically requires larger sample sizes to achieve stable parameter estimates. Regarding the proposed research model and a reflective measurement model, PLS-SEM is more suitable than CB-SEM (Ledden et al., 2007).

The steps to perform structural equation model analysis include evaluating the measurement and structural models to test hypotheses and research models (Dinh et al., 2020). Finally, the research results will be discussed based on a comparison with previous studies to explain the results from practice, thereby giving some management implications based on the results achieved.

B. Sampling method

Convenience and snowball sampling methods were employed to assemble the study's sample, which comprised frontline employees across diverse organizations in Binh Duong, including hospitals, restaurants, banks, hotels, and financial companies. The snowball sampling method was chosen due to the rich diversity of organizations within the region, offering a fertile ground for potential research participants. In total, 24 questionnaires were successfully completed and deemed usable, representing a pool of participants from 15 distinct organizations. Each organization contributed a minimum of 9 participants who actively participated and completed the survey, resulting in a cumulative sample size of 207 participants. The results of descriptive statistics about the survey subjects are presented in Table 1.

Table 1. Descriptive data

	Frequency	Percentage
Gender	**207**	**100%**
Males	91	44%
Females	116	56%
Age	**207**	**100%**
18-23	108	52.2%
24-29	53	25.6%
30-35	21	10.1%
More than 35	25	12.1%
Working experience	**207**	**100%**
0-3 years	116	56%
4-7 years	51	24.6%
More than 7 years	40	19.3%
Monthly salary	**207**	**100%**
0-3 million	68	32.9%
4-7 million	37	17.9%
8-11 million	37	17.9%
More than 11 million	65	31.4%

(Source: Author's Data Analysis)

As presented in Table 1, there were 91 males and 116 females which were 44% and 56% respectively. The participants were mostly in the age of 18-23 which exceeded 52.2% of total. The number of participants who had 0-3 working experience were the majority, which exceeded 56%. In the salary aspect, the number of participants who had got a monthly salary around 0-3 million was highest which reached 32.9%.

IV. RESULTS

After finishing running in SPSS, with the complex model, the data continued to be analysed by the Smart PLS program. The measurement model is to test the relevance of the sample and the structural model is to test the relationships between variables to each other (Wong, 2013).

The first step was analysing Standardised root mean square residual (SMRM) to test the suitability of the model with the sample which the result of the samples smaller than 0.08 is the best result (Henseler, 2017). Table 2 showed that the SMRM of the model was 0.054 < 0.08 which meant the model was perfectly satisfied with the sample area.

Table 2. SMRM

	Saturated Model	Estimated Model
SRMR	0.054	0.054

(Source: Author's Data Analysis)

The next step was evaluating the factor loading that helped to identify how effectively the item represents the underlying construct. The outer loading larger 0.7 is accepted (Vinzi, Vincenzo, Henseler, & Wang, 2010). The outer loadings of all items were greater than 0.07 which meant the items were significant.

The AVE was used to evaluate the convergent validity of the measuring model, which was based on the average correlation between variables with the result that was greater than 0.50 was accepted (Fornell & Lacker, 1981). The results showed that all variables had AVEs greater than 0.50 with autonomy having the smallest AVE of 0.754, creative self-efficacy of 0.759, and innovative activities of 0.761. The model converged with satisfying results.

Table 3. AVE, CA AND CR

	AVE	CA	CR
AU	0.754	0.918	0.939
CSE	0.759	0.920	0.940
IB	0.761	0.921	0.941
LO	0.803	0.919	0.942
TL	0.804	0.939	0.953

(Source: Author's Data Analysis)

The study used Cronbach's Alpha (CA) and Composite Reliability (CR) to assess the reliability of variables in a survey. CA values ranged from 0.70-0.95 (Tavakol & Dennick, 2011), while CR values greater than 0.70 were considered satisfactory (Netemeyer et al., 2003). The study found that all variables were reliable, with CA values exceeding 0.9 and CR values exceeding 0.90. Transformational leadership (TL) had the highest CA value at 0.393, followed by innovative activities (IB), creative self-efficacy (CSE), learning orientation (LO), and autonomy (AU). The highest CR value was achieved in transformational leadership (TL) which was 0.953.

Henseler (2015) developed the heterotrait-monotrait ratio of correlations (HTMT) to test factor correlations, requiring a significant difference between factors for discrimination which meant that the HTMT needed to be less than one, as all discrimination values were accepted.

Table 4. THE HTMT

	AU	CSE	IB	LO	TL
AU					
CSE	0.535				
IB	0.730	0.814			
LO	0.531	0.445	0.637		
TL	0.488	0.556	0.672	0.472	

(Source: Author's Data Analysis)

The regression analysis tests the relationship between variables using the Coefficient of Determination (R2) in the complex model. The results showed that creative self-efficacy (CSE) was influenced by transformational leadership, learning orientation, and autonomy, while innovative activities (IB) were influenced by transformational relationships, learning orientation, autonomy, and creative self-efficacy.

Table 5. Coefficient of determination

	Adjusted R^2
CSE	0.356
IB	0.739

(Source: Author's Data Analysis)

The path coefficient is crucial in regression coefficient analysis. The analysis results of Smart PLS software indicate significant relationships between variables, with p-values less than 0.05, <0.05, or t-values larger than 1.96 (Purwanto et al., 2021). Table 6 shows all variables had a significant positive relationship, with p-values less than 0.05 and t-values larger than 1.96.

Table 6. Path coefficient

Relations	T-value	P-value	Findings
TL → CSE	5,112	0,000	Significant
LO → CSE	2.150	0.032	Significant
AU → CSE	4.150	0.000	Significant
CSE → IB	9.359	0.000	Significant
TL → IB	6.317	0.000	Significant
LO → IB	4.358	0.000	Significant
AU → IB	6.790	0.000	Significant
TL → CSE → IB	4,707	0,000	Significant
LO → CSE → IB	2,042	0,041	Significant
AU → CSE → IB	3,604	0,000	Significant

(Source: Author's Data Analysis)

Effect size (f^2) is a useful tool for understanding significant effects which have a value greater than 0.15, 0.02 or 0.35 considered as weak, moderate and strong (Cohen, 1988). The data shows that transformational leadership and autonomy have weak to moderate effects on creative self-efficacy. Learning orientation has a small effect on creative self-efficacy, while innovation activities have weak to moderate effects. Creative self-efficacy has a strong effect on innovative activities, with a result larger than 0.35 as in the table below.

Table 7. Effect sizes

	CSE	IB
TL	0.130	0.093
LO	0.019	0.094
AU	0.083	0.192
CSE		0.467

(Source: Author's Data Analysis)

Although the effect sizes between the variables were not strong, they still have the effect which could conclude that the model was significant.

V. FINDING AND DISCUSSION

A. Research finding

The study found a significant positive relationship between transformational leadership (TL), learning orientation (LO), autonomy (AU), and creative self-efficacy (CSE). The relationship between TL and CSE was p-value 0.000 < 0.05, while the relationship between LO and CSE was 0.032 < 0.05. The Significant relationship between AU and CSE (p-value 0.000 < 0.05). These results supported the hypotheses H1-H3 that were discussed in the previous part of the paper. The study found that creative self-efficacy mediated the relationship between transformational leadership, leaning orientation, and autonomy with innovative activities. Path coefficients were smaller than 0.05, with a p-value of 0.000 < 0.05. The indirect effects showed a positive relationship between creative self-efficacy and innovative activities which supported the hypothesis H4.

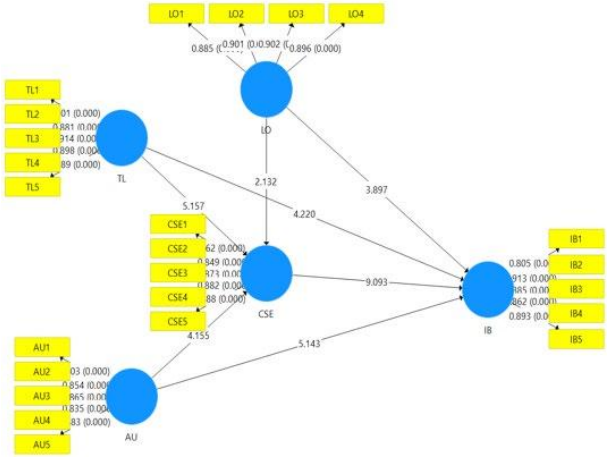

Figure 2. Research findings

Figure 2 shows relationships between transformational leadership, learning orientation, and autonomy in innovative activities, with p-values below 0.05 (hypothesis

H5-H7). The study found a significant relationship between transformational leadership, learning orientation, and autonomy with innovative activities, supporting hypothesis H5-H7. Transformational leadership positively influenced learning orientation, while autonomy significantly influenced autonomy.

B. Discussions

Creativity is crucial in various aspects, such as economic revitalization and market opening. This paper examines individual aspects and determinants affecting creativity in employees. De Stobbelier et al. (2011) suggested that work performance can be influenced by employees' unique traits and characteristics. However, less research has examined creativity from the perspective of front-line office employees who interact directly with customers and require creative self-efficacy to handle customer problems. The study aims to evaluate creative self-efficacy in various industries and explore innovative activities.

This study examined creative self-efficacy as the specific area construct. In the past, Tierney and Farmer (2002) defined the creative self-efficacy as the recognisable belief in individuals' ability to produce the outcomes. The current study aim is to analyse the creative self-efficacy of one person in actual work roles in organisations from various determinants. There were three determinants that were used to become the related promotion of creative self-efficacy which were leader-related, self-related and job-related.

In addition, this paper identified transformational leadership as the most significant factor in enhancing creative self-efficacy. It combined individualised consideration, idealised influence, and stimulation motivation (Jaiswal & Dhar, 2015). Leaders who could influence employees encourage them to create more ideas, leading to increased promotion and engagement (Prochazka et al., 2017). This study concludes that transformational leadership is the most critical factor for enhancing creative self-efficacy.

Learning orientation is a self-related determinant of creative self-efficacy, allowing individuals to develop knowledge, skills, and share information about customer needs individual's ability to develop the knowledge, skills and share information about customer's needs (Atitumpong & Badir, 2018). This positive effect is attributed to the ability to learn independently, improve themselves, and increase creativity. Learning is essential for creativity according to Tran and partners (2018), as it allows employees to explore new perspectives and generate more ideas for tasks and customer problems. Overall, learning orientation is crucial for building creative self-efficacy.

Moreover, this study suggests that autonomy is a crucial factor for creative self-efficacy, as it increases employees' confidence, satisfaction, and creativity. Autonomy helps employees feel more confident, less emotional, and more relaxed (Gagne & Bhave, 2010), leading to more creative ideas and increased productivity. This study supports previous research that autonomy is a key factor in developing creative self-efficacy in employees (Naotuna & Zhou, 2018).

This paper found that creative self-efficacy significantly impacts innovative activities, as it influences employees' thoughts and actions to solve problems. High creative self-efficacy increases employees' confidence, motivation,

and attention to create new ideas and identify problems for successful innovation (Javed, Fatima, Khan & Bashir 2020). The paper also highlights the mediators of creative self-efficacy between three determinants and innovative activities, emphasising the critical role of creative self-efficacy in achieving innovative goals.

The paper examined the relationship between creativity and innovative activities, finding that transformational leadership had the smallest effect. This is because transformational leadership influences employee behaviour and performance through characteristics and actions. However, it is essential for encouraging motivation, vision, and questioning (Weng et al., 2013), which in turn increases innovative activities.

Learning orientation positively impacts innovative activities, with the second most significant effect. Employees who learn new skills and take on challenges are more motivated and adaptable, enabling them to change their behaviour and adapt to uncertain situations (Atitumpong and Badir, 2018). This learning orientation is expected to enhance individuals' innovative activities in their work.

The study found that autonomy significantly impacts innovative activities, as it affects employees' cognitive ability to manage tasks, schedules, and create solutions (Orth & Volmer, 2017). High autonomy allows employees to perform differently in different situations, making it essential for individual-level creativity and innovation.

VI. CONCLUSION

This paper examines the influence of leader-related, job-related, and self-related determinants of creative self-efficacy on innovative activities, focusing on transformational, learning orientation, and autonomy factors. It also examines mediators of creative self-efficacy. Tierney and Farmer (2002) found a relationship between creative self-efficacy determinants and innovative activities. Previous studies focused on organisational levels, but their scope was limited. This paper examined the relationship between these factors using a structural equation model and frontline employees across different industries. The study also found that transformational leadership, job-related factors (autonomy), and self-related factors (learning orientation) were the most influential factors on creative self-efficacy. Creative self-efficacy also influenced innovative activities, with job-related factors being the most influential. The relationships were significant, supporting the hypotheses.

This paper examines factors enhancing innovative activities among employees by analysing creative self-efficacy determinants. Managers play a crucial role in influencing employees through sharing experiences, knowledge, and empathy. Building an open culture and working environment improves learning orientation, especially in service departments. Job autonomy is crucial for dealing with unexpected situations. Leaders and learning orientation support employees in their innovation behaviour, as they guide them and provide knowledge from past and future experiences. Creative self-efficacy may become a key factor for personal attribution in the workplace, where innovation is crucial for organisations' competitive advantages.

This study examined three factors determining creative self-efficacy in innovative activities. Leader-related styles influence employees' ideas and behaviour,

while job-related variables impact creativity and behaviour. Self-related styles also affect creativity and innovative activities. Future research should focus more on variables of leader-related factors, job-related factors, and self-related factors.

This paper sampled medium-large organisations in Binh Duong, specifically in Thu Dau Mot City, including hospitality, healthcare, and finance companies where had frontline employees who work directly with customers. Future research could explore other industries and employees' creative ideas and innovative behaviour.

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EASTERN INTERNATIONAL UNIVERSITY
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EXPLORING COLLABORATIVE FACTORS FOR SUPPLY CHAIN RESILIENCE: A STUDY OF THE MANUFACTURING INDUSTRY IN BINH DUONG

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Abstract: This study examines the relationship between collaboration (connectivity, coordination, integration, information sharing, visibility) and resilience of supply chain. These relationships are examined using sample of 163 respondents who work in manufacturing firms in Binh Duong which was obtained through online survey and then using SPSS for hypothesis testing. The research findings indicated that all five attributes of collaboration including connectivity, coordination, integration, information sharing and visibility which have positive impact on supply chain resilience for manufacturing industry. Concurrently, connectivity is the most significant determinant influencing of collaboration factors on supply chain resilience. Additionally, this paper also provides further findings and recommendations which will not only contribute to the literature on supply chain research but also assist manufacturing firms in Binh Duong becoming more developed and improving their supply chain strategies especially in uncertain events.

Keywords: *Supply chain resilience, components of collaboration, manufacturing industry, supply chain uncertainty, connectivity, coordination, integration, information sharing, visibility, theory of Resource Based View*

I. INTRODUCTION

Manufacturing industry plays a crucial contribution to job opportunities, economic growth and advanced technology which fosters innovation and boosts productivity, leading to increased competitiveness and better living standards (Rocha, 2018). Therefore, promoting and supporting the expansion of manufacturing industry is prioritized for achieving sustainable economic development.

However, disruptions in supply chain have affected on the performance of manufacturing companies in recent years. For instance, Ericsson faced significant consequences when a fire erupted at a Phillips semiconductor plant in 2000, resulting in production disruptions and eventually lead to $400 million loss (Pu et al., 2023). Another example is the catastrophic Thailand flooding in October 2011 which had widespread effects on computer manufacturers relying on hard discs and also disrupted the supply chains of Japanese automotive companies with plants in Thailand (Wieland & Wallenburg, 2013).

Binh Duong is known as one of the economic regions of Southern Vietnam (Nguyen, 2022). Hence, Binh Duong becomes

a potential place to develop in every perspective of economic, especially in manufacturing firms. According to Dinh (2022), the manufacturing sector increased by 8.4% in 2022 compared to the previous year. However, a lot of uncertain events from geopolitical or economic events can lead to the disruption due to sudden preparation and planning in manufacturing firms (Madhavika et al., 2022). More specifically, the shortage of raw materials due to the Zero-Covid policy in China had a significant effect on the garment industry of Vietnam. Hence, this shortage has led to a decline in production and has affected the ability of garment manufacturers to fulfill orders. Additionally, the decrease in demand from the US and European markets has led to order cancellations, further exacerbating the impact on the industry (Binh Dao et al., 2020). In addition, more than 118,000 workers lost their jobs, with a concentration in Binh Duong and Ho Chi Minh City in the third quarter of 2023, which causes supply chain disruption (An, 2023). Hence, it creates bundle of challenging for supply chain management such as cost control, demand forecasting and customer service. Moreover, there are few general researches conducted in Vietnam in general and Binh Duong in particular. Consequently, the purpose of this paper is to identify and access the level of collaboration factor on supply chain resilience of manufacturing industry in context of Binh Duong province, Vietnam.

Additionally, term of supply chain resilience is observed to have significant effect on the success for the performance of company (Abeysekara et al., 2019). That's why it has become a prominent research topic, attracting considerable interest from scholars (Madhavika et al., 2022). The notion of this concept is that adopting a resilient approach which enhances the likelihood of successful recovery from setbacks. In addition, previous studies identified collaboration, flexibility, redundancy, visibility and velocity are critical capabilities of supply chain resilience (Jüttner & Maklan, 2011). However, collaboration is one of the most essential requirements for supply chain resilience (Scholten & Schilder, 2015). According to Pettit et al. (2013), collaboration is the ability to work effectively together in various cases like forecasting and risk sharing, which not only increases firm's performance but also resilience of supply chain. As mentioned above in the paper, collaboration is regarded as the most efficient approach for enhancing organizational performance in the face of uncertain events (Seo et al., 2016). However, there is limited researches in developing countries on manufacturing firms of supply chain resilience in developing countries context especially in the uncertainty (Kumar & Anbanandam, 2020). Therefore, the aim of this research is to identify and access factors of collaboration affect supply chain resilience of manufacturing industry in Binh Duong-Vietnam especially in uncertain events such as the geopolitical between Russia and Ukraine. The contribution of this study is twofold: first, it helps organizations develop actionable theory of SCR by enhancing the subcomponents of collaboration when formulating supply chain strategies; second, the paper provides opportunities for further research and improvement.

II. LITERATURE REVIEW

A. Review of previous studies

According to Scholten & Schilder (2015), their research investigated the collaborative activities of information

sharing and collaborative communication, joint relationship efforts that affect supply chain resilience of manufacturing sector in Netherlands. The study conducted the sample size of 2 companies in fast moving consumer goods with their 8 suppliers in supply chain resilience. In which, it demonstrated that the influence of four collaborative activities namely information sharing, collaborative communication, mutually created knowledge and joint relationship efforts is important and positive with supply chain resilience.

Additionally, the research of Umar & Wilson (2021) also demonstrated the impact of supply chain collaboration components on performance of manufacturing industry, specifically the commercial food. This study collected data from four commercial food supply chains within two food types (staple food- rice and fresh produce) in two which are Punjab and KPK. This research showed the influence of collaboration factors with the resilience of supply chains of natural disasters in rural areas. In which, this study provided evidence about the impact of supply chain collaboration components including: effective communication, mutual dependence, information sharing, informal financial support, and trust which enhance the overall resilience of supply chains in natural disasters.

Furthermore, Madhavika et al. (2022) conducted the research about the impact of supply chain collaboration components on performance of tea manufacturing industry. This research collected data from 163 manufacturing firms in Sri Lanka and also showed how these elements of collaboration influence the resilience of supply chains that experience during Covid-19. In which, this study provided evidence about the impact of supply chain collaboration components including: connectivity, coordination, integration, information sharing and visibility which enhance the resilience of tea supply chains during the Covid-19 pandemic. This paper adopts model from Madhavika et al. (2022) due to the similar context of manufacturing industry and the uncertain events such as Covid-19, hence this model can apply to demonstrate the effect of factors of collaboration on supply chain resilience in the uncertainty.

B. Key concepts

a. Supply chain resilience (SCR)

The term "SCR" refers to the adaptive capability of the supply chain to prepare for uncertain events, respond to disruptions, and recover from them by maintaining operations at the desired level of control and connectedness over the structure and functions (Ponomarov & Holcomb, 2009). Otherwise, supply chain resilience is defined as mitigate the effect of disruptions by proactively identifying strategies that allow the supply chain to respond and recover to its original or even better operational state (Jüttner & Maklan, 2011). Fiksel (2015) emphasized that the concept of SCR is crucial to the success of risk management in many companies, as it contributes in supply chain firms which enables the effective operation of interconnected supply chain components which help gain the competitive advantage in the market (Madhavika et al., 2022). Therefore, SCR requires organizations to look to the whole supply network's capabilities to survive, adapt and grow when confronted uncertain events (Knemeyer et al., 2009).

b. Resilience capabilities

Capabilities of supply chain resilience are defined as the capacity to absorb risk and respond to interruptions effectively (Azadeh et

al., 2014). Jüttner & Maklan (2011) emphasized that the concept of SCR capabilities play important roles to the success of SCR. For instance, considering a scenario where an enterprise has a flexible supply base including multiple suppliers. In this context, if one supplier encounters the disruption, the organization can guarantee to access the alternative sources from other suppliers and maintain the continuity of process (Colicchia et al., 2010).

The previous studies identified redundancy, flexibility visibility, and collaboration as critical resilience capabilities (Jüttner & Maklan, 2011). Another research indicated the factors of resilience capabilities are visibility, velocity, redundancy and flexibility (Azadeh et al., 2014). In which, these factors play important role in enabling the supply chain to address disruptions and ensure the operations continue without interruption (Madhavika et al., 2022). Among all factors, the most formative element of SCR is collaboration due to enhance the responsiveness and reduce the effects of disruption (Singh & Power, 2009).

c. Collaboration of supply chain

Collaboration is the concept that mentions the inter-firm relationship that ranges from simple relations to high level alliancing through the behaviours of information sharing, goal planning, problem solving, risk and reward sharing (Umar & Wilson, 2021). Daugherty, Richey, and Roath (2006) discovered that companies which participate in collaborative partnerships enhanced various performance's aspects including flexibility, customer satisfaction, and reduced cycle times.

Having collaborations within the supply chain will implement in fostering SCR within firms (Madhavika et al., 2022). Consequently, numerous empirical studies have supported the notion that collaboration enhances firm performance during uncertain events. For instance, Scholten and Schilder (2015) conducted a study in the Netherlands, while Umar and Wilson (2021) focused on food manufacturing firms in rural areas during natural disasters in Punjab and KPK. Within collaboration, Singh and Power (2009) highlighted that key collaborative activities encompass information sharing, collaborative communication, jointly created knowledge, and efforts to build strong relationships. Furthermore, Umar and Wilson's research (2021) indicated that effective communication, mutual dependence, information sharing, informal financial support, and trust are components of collaboration that improve overall resilience of supply chain. In addition, Madhavika et al. (2022) identified five critical collaboration factors affecting SCR including: information sharing, connectivity, coordination, integration, and visibility which have positive and significant impact on the performance of the manufacturing industry, particularly during uncertain events.

C. Review of theoretical background of Resourced-Based View (RBV)

The Resource-Based View (RBV) theory is a prominent strategic management framework that has been applied to various fields. It attempts to assert an organization can achieve competitive advantage by creating bundles of strategic resources and/or capabilities (Madhani, 2010). In addition, RBV identifies that a firm can generate competitive advantage by using the resources or capabilities have the attributes of being valuable, rare, inimitable, and non-substitutable. Resources have been

classified into physical capital, human capital and organizational capital (Barney, 1991) and have been extended to include technological capital, financial capital, and reputational capital (Grant, 1991).

Bundling refers to the integration of resources and capabilities to facilitate capability development which organizations enable to achieve and sustain competitive advantage by exploit opportunities and/or mitigate threats (Brandon-Jones et al., 2014). Additionally, competitive advantage created by capabilities tends to be embedded within the organization's management and processes which more likely to be sustainable than competitive advantage created purely by resources (Brush & Artz, 1999).

In the context of SCR, the RBV theory claims that a firm's ability to effectively respond and recover from disruptions is largely influenced by the unique resources and the capabilities it has developed (Parker & Ameen, 2018). These resources and capabilities can be tangible or intangible which include physical assets, technological infrastructure, organizational culture, knowledge, skills, and relationships (Marr et al., 2004). RBV suggests that firms with a strong resource are better positioned to enhance their SCR. This is because these firms can leverage their unique resources to develop specialized strategies, processes, and mechanisms that help them effectively navigate disruptions and recover quickly (Brandon-Jones et al., 2014). According to Bates & Flynn (1995), a manufacturing firm with advanced technological capabilities might be able to quickly reconfigure production processes in response to supply chain disruptions, allowing for rapid adaptation to changing circumstances. Furthermore, RBV emphasizes the importance of resource heterogeneity and immobility (Madhani, 2010). In the SCR context, this implies that firms with distinctive and non-substitutable resources are more likely to gain a competitive advantage in terms of resilience. In which, firms can create barriers from imitating by competitors which makes it difficult for others to mimic their resilience strategies (Brandon- Jones et al., 2014). The RBV also emphasizes the role of dynamic capabilities – the firm's ability to integrate, reconfigure, and adapt its resources and capabilities in response to changing environments (Cavusgil et al., 2007). In particular, in the context of SCR, the disruptions are often unpredictable and require organizations to adapt quickly new challenges. Hence, firms with strong dynamic capabilities can proactively identify potential disruptions, and implement effective recovery strategies (Lin & Wu, 2014). Therefore, the RBV theory provides a valuable management framework to examine SCR (Dubey et al., 2019). It emphasizes the importance of a firm's unique resources, capabilities, and dynamic capacities in enhancing its ability to respond to disruptions, recover effectively, and maintain a competitive advantage in the uncertain events.

D. Hypothesis development

Information sharing (IS)

According to Cao & Zhang (2011), information sharing (IS) in supply chain context refers to which essential information is available for member in supply chain. Otherwise, information sharing can be defined as the exchanging information with other parties including tactical or strategic information by response to a request. Additionally, information sharing can also include "business secrets to success/competitive edge" and even specific tips of industry on effectively handling resilience (Madhavika et al., 2022). The shared data impacts the perception of other parties,

fostering a collaborative working environment and improved understanding between the involved parties (Sonnenwald, 2006). Therefore, the performance of organizations can be enhanced (Madhavika et al., 2022).

The findings from numerous researches have demonstrated the performance of SCR through various results. For instance, IS affected positively on performance through enhancing tracing and tracking, capacity utilization and lower inventory and costs (Lotfi et al., 2013). Additionally, the findings of authors Huo et al. (2014) showed that IS has the positive relationship with SCR by collecting the large data from 617 Chinese manufacturing firms. Furthermore, the study conducted by Heejung Chung, Hyojin Seo, and Sarah Forbes (2004) investigated the impact of IS with operational management of supply chain in disasters, which has a positive effect on supply chain resilience. Therefore, following relevant previous researches, hypothesis H1 has been demonstrated:

H1: *Information sharing has a positive impact on supply chain resilience.*

Connectivity (CN)

Connectivity (CN) refers to the ability for collecting data, exchanging information and communicating by using technologies (Allred et al., 2011). According to Fawcett & Magnan (2002), CN in the supply chain contributes to problem-solving and coordination. In the context of making consistent decisions, it is important to understand that identifying the capabilities and flaws in supply chain is difficult due to turbulence, targeted attacks, external factors, and infrastructure limitations. Therefore, it becomes essential for managers to be linked across organizational boundaries and have access to relevant information in order to have effective preparations and decisions (Fawcett & Magnan, 2002). Furthermore, CN also plays an important role in supply chain activities. This is because when organization adapt the CN in supply chain, it supports the network of supply chain and organizations in authorizing interchange information (Lotfi et al., 2013). Consequently, CN has evolved into an essential component affecting the SCR of many businesses.

According to Kumar & Anbanandam (2020), connectivity has beneficial impact on SCR in term of adopting information and communications technologies for quick response and recovery from supply chain disruptions in the India manufacturing industry. Another finding from Madhavika et al. (2022) also concluded the positive relationship between CN and SCR in the manufacturing sector in Sri Lanka. Additionally, the research of Prajogo & Olhager (2012) found that CN has a significant effect on SCR by using data from 232 manufacturing firms in Australia. Furthermore, according to Aigbogun et al. (2014), CN was illustrated an important element toward the performance of resilience of manufacturing in the pharmaceutical sector in Malaysia. Based on above discussion, H2 hypothesis has been developed.

H2: *Connectivity has a positive impact on supply chain resilience*

Coordination (CD)

Coordination (CD) is defined as a process of arranging the tasks into multiple groups to collaborate effectively and ensure the understanding about each other's actions (Arshinder et al., 2008). According to Dyer & Singh (1998) asserted that the establishment of

effective CD both internally and externally is vital for gaining a competitive advantage and increasing revenue. It also helps organizations prevent firm's supply chain interruptions (Jüttner & Maklan, 2011). In addition, based on CD, the level of SCR increases because working together will speed up the dissemination of information in the event of an interruption (Madhavika et al., 2022). In the context of supply chain companies, improving CD inside and across the partners of the supply chain helps address and prepare the solutions for the uncertainty (Arshinder et al., 2011). Therefore, CD has become a crucial element of collaboration in increasing the SCR.

Several researches have illustrated that CD has the positive and significant results in term of performance of SCR. According to Siagian et al. (2022), the adoption of CD among 446 manufacturing companies in Indonesia has a positive effect on the SCR during the uncertainty from Covid-19 as the result of internal coordination and external coordination. In addition, the findings of authors Xu et al. (2022), showed that CD had a significant and beneficial effect on the SCR of manufacturing industry during uncertain economic through using the data collected from manufacturing companies of 30 provinces in China from 2010-2020. Therefore, the hypothesis H3 has been proposed.

H3: *Coordination has a positive impact on supply chain resilience*

Integration (IN)

Integration (IN) is defined as a process of combining efforts to integrate supplier and customer information and inputs into internal planning (Wieland & Wallenburg, 2013). Otherwise, IN is recognized as the process by which a segment of the most comprehensive system becomes more interlinked, enabling one component to perform tasks previously carried out by another component, and vice versa (Madhavika et al., 2022). According to Wieland & Wallenburg (2013), IN plays an important role in supply chain wide systems in order to detect the disruptions and joint problem solving. Additionally, IN could enhance the operating capacity of organizations by enhancing service quality, knowledge flow, and the flow of cash between internal and procedural procedures of cross organization management (Zhao et al., 2013). Furthermore, according to Fawcett & Magnan (2002), IN also brings diverse advantages for the organizations such as reduced cost, increased product quality and better customer service. Through IN, an organization can manage to implement SCR.

The findings about IN with SCR have been demonstrated from numerous researches. More specifically, IN has a positive impact on performance of factory on SCR through collecting data from 339 supply chain professionals, supply chain managers and operations managers (Mandal et al., 2017). Additionally, the research of Prajogo & Olhager (2012) showed that IN had a positive effect on the SCR performance of 232 Australia firms through integrations of both information and material flows in supply chain. Moreover, Knemeyer et al. (2009) also illustrated the positive relationship between IN and SCR through managing manufacturing firms for catastrophic risk event. In addition, Zhao et al. (2013) investigated the effect of IN on supply chain resilience's performance by using data collecting from 317 manufacturing plants in 10 countries. Hence, hypothesis H4 has been proposed.

H4: *Integration has a positive impact on supply chain resilience.*

Visibility (VS)

According to Wei & Wang (2010), visibility (VS) is the extent to which the supply chain has to assess supply chain's managerial and organizational information. The VS plays an important role in establishing collaboration within resilience of supply chain (Barratt & Oke, 2007). In addition, Makris et al. (2011) emphasized the necessity of supply chain visibility to adapt the changes which enable the acquisition of valuable information related to product movement. Barratt & Oliveira (2001) indicated that focusing on five key factors of VS including receptiveness, planning, shared goals, trust, and forecasting will help supply chain firm address numerous challenges within a supply chain and improve streamlined operation. As a result, managers can be well informed of the changes proactively, which is a requirement for response the uncertain events when having the embedded from supply chain visibility (Wieland & Wallenburg, 2013). Therefore, VS can improve the performance of SCR for companies during the uncertainty.

The findings from various researches have illustrated that VS has a positive impact on SCR. According to Kumar & Anbanandam (2020), the visibility of India manufacturing has a positive impact on the performance of SCR for manufacturing firm through embracing information and communications technologies and VS tools for quick response and recovery from supply chain disruption. In addition, the findings of author Ivanov (2021) showed that the VS had a beneficial effect on SCR performance of manufacturing industry in Germany during Covid-19. Therefore, following relevant discussions above, hypothesis H5 has been proposed:

H5: *Visibility has a positive impact on supply chain resilience.*

Based on the five hypotheses that have been developed above, a conceptual framework in this study is proposed to demonstrate the independent and dependent variables as follows:

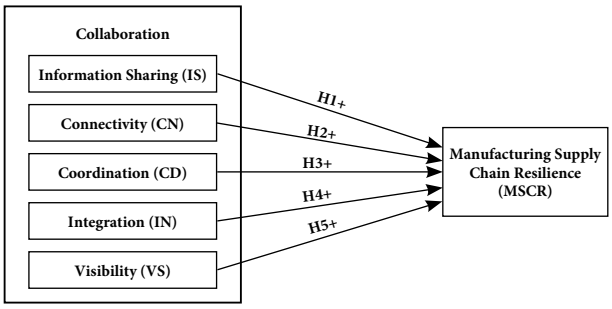

Figure 1. Research model adapted from Madhavika et al. (2022)

III. RESULTS

A. Sampling method

The non-probability sampling technique which is also called the convenience sampling method is adapted to use in this paper. This method can help to access the broader representatives of manufacturing firms from questionnaire with efficient in time and cost (Zikmundet al., 2013). Additionally, a survey will include demographics profile such as gender, age, educational level and the number of employees. Moreover, this paper also collected data from members of manufacturing industry in Binh Duong which experienced uncertain events.

In accordance with Hair (2013), the minimum sample size needed to be estimated for 1 observation variable requires 5 samples with the standard 5:1. In order to ensure the results will be meaningful, the sample size should be used in factor analysis from at least 4 to 5 sample size. Additionally, the number of observations should be at least 4 to 5 the number of variables of Exploratory Factor Analysis

(EFA). Consequently, the sample size for this study is determined by using the formula:

$$n=m*5$$

With:

n: the sample size

m: the number of questions

Adapting the formula above, the minimum sample size is required for this study should be:

$$28*5=140$$

According to the calculation, this study requires minimum sample size of 140 respondents. Nevertheless, the research was conducted a sample size 163 respondents to enhance the study's reliability.

B. Methodology

The six main stages of data collecting are as follows:

Step 1: A survey about SCR of the manufacturing firms in the province of Binh Duong will be conducted using the origin questionnaire. Additionally, the survey will be translated into both English and Vietnamese, with the translation being assured to have the same meaning as the original.

Step 2: Next, the surveys in Vietnamese and English will be imported into a Google Form.

Step 3: Prior to distributing the content to respondents, a pilot study with 10 participants (a convenience sample) will be conducted to ensure that the content is simple and easy to understand by people who work in supply chain firm in Binh Duong Province.

Step 4: The surveys will be delivered to the intended respondents in 163 soft copies.

Step 5: To examine the data, it was then transferred from Excel to the Statistical Package for the Social Sciences (SPSS) program.

- Descriptive data
- Cronbach's alpha reliability analysis
- Exploratory factor analysis
- Correlation test
- Multiple regression analysis

Based on the sample data collected from manufacturing firms in Binh Duong, this paper ensures the large representatives for manufacturing firms due to using convenience sampling method which helps every member of the population has an equal chance of being included in the sample and mitigate bias.

C. Research findings

1. Research findings

There are five demographic dimensions which are gender, age, educational level, work experience and size of company were included in the survey to capture the profile data of the participants. The frequency of response for demographics and its percentage are shown in the table below:

Table 1. Respondent's profile

Items	Frequency (n=163)	Percent
Gender		
Female	102	62.6
Male	61	37.4
Age		
Under 30	18	11.0
30-under 40	69	42.3
40-under 50	62	38.0
50-under 60	11	6.7
Over 60	3	1.8
Educational level		
Undergraduate	5	3.1
Graduate	145	89.0
Postgraduate	13	8.0
Working experience		
Less than 5 years	16	9.8
5-10 years	23	14.1
10-15 years	71	43.6
15-20 years	49	30.1
More than 20 years	4	2.5
Company size		
Less than 50	11	6.7
50-100	24	14.7
101-200	67	41.1
201-500	52	31.9
More than 500	9	5.5

Table 2. Reliability test

Variable	Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Information Sharing	IS1	10.58	5.195	.593	.795	0.819
	IS2	10.67	4.853	.708	.741	
	IS3	10.69	5.081	.644	.771	
	IS4	10.61	5.140	.621	.782	
Connectivity	CN1	10.57	4.555	.552	.743	0.779
	CN2	10.66	4.756	.570	.732	
	CN3	10.80	4.582	.607	.713	
	CN4	10.72	4.608	.606	.714	
Coordination	CD1	10.82	4.892	.578	.732	0.781
	CD2	10.93	4.890	.570	.736	
	CD3	11.03	4.919	.576	.733	
	CD4	10.84	4.740	.619	.710	
Integration	IN1	10.82	4.419	.607	.716	0.780
	IN2	10.47	4.362	.571	.736	
	IN3	10.66	4.694	.546	.747	
	IN4	10.74	4.489	.620	.710	
Visibility	VS1	10.51	5.153	.597	.802	0.824
	VS2	10.68	5.169	.609	.795	
	VS3	10.54	5.250	.633	.784	
	VS4	10.62	4.793	.758	.726	
Manufacturing supply chain resilience	MSCR1	22.42	16.282	.530	.833	0.844
	MSCR2	22.36	15.243	.595	.824	
	MSCR3	22.39	15.868	.612	.822	
	MSCR4	22.44	15.717	.609	.822	
	MSCR5	22.37	15.802	.622	.820	
	MSCR6	22.40	14.761	.624	.820	
	MSCR7	22.47	15.621	.619	.820	

(Note: one attribute of MSCR 8 which belongs to manufacturing supply chain resilience variable is removed from model due to the Corrected ItemTotal Correlation is smaller than 0.3)

The Cronbach's alphas of independent and dependent variables are ranged from 0.779 to 0.844, indicating strong internal consistency. Connectivity (CN), Integration (IN), and Coordination (CD) have the acceptable Cronbach's alpha values which are 0.779; 0.780; 0.781 respectively. Cronbach's alphas of Information sharing (IS), Visibility (VS) and Manufacturing supply chain resilience (MSCR) are 0.819; 0.824; and 0.844 consequently. These indicate good Cronbach's alpha values. In addition, it can be seen that the Corrected Item-Total Correlation of 27 items of six variables ranging from 0.530 to 0.758, which is higher than 0.3, referring to be qualified and kept for Exploratory Factor Analysis (EFA).

Table 3. KMO and Bartlett's test

		Dependent variable	Independent variables
Kaiser-Meyer-Olkin Measure of SamplingAdequacy.		.881	.838
Bartlett's Test of Sphericity	Approx. Chi-Square	368.659	939.678
	df	21	153
	Sig.	.000	.000

Independent variables and dependent variables have high KMO test scores of 0.838 and 0.881, respectively and higher than 0.5. Furthermore, the significant values for Bartlett's Test of Sphericity for both independent variables and dependent variable are 0.000 which is less than 0.05 indicates that exploratory can be appropriate applied for the data set. These numbers reflect that the sample is appropriate for further analysis.

Table 4. Correlation

		MSCR	IS	CN	CD	IN	VS
MSCR	*Pearson Correlation*	1	.555**	.631**	.566**	.544**	.513**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	163	163	163	163	163	163
IS	*Pearson Correlation*	.555**	1	.397**	.329**	.344**	.387**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	163	163	163	163	163	163
CN	*Pearson Correlation*	.631**	.397**	1	.350**	.352**	.352**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	163	163	163	163	163	163
CD	*Pearson Correlation*	.566**	.329**	.350**	1	.311**	.302**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	163	163	163	163	163	163
IN	*Pearson Correlation*	.544**	.344**	.352**	.311**	1	.289**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	163	163	163	163	163	163
VS	*Pearson Correlation*	.513**	.387**	.352**	.302**	.289**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	163	163	163	163	163	163

***. Correlation is significant at the 0.01 level (2- tailed).*

According to Pearson correlation coefficients with significance levels of 0.000, which are lower than 0.05, all independent and dependent variables are proved to have linear correlations. In particular, the CN variable and dependent variables have the highest correlation value (r = 0.631) and the VS variable and dependent variables have the lowest correlation coefficient (r = 0.513), respectively. Although there is a correlation between independent variables, the correlation strength is insignificant. All independent variables meet the requirements for regression analysis based on the above-mentioned findings.

IV. REGRESSION ANALYSIS

Table 5. Model summary[b]

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.822[a]	0.676	0.665	0.37605	2.040
a Predictors: (Constant), IS, CN, CD, IN, VS					
b Dependent Variable: MSCR					

To assess the model's level of relevance, the R Square and the Adjusted R Square are provided in the Model Summary. With the adjusted R square value of 0.665 (66.5%), it is clear that all independent variables (including IS, CN, CD, IN, and VS) can account for 66.5% of the dependent variable (MSCR). As a result, the remaining 33.5% of Manufacturing Supply Chain Resilience to other factors that were left out of the study. In addition, the Durbin-Watson number is 2.040, which is within the permitted range (1.5 to 2.5), confirming that this statistical model does not contain autocorrelation.

Table 6. ANOVA[a]

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	46.283	5	9.257	65.459	.000[b]
	Residual	22.202	157	0.141		
	Total	68.485	162			
a Dependent Variable: MSCR						
b Predictors: (Constant), IS, CN, CD, IN, VS						

The F test result in the ANOVA table is 65.459, and the Sig value is 0.000, which is less than 0.05. It can be concluded that there is a linear regression model connecting manufacturing supply chain resilience and its five determining components as a result.

Table 7. Coefficient[a]

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-0.172	0.219		-0.784	0.434		
	IS	0.171	0.047	0.193	3.622	0.000	0.728	1.373
	CN	0.298	0.050	0.317	5.973	0.000	0.733	1.364
	CD	0.243	0.047	0.265	5.213	0.000	0.796	1.256
	IN	0.221	0.049	0.232	4.552	0.000	0.794	1.260
	VS	0.160	0.046	0.179	3.480	0.001	0.777	1.288
a Dependent Variable: MSCR								

The linear regression model's multicollinearity is examined using the collinearity statistic. When variance inflation factor (VIF) is high and tolerance values are low, multi-collinearity occurs. When the VIF values exceed two, there is a strong probability of multicollinearity (Hair, 2009). It is evident that all the VIF values are lower than two, as shown in the table coefficients. In details, the VIF values for IS, CN, CD, IN and VS are 1.373,1.364,1.256,1.260, and 1.288, respectively, proving that multicollinearity does not exist. As sig value of IS, CN, CD, IN and VS are lower than .005, these five variables have significant effects on dependent variable, in

which Connectivity (CN) shows the strongest effects with Standardized Coefficients at .317. Coordination (CN) is the second important determinant with Standardized Coefficient at .265. In addition, integration (IN) is the third important determinant with Standardized Coefficient at .232. With the Standardized Coefficient at .193; Information sharing (IS) is the fourth important determinant and finally, Visibility (VS) with Standardized Coefficient at .179. As a result, hypotheses 1; 2;3;4 and 5 are accepted.

The regression equation would be written as follows, using unstandardized coefficients

MSCR = -0.172 + 0.171 IS + 0.298CN + 0.243CD + 0.221IN + 0.160VS

Table 8. Hypothesis testing results

Hypotheses	Hypotheses result	Impact ranking
H1: *Information sharing positively influences SCR.*	Supported	4th
H2: *Connectivity positively influences SCR.*	Supported	1st
H3*: Coordination positively influences SCR.*	Supported	2nd
H4: *Integration positively influences SCR.*	Supported	3rd
H5: *Visibility positively influences SCR.*	Supported	5th

2. Discussion

The core of this study is to discover key elements of collaboration that affect SCR of manufacturing industry. Accordingly, not all collaboration attributes have significant effects on resilience of supply chain. In fact, these attributes have different impacts of manufacturing's SCR. More specifically, among five attributes which are connectivity, coordination, integration, information Sharing, and visibility have significant effects (with positive direction) on SCR of manufacturing firms in Binh Duong. It can be observed that connectivity is the most significant factor with the highest Standardized Coefficient of Beta (β = 0.317) and Significant value is 0.000 which is obviously acceptable.

The first discovery indicates that the most significant factor influencing SCR of manufacturing in Binh Duong - Connectivity. With the outcomes' Beta value is the highest (β = 0.317) and the Significant value is 0.000 (0.000 < 0.05). Actually, the previous research of Madhavika et al. (2022) conducted in Sri Lanka also resulted as Connectivity is the strongest factor affecting SCR with the Beta value at 0.358 and Sig. 0.001. Moreover, previous research of Asamoah et al. (2020) also resulted as Connectivity is the strongest factor affecting their SCR with the Beta value at 0.3017 and Sig. 0.000. In addition, many previous research demonstrated positive relationship between connectivity and SCR as well (Aigbogun et al., 2014 and Prajoco & Olhager, 2012).

The second finding is about the second significant factor which positively affects SCR of manufacturing industry- Coordination. The data result as its Standardized Coefficients Beta equal to 0.265 and the Significant value is 0.000 signifies. According to Madhavika et al. (2022), the coordination relates to the process of arranging activities in multiple groups in order to aware of each other's actions and work together successfully (Arshinder et al., 2011). Hence, coordination will help organizations to better understand the interruptions and seek solutions for the disruptions (Madhavika et al., 2022). As a result, coordination becomes one of the vital components of collaboration impacting SCR.

The third finding is about the next determinant which has a positive impact on SCR of manufacturing industry- Integration. In more details, Integration has the Standardized Coefficients Beta value is 0.232 and the Significant value is obviously acceptable (0.000 < 0.05) is clearly acceptable. Therefore, collection of internal and external relationships about natural mechanisms which enhance service quality, knowledge flow, and the flow of cash between internal and procedural procedures of cross organization management (Zhao et al., 2013). Hence, integration helps firms enhance operational and strategic performance during uncertain events (Mellat-Parast & Spillan, 2014).

The fourth finding is about the demonstration of information sharing which has a positive effect on supply chain resilience of manufacturing firms. To be more specific, the data result as its Standardized Coefficients Beta equal to 0.193 and the Significant value is 0.000 signifies. Lotfi et al. (2013) showed that information sharing is essential for business since it helps companies to reduce inventory, lower costs, and improve monitoring, which mitigates disruptions in organizations.

Visibility was indicated as the fifth finding and the least significant influence on the SCR of manufacturing industry with a positive Beta value of 0.179 and Sig. value of 0.001. According to Madhavika et al. (2022), the visibility in supply chain resilience requires the use of technology such as track and trace system, understanding information of pick-ups and deliveries which implied visibility of the supply chain in organizations especially during uncertain events. Additionally, visibility also helps business acquire the up-to-date market data which help organizations match the need of customers and achieve the customer satisfaction (Pettit et al., 2013). Due to the beneficial effect of visibility on SCR in the uncertainty, the factor of visibility needs to be improved.

The research framework after analysis is illustrated as below:

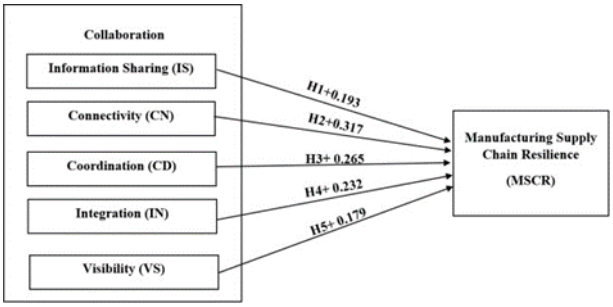

Figure 2. Research framework (after analysis)

V. CONCLUSION

This study aims to discover factors of collaboration affecting SCR of manufacturing industry in Binh Duong as well as to evaluate the level of significance between five sub-components of collaboration and supply chain resilience. The study was able to identify five key determinants, including information sharing, connectivity, coordination, integration and visibility which have a positive impact on supply chain resilience of manufacturing in Binh Duong province with the participation of 163 survey respondents and the support of SPSS with conducting statistical analysis. Especially, the study found that connectivity has the biggest impact on SCR. Manufacturing firms will adapt connectivity until they observed the favorable outcomes in term of organizational achievements, such as accuracy, timely information and cost-efficiency which leads to improvement and effective decision-making. Following the application of the Regression Model, the results indicate that among the five

elements of Information Sharing, Connectivity, Coordination, Integration and Visibility can explain changes in SCR. More specifically, the following five components of collaboration have the strongest relationships with SCR: Information Sharing (β =0.193), Connectivity (β =0.317), Coordination (β=0.265), Integration (β =0.232) and Visibility (β=0.179).

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FACTORS AFFECTING EWOM ENGAGEMENT: A STUDY OF PURCHASE INTENTIONS ON SOCIAL MEDIA PLATFORMS

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Abstract: Based on the combination of Theory of Planned Behavior and Elaboration Likelihood Model to evaluate the effect of eWOM communication in the social commerce context, which was known as the rapid growth industry of Vietnam in recent years. The purpose of this research is to examine the influence of product selection, information credibility, information quality, and attitude to eWOM engagement and purchase intention; then the results based on the questionnaire-based survey design that gathered data from 325 valid respondents revealed that eWOM engagement emerged as the mediated factor between the relationship between these factors and purchase intention which was applied CB-SEM method for analysis. The theoretical and practical implications could lead to the oriented strategy for the managers who utilized eWOM engagement as the effective communication channel to enhance their purchase intention in social networking sites such as Facebook and Zalo.

Keywords: *eWOM engagement, purchase intention, product selection, information quality, information credibility*

I. INTRODUCTION

According to De Vries and colleagues (2008), in recent studies on the effects of positive behaviors such as commenting and sharing information on social networking sites, research was conducted on how people consumers engage and interact on platforms like Facebook, TikTok and Instagram. This study is interested in users voluntarily sharing information, opinions and suggestions about their products and services on social networking sites. Intention of this action is to draw attention from their friends, relatives, cousins, even potential customers that are concerned with products and services which are familiar to them. In their perspective, it is possible to have a significant impact on factors' decisions because of featured information, essence of social relations in different social media channels. This implies characteristics and influence, which is driving distinct trends towards e- words of mouth (Kudeshia và Kumar, 2017).

Based upon the development of computer networks (so called the Internet) nowadays, a large number of devices supporting user's registration on social media channels becomes more common with lower costs compared to the stages in the past. This can be the motivation that can change customers' routine and behavior engagement, exchanging user's information nowadays. As a report of We are

social (2019), global users who are using the Internet, accounting for 57% and this number is recorded for the Vietnam market up to 66% and 94% of people using Cyberspace daily. The majority of this number is that they utilize more than 7 hours each day for Internet exploration. To have this consequence, throughout of the years, the Vietnam government conduct sustainable policies and economy development to boost economy's speed, reaching over than 7% in 2018, following by GDP in the stage from 2016 – 2018.

Vietnam has a GDP rate of 10% per year. Therefore, income and living conditions of residents have improved significantly, and this is deriving a large number of basic needs involving modern social media such as mobile phones, personal laptops... Nevertheless, it promotes the approach and the Internet utility of the Vietnamese over the years.

Although the majority of precedent research has played an important role in contribution to the brand using their own private fanpage on social media channels as an efficient instrument to convey quickly messages to consumers – that can be users following Facebook, Instagram, Tiktok. Then, most research concentrates on seeking the reasons why social media channels can be seen as a media tool (Kudeshia et al, 2016) and motivations promoting brands engaging their customers by posting creative content on social media (Luarn et al., 2015). According to Kudeshia and Kumar (2016), the majority of precedent research ignored a dramatic impact on eWOM, related to customer's behaviour on social media.

From that reason above, the process of topic "**Factors affecting eWOM engagement: a study of purchase intentions on social media platforms**" is likely to contribute the audit of influence related to important factors that affect the concept of eWOM on social media channels, by measuring influence from factors such as information quality, innovative and attitude towards eWOM. After that, the evaluation of direct WOM engagement at the point of new approach of Gvili and Levy (2018) for intention buying behavior in the context which is related to social media channels in Vietnam.

II. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

A. Theoretical background

Concept of Word-of-Mouth (WOM)

According to Grewal et al. (2003), WOM defines a series of actions involving the exchange of marketing information among buyers. The research of Rogers (1995) considers that WOM is a feature of oral communication between the communicator and the receiver. Meanwhile, the communicator expresses non-trade messages through WOM. In this business sector, East et al. (2008) say that consumers often use WOM to collect data about brands, products, services, and even the identity of a group when they have a need for this information.

In previous research, Smith et al. (2005) identified that WOM is one of the most important sources of information affecting consumer choice of products. In addition, Chu and Kim (2011) mention the strong impact of WOM as a reference source that directly affects consumers in terms of product innovation and launching new products. At the same time, based upon the view of users, information sources coming from individuals are often rated as more reliable than information sources coming from marketers and organizations,

so WOM is often more effective. It is more effective than mass media and other types of advertising in changing consumer behavior and attitudes (East et al, 2008; Chu and Kim, 2011). In addition, the study of Trusov et al. (2008) suggests that if the organization makes the most of the effectiveness of WOM for its products and services, the impact brought from the marketing method of this WOM will be more powerful; this can be able to replace other conventional communication tools in certain cases, and this is one of the intangible assets that has the potential to make a huge impact. organizational strength (Yusuf et al., 2018).

From the above concept, the author recognizes that WOM is a typical form of communication between the communicator and the recipient of information to serve the purpose of information exchange (non-commercial messages). Between these two objects, through WOM, information related to products and services is transmitted to the recipient or the brand's own customers. At the same time, these same sources of word-of-mouth information will greatly influence the choice and consumption decisions of customers for the brand's products and services.

Electronic Word-of-Mouth (eWOM)

According to Hennig-Thurau et al. (2004), online word-of-mouth (WOM), electronic word-of-mouth (eWOM) are defined according to whether positive or negative statements are made by potential customers, current customers, etc. Customers who are using a company product or service, and these statements are always available to share with different audiences or as a source of information through the Internet. More specifically, according to Chu and Kim (2011), online word-of-mouth is defined as the act of exchanging marketing information among consumers in the online environment through the Internet and online platforms. Online communication channels such as forums, e-commerce sites, social networking sites, and email marketing (Dwyer et al., 2007). By engaging in online word-of-mouth, customers of any brand can take advantage of social media tools to gather information about products, provide different perspectives on the products, and suggest the most suitable options for them (Yayli and Bayram, 2012).

From the standpoint of marketing management, according to Goldsmith and Horowitz (2006), online WOM is considered as an important marketing technique in brand communication. Thereby, the online influence of individuals on the Internet, or the online WOM itself plays a certain role in the development of e-commerce. Today, marketers are becoming more interested in leveraging the power of online WOM to build and grow brands through online consumer personalization features across platforms. In today's social media environment, online WOM provides marketers with opportunities to engage with customers, create and execute online communication strategies, and manage customer relationships. better (Chu and Kim, 2011; Dellarocas, 2003).

In addition, depending on the differences between the functions and communication methods of customers in the online environment, Kudeshia and Kumar (2017) and Hu and Ha (2015) classify online WOM into four different forms:

(1) Specialized (eWOM) – relates to customer reviews posted on product

comparison or review websites that are not directly involved in the sale of these products (Shopping.com, sosanhgia.com)

(2) Affiliate (Affiliate eWOM) - refers to customer reviews that are directly linked to retail e-commerce sites (Amazon, Tiki, Shopee, etc).

(3) Social (Social eWOM) – refers to any brand- or product-related information exchanged by users through social networking platforms (Facebook, Tiktok, Instagram).

(4) Miscellaneous (Miscellaneous eWOM) – includes brand or product information exchanged on other online social media platforms, such as blogs and discussion boards.

Above all that concepts, online WOM is the collection of opinions and evaluations of customers about the organization's products and services through the exchange of marketing information on the Internet, typically on social networking platforms such as Facebook, Instagram, and Tiktok. Then, users of these platforms can take advantage of these platforms to collect information related to the products and services they are interested in and intend to consume. Different reviews of products or services from previous customers will give them different perspectives on the brand's own products, which significantly influences their consumption decisions

eWOM engagement

Deriving from the concept of customer interaction, according to Bijmolt et al. (2010), this is the interaction behavior of customers with a certain product or brand, such as word of mouth, product reviews, informative articles on personal pages (blogs), helping other customers, and even the act of participating in and co-creating content for our own community of that brand (Hollebeek et al., 2014; Rossmann et al., 2016). In the context of online interaction, grasping the interaction tools among consumers, brands, organizations, and other members of the live community will bring growth potential for its brand as well as the organization (Brodie et al., 2013), such as the fact that a brand posts contents on social media platforms, which creates the opportunity for customer interactions such as liking content (likes), comments, shares, etc.

More specifically, in the context of research on online social networking platforms, research by Chu and Kim (2011) also mentions different levels of customer interaction when participating in social networking sites. In particular, according to Hashim and Ariffin (2016), they identified the lowest level of consumer interaction with a product or service of any brand by viewing or reading posts about this brand while doing research on social media platforms. In addition, when customers participate in product reviews, comments, and conversations related to products or brands, this is the average to moderate level of interaction for the brand. Additionally, the highest level of engagement occurs when consumers create their own content and share that information with other users, such as by uploading images related to that product or brand or recommending a website. Therefore, it can be said that online word of mouth interaction (eWOM engagement) is the willingness to request or share word of mouth information, their experiences with other customers in the group, or their community, thereby making customers more inclined to develop a greater purchase intention if they are willing to engage in eWOM engagement with their community (Yusuf and Busalim, 2018).

Thereby, it can be said that eWOM engagement refers to the interacting behaviors of customers with word-of-mouth information on the online platform that they have or are participating in, such as social networks. In particular, in the context of the social network channels, customers' online interactions with the word-of-mouth information they receive, such as likes, engagements through different emoticons, comments, sharing, or even exchanging the information they receive on their social groups within media channels including Facebook, Instagram, Tiktok, themselves, or through other online social media platforms.

The dimensions of eWOM engagement

Consumption per area and the annual power consumption per capita, as suggested by Li et al. (2017), as well as the total consumption of each electrical equipment in each building and the aggregate consumption

When focusing on customers' interaction behavior related to the organization's products and services on online social networking platforms, according to Muntinga et al. (2011), consumers' interaction behavior on social networking sites can be divided into two main categories: passive, when customers only receive information related to the brand, and proactive, when consumers begin to create and share information related to the brand. On that basis, the research of Chu and Kim (2011) has shown two key dimensions of eWOM engagement: the intention to send and the intention to receive, namely:

(1) Intention to send (ITS) refers to the behavior of customers in expressing and communicating opinions. These behaviors characterize customers actively creating and sharing brand-related information among other members (Calder et al., 2009). Customers who often have their own opinions tend to be knowledgeable. They have relatively complete information about aspects related to products and services, and they begin to discuss that information with others (Barnes and Pressey, 2012). At the same time, receptive customers also contribute to the flow of product-related information by forwarding this information to other members of their online community (Norman and Russell, 2006).

(2) Intention to receive online (ITR) relates to the behavior of customers who have the need to seek information and opinions about products and services. They tend to be more individual when interacting with the messages of the brand (Calder et al., 2009). These customers tend to passively receive information related to the brand or actively seek available information from customers who have used or experienced the product or service before in their community (Chu and Kim, 2011)

III. RESEARCH MODEL AND HYPOTHESIS DEVELOPMENT

Product selection

Compared to conventional businesses, customers shopping online can find a wider variety of goods that meet their needs in a more convenient way due to the sheer number of online sellers (Ghose, Smith, and Telang, 2006). When it comes to buying intentions, the location of offline businesses may occasionally be a deterrent, especially when the product variety is taken into account. The convenience of having a wide range of goods accessible through a single channel is therefore considered to be a factor in online shopping, especially when reaching them physically takes time (Forman,

Ghose, and Goldfarb, 2009). In addition, there is an interesting fact that the products having in stock of online shops are not limited, can raise its awareness by advertisements, which is preordered upon request (Alba et al., 1997)

This is a significant benefit for businesses with an online presence. Brown, Pope, and Voges (2003) discovered that the variety of products available in online settings has a significant impact on purchase intention. Similarly, social commerce sites allow marketers to display their entire product line without having to stock it (Wolfinbarger and Gilly, 2001). In essence, social commerce platforms provide a sense of convenience to potential customers by aggregating products sold by multiple retailers under one portal (Anderson et al., 2014; Chung, Song, and Lee, 2017). As a result, online consumers are presented with a greater variety of products from which to choose, increasing the likelihood of finding a suitable product and purchasing it. As a result, we can hypothesize:

H1: *Product selection positively affects electronic word-of-mouth engagement.*

In a number of studies, it is noted that one of the main reasons consumers use social commerce sites is due to the convenience they provide to browse products (Stephen and Toubia, 2010). Through a single website, consumers are able to go through a large range of products without having to navigate to various online locations. The importance of attracting and retaining online consumers is manifested in a number of ways, such as online malls, product meta-search engines etc. The purpose of these applications is to enhance the consumers' online experience by presenting a broad range of products that will meet their requirements. Social commerce sites exhibit such characteristics since they allow marketers to advertise their full range of products. This variety makes it possible for consumers not only to identify products that they may be interested in, but also items that their peers may like. Engel, Blackwell, and Miniard (1993) note that one of the reasons consumers engage in WOM is due to their concern for others. This is explained as the genuine desire of consumers to help a friend or relative to make a better purchase decision (Hennig-Thurau et al., 2004). This behavior has been confirmed in online stores in which the selection of products in found to influence consumer attitudes to engage in WOM (Lu, Chang, and Chang, 2014). Such behaviors can also be explained through the prism of collectivism, which is the motivation of users to share information for the welfare of a group or collective (Cheung and Lee, 2012). When faced with a large selection of products on social commerce platforms it is likely that consumers will share information with their peers in order to enhance their sense of emotional involvement with the group (Berger and Iyengar, 2013). This is also in line with the idea that in order to talk about a product, it has to be interesting enough to the receiving side (Hughes, 2005). Therefore, the medium – i.e. social commerce platforms – provides more opportunities to identify products that are interesting to fellow peers, and it is more likely that this will lead to engagement in WOM (Berger and Iyengar, 2013). Based on the vast range of products available on social commerce sites, we can assume that there will be an increased probability for consumers to stumble upon products that will interest their social circle, and as a result, engage in WOM. Therefore, we hypothesize that:

H2: *Product selection positively affects purchase intention.*

Information credibility

According to McKnight and Kacmar (2007), the reliability of information is the degree to which the information a person receives is reliable and trustworthy, acting as an important precursor for promoting information and motivating their willingness to accept the information's viewpoint (McKnight and Kacmar, 2006). More specifically, Li and Suh's (2015) study on social networking platforms found that the reliability of information is greatly influenced by the source of information, as well as the source's level and ability to provide reliable information.

Additionally, Cheung and Thadani (2012) argue that the reliability of information is considered that the extent to which customers perceive the trustworthiness of the messages sent to them. When customers evaluate information as trustworthy, they are more willing to engage in further interaction with that brand's communication activities (Yusuf and Busalim, 2018).

In contrast to face-to-face interactions, online word-of-mouth customers cannot use verbal cues and expressions to evaluate the reliability of the information they receive (Filieri et al., 2015; Litvin et al., 2008). Therefore, assessing the reliability of word-of-mouth information in online social networking platforms poses certain difficulties because the information comes from anonymous sources on the social network (Dellarocas, 2003).

The reliability of information is considered one of the important drivers related to customers' interaction behavior with the messages conveyed to them. According to Cheung and Thadani (2012), the recipients of information will form perceptions about the reliability of these messages in the face of influence from different sources of information. The results of Yusuf et al.'s (2018) study indicate that customers are willing to participate in any form of communication and trust the brand's information once they evaluate and consider the source trustworthy.

Additionally, according to Awad and Ragowsky's (2008) research, the reliability of information is a key factor that strongly influences consumer decision-making. Prendergast et al. (2010) study shows the influence of information reliability on the customer interaction process for brands that convey product or service messages to customers. The above study also demonstrates the influence of information reliability on consumers' intentions to buy. However, this study focuses on testing the relationship between the reliability of information and customers' word-of-mouth interactions on the online social networking site Facebook. Therefore, the proposed hypothesis is as follows:"

H3: *Information credibility positively affects electronic word-of-mouth engagement.*

Information quality

The idea of information quality, as proposed by Park et al. (2015), according to Filieri et al. (2015), relates to the quality of information when customers have the aim to evaluate online information transmitted to them (2007). The fundamental definition is how well customers judge the material when they examine it from a variety of perspectives. Information quality for online word-of-mouth research refers to the usefulness, value, completeness, accuracy, and relevancy of the information conveyed to

customers (Cheung et al., 2009). According to Cheung and Thadani (2012), who claim that the quality of information is considered the persuasive power of a message as it is received by customers through a brand's or organization's communication process, the quality of information has thus played a significant role that directly affects the reception of communication messages by customers. Customers accept the judgements and conclusions once they proceed with any specific information in order to assess its legitimacy and identify other features of the information source they receive. If they are sensible, they will believe the sexuality, or the caliber of the knowledge, if you will (Sussman and Siegal, 2003). The author thus links elements relating to the quality of the information source conveyed between the sender and the recipient to the information quality in the context of online word-of-mouth contact.

According to a study by Cheung and Thadani (2012), the quality of information plays a critical important role in conveying any message to the customers of the brand, which is one of the persuasive powers of the message as it is transmitted. According to Yusuf et al. (2018), information quality is a key driving force of a message coming from a brand, given that more and more information is derived from WOM interactions on the lips, customers' online markets through social networks, e-commerce sites, etc. At that time, users or online customers of this brand always tend to try to process specific information that may be received by them to determine authenticity. In addition, depending on the importance and priority of the information they receive, customers will have different levels of evaluation and judgment about the quality factor of the information that they receive.

Once these customers themselves trust the quality of the information they receive, then they will trust the convenience of that information (Sussman and Siegal, 2003). In addition, previous studies by Aghakhani and Karimi (2013) and Cheung et al. (2008) also pointed out and emphasized the importance of the quality factor as one of the important structures of the source. Information is transmitted to the customer. More specifically, in recent studies on information quality, typically in the study of Lee and Shin (2014), it was stated that information quality creates positive effects on purchase intention and that more important is the word-of-mouth interaction in the customer's online environment. Thereby, the following hypothesis is proposed:

H4: *Information quality positively affects electronic word-of-mouth engagement.*

Attitude towards eWOM

Research by Ajzen (1991) suggests that a person's attitude towards a particular behavior is measured by how favorable or unfavorable their evaluation of that behavior is, and this attitude affects the behavioral intentions of customers, according to Ajzen and Fishbein (1980). Additionally, Fu et al. (2015) argue that in the context of consumption, identifying and measuring how consumers react to conveyed ideas or messages shows their attitudes towards information. The information that customers receive on a daily basis from any product or brand is considered an important factor influencing customers' intention to interact with WOM online (Yusuf, 2018). Therefore, consumers' attitudes towards WOM online are one of the important prerequisites for measuring their response to the message of any product or brand (Gvili et al., 2018; Levy, 2018).

Based on the above, the concept of attitude toward WOM online refers to the different emotions and attitudes of customers towards the word-of-mouth behavior of other members on typical online platforms such as social networking platforms in this study. Thus, customers will show positive as well as negative attitudes towards the online word-of-mouth information they receive, and these attitudes will simultaneously exert a significant influence on their future purchase intentions for a given product or service of the organization.

According to Fu et al. (2015), the attitude towards WOM online is the sum total of emotions and evaluations of customers about positive and negative information from online WOM communication on websites. At the same time, the study also points out the importance of attitudes towards information in creating a significant influence on customers' eWOM engagement intentions. Moreover, the studies by Reichelt et al. (2014) and Fu et al. (2015) suggest that customers' attitudes towards online WOM contribute to helping them determine how to react to ideas as well as the information they receive through their online interactions.

Once consumers have a positive attitude towards WOM online, this attitude becomes the driving force that motivates them to actively engage in eWOM engagement (Yusuf et al., 2018). Specifically, according to Ruiz-Mafe et al. (2014), customers' attitudes towards a particular object are more likely to affect their behavior involving that object in the context of research on customer behavior on the Facebook social network platform. Once customers have positive attitudes towards the brand's pages on Facebook, it creates positive influences that motivate them to intend to use and participate in WOM interactions on the brand's Facebook pages. Therefore, the following hypotheses is proposed:

H5: *Attitude towards electronic word-of-mouth positively affects electronic word-of-mouth engagement.*

H6: *Attitude towards electronic word-of-mouth positively affects purchase intention.*

eWOM engagement

Purchase intention was identified by Ajzen (1991) as a set of motivational factors that exert a significant influence on the performance of a particular customer behavior, which here is the intended behavior of making a purchase. Once the behavioral intention is stronger, it is more likely that these customers will make an actual purchase. Accordingly, the findings of the study by Sam et al. (2009) state that purchase intention is the likelihood that the customer will then perform the actual purchase behavior.

In addition, previous studies have shown that a stronger buying motivation will motivate customers to increase their actual buying behavior. In this context, buying motivation refers to the intention to purchase, desire to own, or experience certain products or services that they are interested in (Ajzen, 1991; Sam et al., 2009). Furthermore, Wu et al. (2011) argue that purchase intention is the consideration or intention to buy or use a particular good or service in the future.

According to research by Bijmolt et al. (2010), customer interaction is defined as the sum total of their positive as well as negative behaviors towards brands based on their experiences with the products or services of those brands. More specifically, Doorn et al. (2010) and Hollebeek et al. (2014) argue that word-of-mouth interactions on customers'

online platforms include behaviors such as recommending, helping other customers, sharing, evaluating, engaging, and co-creating behaviors with the brands themselves.

In the initial research on consumer interaction in the process of online word-of-mouth communication (eWOM communication), Yusuf et al. (2018) suggested that customers' eWOM engagement involves finding and sharing WOM information with other customers in their community, and customers gradually develop a greater purchase intention as they increase the frequency and intensity of eWOM engagement. Moreover, Sharifpour et al. (2016) discovered positive effects from customer interaction in the relationship between eWOM engagement and their purchase intention. Therefore, the following hypothesis is proposed:

H7: *Electronic word-of-mouth engagement positively affects purchase intention.*

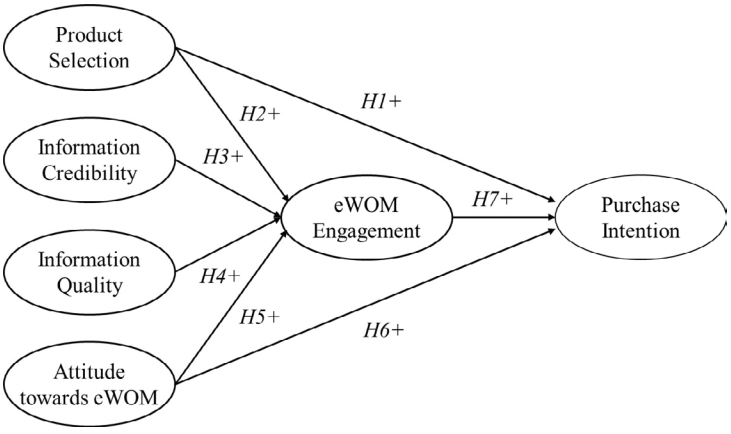

Figure 1. Proposed model

IV. METHODOLOGY

A. Data collection and sampling

To test the hypothetical relationship between the variables in the proposed research model, conducting the pretest was applied. The main aim of carrying out the pretest was to assess the construct validity of constructs. This was done to identify whether there were any confusions that arose from the phrasing, translation, or research context adoption (Colton & Covert, 2015). In this study, the non-probability method with convenience sampling technique was applied because of utilizing the conducting time and cost constraints. Finally, the data were analyzed based on the survey results of 325 valid samples after removing incomplete or error questionnaires. Table 1 presents the sample characteristics of the valid respondents.

Table 1. Sample characteristics

Demographic	Range	Total: n = 325	
		Frequency	Percentage (%)
Gender	Male	137	42%
	Female	188	58%
Age	18 - 22	43	13%
	23 - 27	129	40%
	28 - 32	107	33%
	33 - 37	41	13%
	38 - 42	5	2%
Occupation	Students	32	10%
	Housewife	56	17%
	Office worker	216	66%
	Others	21	6%
Income **23,750 VND/USD*	Lower 211 USD	42	13%
	211 - < 380 USD	136	42%
	380 - < 633 USD	123	38%
	Over 633 USD	24	7%
How long have you been purchasing products on SNSs?	Lower 6 months	23	7%
	From 6 months to 1 year	50	15%
	From 1 to 2 years	117	36%
	Over 2 years	135	42%
Frequency of SEEKING information	Always	24	7%
	Usually	100	31%
	Sometimes	146	45%
	Never	55	17%
Frequency of SHARING information	Always	16	5%
	Usually	92	28%
	Sometimes	182	56%
	Never	35	11%

B. Measurement scale

To enhance the validity and reliability of the survey, a multi-item approach was employed in which each construct was measured by multiple items which were adapted from previous studies and modified to match the current research context. A five-point Likert scale was applied to assess all variables, ranging from 1 for strongly disagree to 5 for strongly agree. For measuring product selection construct, its scales were adopted by To et al. (2007) and Mikalef et al. (2017). Information credibility and information quality were adopted by Park et al. (2007) and Erkan and Evans (2016). Purchase intentions were measured by four items adapted from Coyle and Thorson (2001) and Erkan and Evans (2016). For measuring attitude towards

eWOM, its scales were adopted by the research of Pollay and Mittal (1993) and Gvili and Levy (2018). Finally, eWOM engagement is known as a second-order construct with two dimensions: intention to send and intention to receive, which were adopted from Sun et al (2006) and Chu and Kim (2011), then modified by Gvili and Levy (2018) to better fit with this present study. All the measurement scales of these constructs were presented in Table 2.

V. EMPIRICAL FINDINGS

This research accessed covariance-based structural equation modeling (CB-SEM) to analyze the data. According to Ramlall (2016), this method has been proven to be useful for analyzing data and estimating parameters with a lot of information, which leads to reliable and efficient estimates.

Before using CB-SEM, they first checked the internal consistency of all constructs in the proposed model by the coefficient of Cronbach's alpha, which is useful to evaluate how reliable and valid their data was. Then, exploratory factor analysis (EFA) is applied to understand the complexity of the variables. Finally, AMOS 24 is used to CFA - Confirmatory Factor Analysis and SEM - structural equation modeling

A. Measurement model assessment

This research used AMOS 20 to test the research model, applied initially CFA to assess the convergent and discriminant validity of the measurement model and even explain the correlations between the measurement scales of proposed constructs. Using composite reliability – CR and Cronbach's alpha – CA to verify the reliability of the measurement model, which showed the detail in Table 2, both CA and CR were greater than 0.7 compared to the standards proposed by Hair et al. (2010). Then, all individual constructs satisfy the standard of the average extracted variance (AVE) and maximum shared variance (MVS) greater than 0.5, so that the construct in the proposed model reached the convergent validity. According to Fornell and Larcker (1981), the results in Table 3 revealed that all the AVE values for each construct were greater than their corresponding squared multiple correlation values, so the data of these constructs reached the discriminant validity. Mover, the measurement model performed the goodness-of-fit indices after assessing the CFA, the results stated that $\chi 2 = 280.158$ ($p=.000$), $\chi 2/df = 1.315 < 3$ by Carmines and McIver (1981), RMSEA = 0.031 < 0.08 by Steiger (1990), CFI = 0.985 and TLI = 0.983 are greater than 0.90 as mentioned by the research of Bentler and Bonett (1980).

Table 2. Constructs reliability and validity

Construct Name	Items	Loadings	CA	CR	AVE	MSV
Product selection	PDS3	0.854	0.870	0.871	0.693	0.191
	PDS1	0.843				
	PDS2	0.782				
Information Credibility	IFC2	0.887	0.882	0.883	0.654	0.226
	IFC1	0.828				
	IFC3	0.778				
	IFC4	0.725				

Construct Name	Items	Loadings	CA	CR	AVE	MSV
Information quality	IFQ1	0.865	0.857	0.859	0.670	0.264
	IFQ3	0.819				
	IFQ2	0.742				
Attitude towards eWOM	ATT2	0.864	0.889	0.888	0.727	0.269
	ATT3	0.856				
	ATT1	0.823				
eWOM engagement (eWOM)			0.883	0.757	0.612	0.315
- Intention to send	ITS3	0.919				
	ITS2	0.850				
	ITS1	0.804				
- Intention to receive	ITR3	0.898				
	ITR2	0.883				
	ITR1	0.759				
Purchase intention	PUI2	0.846	0.877	0.878	0.643	0.315
	PUI4	0.822				
	PUI3	0.782				
	PUI1	0.744				

Table 3. Constructs discriminant validity

Constructs	Information Credibility	Purchase Intention	Information Quality	Product Selection	Attitude to eWOM	eWOM
Info.Credibility	**0.809**					
Pur.Intention	0.424***	**0.802**				
Info.Quality	0.470***	0.345***	**0.819**			
Product.Selection	0.295***	0.413***	0.392***	**0.833**		
Attitude	0.325***	0.500***	0.444***	0.422***	**0.852**	
eWOM	0.475***	0.561***	0.514***	0.437***	0.519***	**0.783**

****p <0.01*

B. Structural model assessment

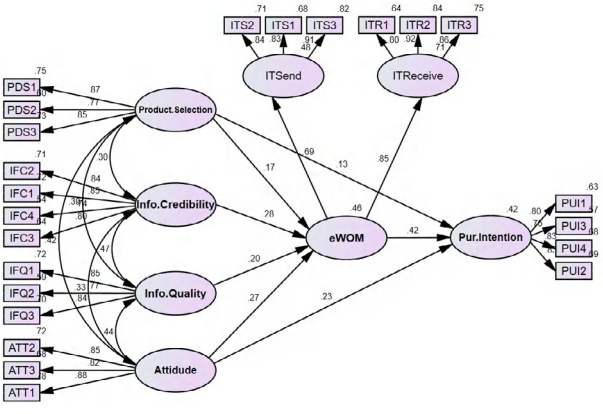

Figure 2. Structural model

Firstly, the results of the goodness-of-fit indices figured out that the structural model did fit the data compared with the relevant standards previously described in CFA, specifically, $\chi 2$ = 287.555 (p=.000), $\chi 2/df$ = 1.337, RMSEA = 0.032, CFI = 0.984 and TLI = 0.981. Then, using a one-tailed test, the structural model was evaluated in line with the hypothesized effect in this model. Based on applying the SEM, the presented results in Figure 2 and Table 4 indicated that seven proposed hypotheses were statistically significant. In particular, product selection has the positive influence on purchase

intention (H1: $\beta = 0.134$, $p < 0.05$) and eWOM engagement (H2: $\beta = 0.166$, $p < 0.05$). Then, both information credibility (H3: $\beta = 0.275$, $p < 0.05$) and information quality (H4: $\beta = 0.198$, $p < 0.05$) has a significant impact on eWOM engagement in the present research context. Additionally, attitude towards eWOM has positive effects on eWOM engagement (H5: $\beta = 0.275$, $p < 0.05$) and purchase intention (H6: $\beta = 0.226$, $p < 0.05$). Finally, the relationship between eWOM engagement and purchase intention is statistically significant in this research at the significant level by 5% with the standardized estimate $\beta = 0.416$.

C. Mediator analysis

For the mediator analysis, this research applied the bootstrapping method with 5000 bootstrap resamples, the results in Table 5 indicated that eWOM significantly meditated the relationships between the antecedents, such as product selection, information quality, information credibility and attitude towards eWOM and purchase intention at p-value 2 tailed < 0.05. More specifically, eWOM engagement played the Full mediating role between the relationships of Information quality ($\beta = 0.082$, $p < 0.05$) and information credibility ($\beta = 0.114$, $p < 0.05$). Besides, the partial mediating roles of eWOM engagement were demonstrated in the impact of product selection ($\beta = 0.069$, $p < 0.05$) and attitude towards eWOM ($\beta = 0.114$, $p < 0.05$) on purchase intention.

Table 4. Hypotheses testing

Path model	Estimate	S.E.	C.R.	P-value	Result
H1: Product Selection → Purchase Intention	0.134	0.053	2.064	0.039	Supported
H2: Product Selection → eWOM Engagement	0.166	0.046	2.387	0.017	Supported
H3: Information Credibility → eWOM Engagement	0.275	0.053	3.631	***	Supported
H4: Information Quality → eWOM Engagement	0.198	0.058	2.572	0.010	Supported
H5: Attitude towards eWOM → eWOM Engagement	0.275	0.050	3.739	***	Supported
H6: Attitude towards eWOM → Purchase Intention	0.226	0.060	3.191	0.001	Supported
H7: eWOM engagement → Purchase Intention	0.416	0.109	4.781	***	Supported

Table 5. Mediator analysis

Independent variables	Dependent variables	Direct effect	Indirect effect		Mediating role
		Estimate	Estimate	P-value (2-tailed)	
▪ ***Product selection → eWOM engagement → Purchase intention***					
Product selection	Purchase intention	0.134	0.069	0.020	Partial mediator
▪ ***Attitude towards eWOM → eWOM engagement → Purchase intention***					
Attitude towards eWOM	Purchase intention	0.226	0.114	0.002	Partial mediator
▪ ***Information Quality → eWOM engagement → Purchase intention***					
Information Quality	Purchase intention	0.198	0.082	0.019	Full mediator
▪ ***Information Credibility → eWOM engagement → Purchase intention***					
Information Credibility	Purchase intention	0.275	0.114	0.002	Full mediator

VI. DISCUSSION AND CONCLUSION

A. Discussion

Firstly, the study examines the online purchase behavior of customers using social networking sites in Vietnam and evaluates how it affects purchase intention and WOM behavior. The study builds on previous research and contributes to developing an eWOM engagement concept scale in the Vietnamese market, especially for several online social networking platforms. Furthermore, businesses planning to move their products and services online could utilize the findings and implications of this study to create oriented strategies that positively influence customer purchase intention towards their brand.

Secondly, as the results in the structural model assessment, this study found that the concepts of product selection (H2: $\beta = 0.166$ and $p < 0.05$), information credibility (H3: $\beta = 0.275$ and $p < 0.05$), information quality (H4: $\beta = 0.198$ and $p < 0.05$), and attitude towards eWOM (H5: $\beta = 0.275$ and $p < 0.05$) had significant positive effects to the eWOM engagement of customers using social networking sites for online purchasing. Under the current limited business conditions, firms that are seeking to increase customer engagement on their online platforms, especially eWOM behavior, should focus on improving and developing factors related to the credibility and quality of the content in the eWOM process among customer groups or communities, such as communication sources from brands and sources of eWOM related to the brand's products or services. These factors should be properly invested in to increase the quality and quantity of customers' online engagement with online activities of firms in entire online platforms. Additionally, e-commerce firms should aim to enhance and enrich the content of communication messages regarding their products and brands to significantly align with the suggestion from the findings of Yusuf et al. (2018) on the impact of credibility and quality on the online word-of-mouth behavior of customers using social e-commerce platforms.

Thirdly, based on the effect of eWOM engagement, namely, intention to receive and intention to send, the positive relationship between them and purchase intention has been statistically significant with p-value < 0.05 and $\beta = 0.416$. Besides, product selection (H1: $\beta = 134$, $p < 0.05$) and attitude towards eWOM (H6: $\beta = 226$, $p < 0.05$) also significantly influence purchase intention in the social commerce context, then this find substantially contributes to the expected purchasing behavior of customers when utilizing several popular social networking platforms. Additionally, this finding is consistent with previous studies by Erkan and Evans (2016) and Yusuf et al. (2018), which stated that the importance of media information and online behavior factors in forecasting customer purchase behaviors on social networking sites. Based on the content of brand communication, if a firm is successful in altering customers' perceptions and attitudes towards their product or service messages, it can be helpful to promote greater engagement and interaction on social media platforms owned by the brand, then leading to stronger motivation for customers to complete their online shopping and ultimately shift their behavior towards the organization's commercial activities.

B. Conclusion

From the results of quantitative analysis of the research model, some managerial

implications are concluded by the author as follows:

Firstly, by assessing the factors affecting the eWOM engagement behavior of customers on the Facebook social networking platform, this study, the factors of information quality, trust, and information reliability, as well as attitudes towards word of mouth, have a great influence on customer engagement behavior on Facebook as well as other online platforms. This is consistent with the research of Yasuf et al. (2018), therefore, companies or organizations that are exploiting online channels, especially online social networks such as Facebook, Instagram, etc., can enjoy a lot of benefits. Many benefits come from customer interaction, such as participating in comments, expressing emotions, as well as sharing information that these brands post on these social networks. More specifically, this study mentions the rather important role of the concept of information Credibility ($\beta = 0.275$) and the attitude towards eWOM ($\beta = 0.275$) for communication interaction, customer's online mouth on social media platforms. If brands focus on factors related to the message conveyed, especially the reliability of information or the reliability of the source of the information transmitted in the WOM environment. Online information shared between customers can create effects beyond the control of any one organization/brand. If the interaction and sharing of customers' brand information comes from an unreliable source, it will have significant consequences for the brand's image as well as the brand building process that the organization uses. Therefore, the priority for brands in this current period is to constantly standardize the source of media information and continuously control the information shared on social networking sites related to the products, and services as well as the company's brand. If there are problems or crises that are detrimental to the brand or organization, the priority is to identify the source of false information that customers are interacting with and sharing online before the company makes follow-up decisions to address these issues and crises for the organization's products and brands. Thus, these findings would solidify theories related to the interplay between the characteristics of information, such as credibility and quality as a whole, and electronic Word-of-Mouth (eWOM) engagement of customers, especially in the context of social commerce. Furthermore, this finding substantiates the fact that expanding a customer's choice within a brand's product range enhances their engagement with the brand and indirectly influences their intention to consume our products, including other categories within this brand.

Secondly, by discovering the impact of eWOM engagement on purchase intention behavior (H6: $\beta = 0.416$), this study has contributed to the foundation of predictive theories. determine customer behavior on online platforms, especially social networking platforms, and at the same time close previous research gaps in exploring and testing the role of eWOM engagement for purchase intentions and the scope of research on social networking sites as well as e-commerce sites in Vietnam. By testing the model in the commerce market on online social networking platforms in Vietnam, it is possible to see the different levels of participation of customers in eWOM engagements on different platforms. On an online social network, typically, the interaction behavior on Facebook has a positive effect on the purchase intention of customers who

have been using this platform. Thereby, it can be seen that eWOM engagement is one of the essential components, acting as a motivation for purchase intention, which is consistent with the study of Balakrishnan et al. (2014), while conducting research and testing the model in the Vietnamese market. More specifically, by the brand's efforts in encouraging customers to interact with the brand's communication messages on existing social networking platforms such as Facebook, Zalo, etc., information will flow back and forth between the brand and its customers. For customers, when increasing their participation in online interactions with brands, such as evaluating the quality of products/services of that brand that they have been using, or participating in games, or contests on the brand's Facebook pages, the flow of information will carry the positive messages that the brand is trying to convey to customers, with the expectation of contributing to a change in this customer's own buying behavior, especially their buying intention. In addition, for brands, the source of information is the flow of customers to the brand, thereby giving the organization an important source of data about the status of its customer behavior in the period. From there, it will motivate brands to build strategies/programs to respond to the constant changes and updates in customers' shopping behavior, especially their intended purchase behavior in any new product.

Thirdly, from the analysis results of customers' eWOM engagements, it can be seen that customers who use social media platforms are more likely to give positive comments about the messages being transmitted through the social groups they are interacting with. Therefore, in order to maximize the effectiveness of communication channels in this online word-of-mouth environment, the top goal for a brand is to successfully design advertising campaigns and strategies on different platforms. The social networking platform is growing at a rapid pace and with a high prospect. To accomplish the above goal, it is required that the content that conveys a brand's message on social networking sites, which should be displayed to important members. In this case, the customers are participating in regular interactions with the brand on Facebook or other similar social networks, thereby becoming a sure bridge for spreading the brand's message to more potential customers on the network systems. current society. As the driving forces behind customer interaction increase, there is also a need to focus on improving the reliability and quality of the information transmitted, combined with the ongoing efforts of a brand's effectiveness in motivating customers to have slightly positive judgments and attitudes towards their products and services, which will increase the probability of a change in customers' intention to purchase behavior in the short and long term

C. Limitations and future work

Like any other research project, the implementation of this study also encounters certain limitations. First, due to the limitation of time as well as other resources when implementing this topic. The author only focuses on evaluating purchase intention behavior under the influence of eWOM engagement on shops residing in Ho Chi Minh City. In large cities, it is hardly to fully cover the purchase intention behavior of customer groups in different geographical areas. In addition, another limitation of the study is that it focuses on studying customer interaction behavior on the social networking platform Facebook, as a major purchase channel of customers for this

platform. Expanding the scope to other online social networking platforms such as Instagram, Zalo, Twitter, will contribute to increasing the generalizability of the model to customer behavior in the Vietnamese market.

Next, the present study only considers factors such as quality and reliability of information, and factors related to customer attitudes towards the concept of eWOM engagement. through the intended sending behavior and the intended receiving behavior of customers using Facebook. However, customers' eWOM engagements also include many other aspects and also constitute great impacts on customers' purchase intentions, including the evaluation behavior of customers. content of word of mouth, evaluate the positive and negative of online word-of-mouth information on these social networking platforms. At the same time, future studies can further clarify the role of the concept of customer shopping behavior observation for customers who have purchased/used products/ services of this earlier brand (Wang and Yu, 2015). In addition, further studies can develop this model by focusing further research on the actual buying behavior of customers, including the purchase acceptance behavior and the post-purchase behavior of the customers.

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INFLATION-HEDGING PROPERTIES OF GOLD IN VIETNAM

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Abstract: Using Markov Switching Regression models, including MS-DR and MS-AR, on monthly data from August 2015 to December 2021, we examine the short-term hedging ability of gold against inflation in Vietnam, identifying two distinct regimes triggered by sudden economic shocks. The results show that Regime 1 fails to deliver a noticeable relationship between gold prices and inflation, but it becomes significant and positive in Regime 2. Moreover, in Regime 2, the interest rates are significantly inverse related to gold prices. Therefore, gold can be an effective safe-haven during the high-inflation environment. This paper's findings can serve as a recommendation for portfolio selection and risk management strategies when investing in Vietnam.

Keywords: *gold price, inflation, interest rates*

I. INTRODUCTION

Since its inception in the 1990s, inflation has always been a concern for investors and monetary authorities, who have sought to mitigate its consequences and ensure it is under control. Analyzing the World Bank data, Ha et al. (2023) emphasize the worldwide inflation rate has declined from roughly 17 percent in 1974 to around 2.5 percent in 2020. In reality, some countries had high inflation rates a few decades ago. According to the World Bank Data (2022), from 1996 to 2022, Vietnam's inflation rate mainly fluctuated around 3 to above 5 percent during the period. Significantly, as a consequence of the Global financial crisis in 2008, it rose sharply and peaked in 2008 at 23.12%, followed by a steep plunge to 6.7% in 2009. The CPI went up again to approximately 18.68% in 2011.

The outbreak of the COVID-19 pandemic in 2020 changed the situation of the economies of the whole world. After the long period of lockdown disrupting the supply chains around the world and slowing down economic growth, several governments and central banks implemented accommodating policies in order to boost demand again. As a result, the high-inflation economic environment has returned in several nations during the last two years. The global inflation in 2022 is 8.8 percent (IMF, 2023). According to the International Monetary Fund (IMF), the reopening of China in the second quarter of 2023 boosts the global economy's recovery. Therefore, IMF (2023) forecasts that the inflation rate will decline to 6.6 percent and 4.4 percent in 2023 and 2024, respectively. Nevertheless, this rate is still higher than the pre-pandemic period (2017-2019) of approximately 3.5 percent. In Vietnam, the inflation level remains stable at the rate of 3.2 percent in 2022, while this rate was 2.8 percent in the pre-COVID period (World Bank Data, 2022).

Investigating the nexus between gold prices and inflation is essential for two reasons. First, the notably increasing inflation rates in the global economy are the result of the expansion of monetary policies in many developed and emerging countries responding to COVID-19 (Benmelech & Tzur-Ilan, 2020; Brzoza-Brzezina et al., 2021; Feldkircher et al., 2021; Wei & Han, 2021). Second, the world economy is experiencing a remarkable shock caused by the Russia and Ukraine war, especially in the oil and food markets. As a result, it compresses supply and drives prices to record highs. The conflicts between the two European countries represent a massive cost in humans, weapons, and economic costs (Mbah & Wasum, 2022). According to Khudaykulova et al. (2022), this war adds to the global inflation rate by 2% in 2022 and 1% in 2023, in comparison with NIESR's inflation projection at the beginning of 2022- before the start of the war.

To prepare well for the possible high-inflation economic environment in the future, finding hedging properties is a top priority for portfolio investors. As discussed in the literature review in section two, the findings of gold's inflationary hedging capabilities are inconsistent. The conclusions vary depending on the time frame, the countries, and the methodology used. The data in the US shows that gold can hedge against inflation (Chua & Woodward, 1982; Beckmann & Czudaj, 2013). In addition, gold appears as a helpful hedging tool in the UK (Aye et al., 2017), in the OECD (Salisu et al., 2019), and in Vietnam (Le Long et al., 2013). However, in the long term, the hedging ability of gold may not be as practical as expected (Hoang et al., 2016). Their relationship may be nonlinear because the business cycle affects the gold price and inflation rate fluctuations. It is essential to use methodology taking account of the interruptions and the shifts in this nexus. The flexible nonlinear method results suggest that the interim cointegration between gold price and inflation exists (Aye et al., 2016). By applying the binary probit model and quantile regression, Dee et al. (2013) point out that for Chinese investors, gold is not an effective inflation hedge in the short term, but it can be a strong hedge in the long run. Examining the ability of gold in short-run and long-run hedging inflation in the USA and Japan by using both linear and nonlinear cointegration tests to take into consideration interrupted periods, Wang et al. (2011) conclude that gold can hedge effectively in the long-term but cannot consistently hedge effective for Chinese short-term investors.

This paper conducts an investigation into the relationship between Vietnam's gold price and the consumer price index (CPI) using the data from August 2007 to December 2021. This research uses CPI as an indicator of inflation. This study aims to examine the question: Can gold be effectively used to hedge against inflation in Vietnam?

This paper contributes to the existing literature in two ways. First, we investigate the relationship between gold prices and CPI using Vietnam data to examine the hedging ability of gold against inflation since not many studies in Vietnam illustrate this relationship (Le Long et al., 2013; Duong, 2022). This study employs Markov Switching Regression models, which are most suitable when regime changes are triggered by sudden economic shocks (Psaradakis et al., 2004). Second, the model used in this paper considers the interest rates, which other research has not mentioned in previous research. We extend the existing

model by adding interest rates because interest rates correlate with gold and inflation through the Fisher effect theory and the asset pricing models (Fisher, 1896).

Following the introduction in section one, the rest of this paper presents five other sections. Section two illustrates the relevant literature review on gold, interest rate, inflation rate, and the nexus between these three factors. Section three analyzes the data used. The methodology is discussed in section four. Section five demonstrates the empirical results. Finally, the conclusion of the paper is in section six.

II. LITERATURE REVIEW

Gold is a valuable and expensive metal that many investors usually choose to invest in and hold for an extended period. Investors believe that gold is a place to store value to protect themselves against inflation risk. Since the 1990s, many studies have examined the nexus between gold and inflation (Chua & Woodward, 1982; Jaffe, 1989; Harmston, 1998; Ghosh et al., 2004; Worthington & Pahlavani, 2007; Dempster & Artigas, 2010; Wang et al., 2011; Beckmann & Czudaj, 2013). The empirical research shows that gold is an excellent hedge against ex-ante and ex-post inflation, but the conclusions are inconsistent. It shows that the protection may only be partial and vary depending on the nations, economic conditions, and holding time (Lucey et al., 2017; Shahzad et al., 2019). For instance, by using the data set of gold price and consumer price index (CPI) for the US and UK from 1971 to 2010, Bampinas and Panagiotidis (2015) conclude that gold can hedge against estimated and core CPI in the long run. Still, the ability in the US market is higher than that of the UK. Adding the data set for Japan to the previous research, gold offers less protection against inflation in Japan than in the UK and the US (Lucey et al., 2017).

On the other hand, analyzing the data from 1975 to 1980 from six major industrial countries, Chua et al. (1982) conclude that the returns of investment in gold can offset the changes in CPI level. Therefore, gold is an excellent tool to hedge against inflation. However, this hedging tool is effective in the short term only. The authors prove that gold hedges effectively over one and six months against US inflation. Hoang et al. (2016) investigate the hedging inflation ability of gold in five economies, namely France, the UK, the US, China, and India. The authors emphasize that gold is not a good choice for all five countries in the long run. However, it is an effective hedge against inflation in the short term for the UK, the US, and India.

The research about the nexus between inflation and gold analyzes the data from Western and Asian economies. By examining domestic gold and CPI from 2001 to 2011, Ghazali et al. (2015) point out that Malaysian domestic gold is not a suitable hedge against inflation since there is no substantial correlation between gold return and predicted inflation, as well as unexpected inflation. Additionally, due to its inability to maintain sustainable purchasing power over a short period, gold is not a great store of wealth. On the other hand, Afham et al. (2017) remark that gold return performs better under high momentum regimes than during low momentum regimes in the Malaysian economy. Pangestuti (2017) finds that gold is a reliable safe- haven in Singapore and Malaysia. Duong (2022) emphasizes the role of gold as a valuable strategy for maintaining the value of assets against inflation in the Vietnamese economy from 2001 to 2020.

The framework of Fortune (1987) permits that the predicted future interest rates impact gold prices via substitution effects. The author emphasizes that the interest rates are inverse to the gold prices, implying that the increase in expected interest rates leads to declining gold prices. The link between gold returns and inflation is frequently studied, but the impact of interest rates is usually neglected. Coupled with the idea that the long end of the yield curve provides essential information about predicted interest rates (Fisher, 1930), this shows that omitting to include a long-term interest rate as an explanatory variable may explain some of the literature's contradictory empirical findings. Not many studies are exploring the relationship between interest rates and gold prices within the Markov Switching Regression models when analyzing the inflation hedging property of gold. Consequently, we conduct this study to fill in the literature gap.

III. DATA

The Vietnamese General Statistics Office (GSO) provided monthly data from August 2007 to December 2021, encompassing all variables considered in this study. The dataset comprises 173 observations, including the gold price index, the consumer price index (CPI) representing inflation, and the 10-year government bond yield as a proxy for interest rates. The raw data was then transformed into logarithm returns.

Figure 1 illustrates the natural logarithms of gold returns and CPI over the sample period. Additionally, Table 1 presents descriptive statistics for gold returns, CPI, and interest rates. The analysis reveals that gold returns exhibit significantly greater variability than inflation rates. Notably, inflation rates in Vietnam experienced substantial fluctuations in 2007-2008 during the global financial crisis and in 2012. According to a report by the World Bank, inflation rates in Vietnam reached 23.12% in 2008 and 18.68% in 2011. Since 2012, the government's anti-inflation efforts have successfully lowered the CPI and maintained the CPI below 5% since 2014 (Han, 2009).

In 2020, CPI experienced a surge primarily due to the increase in utility prices, as reported by the Vietnamese GSO (2021). Subsequently, in 2021, CPI declined, owing to decreased demand for travel and tourism caused by the COVID-19 pandemic. The government also implemented support packages for individuals and producers facing difficulties arising from the pandemic. Throughout periods of significant CPI changes, gold returns generally followed the CPI trend but displayed higher levels of volatility. Furthermore, even in stable CPI periods, gold returns exhibited more significant fluctuations compared to CPI. Among the three variables, interest rates demonstrated the highest mean of -0.8% and the highest standard deviation of 0.072.

Regarding normal distribution tests, all variables exhibited skewness and leptokurtosis, indicating a fat-tailed distribution. This observation supports the use of Markov switching models, which account for the specific characteristics of economic time series with fat-tailed distributions (Cecchetti et al., 1993). Additionally, the Jarque-Bera statistics indicate the rejection of a Gaussian distribution. Lastly, the ADF test for unit roots implies the stationarity of the time series data, rejecting the null hypothesis of unit roots in the data.

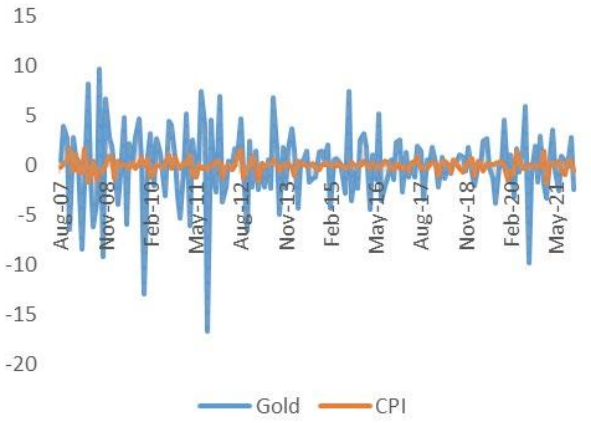

Figure 1. Monthly variations of gold returns and CPI (in %)

Table 1. Descriptive statistics

	G	P	IR
Mean	-7e-03	-4e-03	-0.8
Std. Dev.	0.0356	0.006	0.072
Skewness	-0.827	-0.166	2.785
Kurtosis	6.334	4.16	37.891
Jarque-Bera	99***	10***	8946***
ADF	-9.9***	-9.3***	-6.9***

****,**, and * denote the significant level of 1%, 5%, and 10%, respectively*

IV. METHODOLOGY

In this study, we employ Markov Switching Regression models to evaluate the inflation-hedging capability of gold in Vietnam. Bodie (1976) states an inflation hedge has three possible interpretations. First, it is an asset that can eliminate or diminish the possibility of negative actual returns. Second, when paired with other assets, an asset lessens the volatility of real returns. Finally, an asset that exhibits a positive correlation with inflation. Using the third definition as a foundation, Arnold et al. (2015)argue that a correlation equal to 1 implies that the asset is considered a perfect hedge against inflation, indicating that the asset's price increases perfectly compensate for inflationary effects. They further suggest that even if an asset has a positive correlation below 1, it is not an ideal hedge. However, the positive correlation means the asset is still valuable due to its stable and positive relationship with inflation. By adopting this viewpoint, our research investigates how changes in CPI affect gold prices to analyze gold's usefulness as an inflation hedge. If gold prices align with the upward trend of the CPI, it can be considered an effective inflation hedge. Therefore, investors are enabled to protect their purchasing power and real returns.

We applied Hamilton's (1989) Markov Switching Regression models to validate our proposed model. He characterizes Markov-switching models as suitable for capturing discrete shifts in the regime, wherein the dynamic behavior of the series significantly differs across episodes. Additionally, Psaradakis et al. (2004) note that these models are most suitable when regime changes are triggered by sudden economic stress, which models with smooth transitions or threshold effects may not adequately describe. Changes in price transmission behavior can occur temporarily due to external factors such as shifts in national policies, economic recessions, financial panics, or wars, all of which influence business cycles (Raj, 2002). Given this characteristic, the Markov Switching (MS) approach finds broad applicability in financial and economic research, as phenomena can be easily classified into different regimes (Smith, 2008).

The MS model considers the conditional distribution of a time series sample to be subject to an inherent latent state or regime. The MS model considers a finite set of values and allows them to vary over time as a Markov chain (Smith, 2008). In our study, we employed

monthly CPI data to test for a structural break, following the approach proposed by Bai and Perron (2003), and identified a structural break point in CPI in March 2013. Hence, the use of the MS approach is justified.

The MS model consists of two main categories: Markov-switching dynamic regression (MSDR) models and Markov-switching autoregression (MSAR) models. The former exhibits a rapid adjustment after a state change and is often employed for modeling monthly and higher-frequency data. The latter allows for a gradual adjustment after the process changes state and is commonly used for modeling quarterly and lower-frequency data. Since our study focuses on monthly data, both models are appropriate for our analysis.

The MSDR is presented below:

$$G_t = \mu_{s_t} + \alpha_{s_t} G_{t-1} + \beta_{s_t} P_{t-1} + \gamma_{s_t} IR_{t-1} + \varepsilon_s \quad (1)$$

where G_t is the gold returns at time t. μ_{s_t} is the state-dependent intercept. G_{t-1}, P_{t-1}, and IR_{t-1} are the gold returns, changes in CPI, and changes in interest rates at time $t - 1$ with state-dependent coefficients α_{s_t}, β_{s_t}, and γ_{s_t}, respectively. ε_s is an independent and identically distributed (i.i.d.) normal error with mean 0 and state-dependent variance σ_s^2.

A general specification of the MSAR model is written as follows:

$$G_t = \mu_{s_t} + \alpha_{s_t} G_{t-1} + \beta_{s_t} P_{t-1} + \gamma_{s_t} IR_{t-1} + \Sigma_{i=1}^{p} \varnothing_{i,st} (G_{t-i} - \mu_{s_{t-i}} - \alpha_{s_{t-i}} G_{t-i} - \beta_{s_{t-i}} P_{t-i} - \gamma_{s_{t-i}} IR_{t-i}) + \varepsilon_s \quad (2)$$

where other variables are similar to equation (1), $\varnothing_{i,st}$ is the ith AR term in the state s_t.

s_t is an irreducible and aperiodic Markov chain. The probability that s_t is equal to $j \in (1,..., k)$ depends only on the most recent realization, s_{t-1}, as given below:

$$\Pr(s_t = j | s_{t-1} = i) = p_{ij} \quad (3)$$

where $\Sigma_{j=1}^{k} p_{ij} = 1$.

V. EMPIRICAL RESULTS

Table 2 summarizes the findings of the Markov switching regression models. Based on the sample dataset, a two-regime model is suggested, consistent with the results of the structural break test mentioned earlier. The second column presents the results of the MS-DR. In Regime 1, the impact of the CPI on gold returns is found to be statistically insignificant, indicating that the inflation hedging property of gold in this regime is inconclusive (Ghazali et al., 2015; Hoang et al., 2016; Lucey et al., 2017) Additionally, gold returns demonstrate a statistically significant negative association with their own lagged values and the one-lagged-period interest rate at a 1% level of significance. This result supports the findings of Valadkhani et al. (2022), who also confirm a negative relationship in the US market. According to Fisher's effect theory, a rise in domestic inflation should be offset by an increase in the interest rate. A higher interest rate may encourage investment in less risky assets such as bank deposits, government bonds, or gold, considered a traditional saving asset in Vietnam. Therefore, this could result in a rise in gold prices. However, in regime 1, since the impact of inflation on gold returns is insignificant, it is also difficult to explain the link between interest rates and gold prices.

In regime 2, CPI positively impacts gold prices at a 10% level of significance, indicating that gold can serve as an inflation hedge in this regime. Although gold is unable to hedge

inflation fully, the coefficient of 0.706 suggests a 70.6% hedge, which still makes gold a valuable asset for inflation hedging (Arnold & Auer, 2015). This positive relationship aligns with arguments made by other authors (Baur & McDermott, 2010; Wang et al., 2011; Dee et al., 2013). Additionally, changes in interest rates also exhibit a significant and positive relationship with gold prices. Consequently, when there is a rise in interest rates following higher inflation rates, there is an increase in the demand for gold as a saving asset, leading to higher gold prices.

The third column in Table 2 displays the results of the MS-AR. Only one autoregressive (AR) term is necessary to fit the AR model, and the significant coefficient confirms the impact of lagged gold prices, CPI, and interest rates on gold prices in Vietnam. The results are consistent with the MS-DR findings in the second column, as the gold's usefulness as an inflation hedge is insignificant in Regime 1 but becomes significant in Regime 2. The coefficient of CPI is statistically significant and positive at 0.644, which represents the sum of β_{s_t} and the absolute value of $\emptyset_{i,st}$ in Equation 2.

Moving on to the transition probabilities, p11 indicates the likelihood of remaining in state 1 in the next period, given that the process is in state 1 in the current period. Values closer to 1 suggest a more persistent approach, indicating that state 1 is expected to persist for a longer time. In both models, these values are relatively close to 0, meaning Regime 1 continues in the short term. On the other hand, p21 represents the probability of transitioning to state 1 in the next period, given that the process is in state 2 in the current period. This probability is also low, at less than 5%, indicating the persistence of regime 2, where gold can effectively be used as a hedge against inflation. Hence, according to Arnold & Auer, 2015, the stable and positive association between CPI and gold price highlights the inflation ability of gold in Vietnam.

Table 2. Results for the Markov-switching regressions

	MS-DR	**MS-AR**
AR(-1)		-0.231**
Regime 1		
G(-1)	-3.319***	-1.549***
P(-1)	-2.012	-1.147
IR(-1)	-2.15***	-1.299***
Constant	-0.039***	-0.081***
Regime 2		
G(-1)	-0.197***	-0.11
P(-1)	0.706*	0.413*
IR(-1)	0.068**	0.073**
Constant	0.002	0.004*
Sigma	0.027	0.027
p11	1.41e-06	1.93e-07
p21	0.049	0.046

****, **, and * denote the significant level of 1%, 5%, and 10%, respectively.*

VI. CONCLUSION

This study examines the inflation hedging ability in Vietnam using the monthly data from August 2007 to December 2021. The Markov Switching Regression models, including MS-DR and MS-AR, were used to document the short-run nexus between gold prices and CPI in Vietnam. These models are superior to others when regime changes are triggered by sudden economic stress (Psaradakis et al., 2004). Extending the existing research about this topic, the equations add interest rates because they correlate with gold prices and inflation through the Fisher effect theory and the asset pricing models. The results show that Regime 1 fails to witness a significant relationship between gold

prices and inflation, but it turns substantial and positive in Regime 2. Besides, the persistence of Regime 2 is highlighted through the transition probabilities. As a result, gold can be an effective inflation hedge asset. In addition, interest rates are also significantly and negatively related to gold prices in Regime 2, as expected (Neill Fortune, 1987).

These findings derive implications for investors, policymakers, and researchers. Investors can use the results of this study to make better asset allocation portfolio decisions. Even though Vietnam's stock market has recovered and is seeing an impressive expansion in 2023, it is necessary for Vietnamese investors to include gold in their diversified portfolios to protect the value of Vietnamese investors against the heightened inflation rates. Yet, although gold can be used to manage the market risk of high inflation, higher gold demand may worsen the inflation rates. Therefore, fiscal and monetary policies should be considered to avoid that scenario. The authorities can offer more channels for investors to invest their money to prevent storing too much capital in the gold market. For academics, this paper contributes to the literature about the association between inflation hedges and precious metals. However, although the short-term inflation hedging characteristics of gold were confirmed in this, the long-term features are left for future research as the long-term cointegration nexus between gold prices and CPI has been broadly discussed (Dempster & Artigas, 2010; Beckmann & Czudaj, 2013; Bampinas & Panagiotidis, 2015).

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RESEARCH ON THE STATE OF CONSERVATION AND DEVELOPMENT OF TRADITIONAL LACQUER VILLAGE TUONG BINH HIEP

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Abstract: This research delves into the conservation and development of Tuong Binh Hiep Village, a traditional lacquer village nestled in Binh Duong province, Vietnam. With its rich heritage of lacquerware craftsmanship, the village has been a cradle of artistic expression for centuries. However, amidst modernization and changing market dynamics, the village faces challenges that necessitate strategic interventions. Drawing on historical context, conservation initiatives, and a case study of a local business, this research offers an initial exploration into the status of cultural preservation and economic development within Tuong Binh Hiep Village. By analyzing the challenges of artisan retention, market competition, and design innovation, recommendations are formulated to bolster conservation efforts and sustainable development. Government support, collaborative networks, technology integration, and sustainable practices emerge as pivotal avenues for success. Ultimately, this research underscores the urgency of collective actions to ensure that Tuong Binh Hiep Village thrives as a beacon of traditional lacquer craftsmanship while adapting to the evolving global landscape.

Keywords: *traditional village, Tuong Binh Hiep, conservation, development*

I. INTRODUCTION

Traditional lacquer villages in Vietnam are renowned for their rich cultural heritage, unique craftsmanship, and artistic traditions. These villages have played a vital role in preserving and promoting the ancient art of lacquerware. One such village, Tuong Binh Hiep, located in Binh Duong province, stands as a testament to the cultural significance and artistic excellence of traditional lacquerware in Vietnam (Huynh, 2017).

Tuong Binh Hiep village, with its historical legacy and intricate lacquer craftsmanship, has captivated both domestic and international audiences. The village has a long-standing tradition of producing high-quality lacquerware, with skills and techniques passed down through generations (Le, 2021). However, in an era of rapid modernization, Tuong Binh Hiep village faces numerous challenges that affect its conservation and development (Le, 2021).

The preservation and development of Tuong Binh Hiep village are crucial for safeguarding the cultural heritage, sustaining the livelihoods of local artisans, and contributing to the local economy (Minh, 2020). This research paper aims to explore

the state of conservation and development of Tuong Binh Hiep village, with a particular focus on the challenges faced and the efforts undertaken by government agencies and local stakeholders. The paper draws insights from a case study of Tu Bon business, one of the enterprises operating in the village.

Tu Bon business represents a valuable case study within the context of the village's conservation and development. As a family business, Tu Bon has been actively engaged in the production of traditional lacquerware, contributing to the artistic heritage and economic vitality of the village (Tieu, 2020). By examining the experiences and perspectives of Tu Bon's owner, the study gains insights into the challenges, opportunities, and strategies employed by a local business in the village.

The research findings contribute to the discourse on preserving traditional lacquer villages and offer recommendations for sustaining the cultural heritage and fostering the development of not only Tuong Binh Hiep village, but also of other traditional villages across Vietnam.

II. METHODOLOGY

A. Field investigation

Fieldwork constitutes a fundamental approach within anthropology (Lu & Ahmad, 2023). This research employed a field investigation methodology to gather data, aiming to comprehensively comprehend and capture the authentic local context. This approach was chosen to establish a dependable and authentic foundation for the study. From October 2022 to April 2023, the authors visited Tu Bon business, one of the enterprises operating in the Tuong Binh Hiep village, and learned about their operations and development history through taking photos and participatory observation.

Figure 1. Tu Bon business's operational area

Figure 2. Tu Bon's products

B. Interview

The research adopted a combination of semi-structured, in-depth interviews and participant observation techniques, along with the utilization of online websites, printed newspapers, and various literature sources. These methods were employed to gather qualitative data for the study (Lu & Ahmad, 2023). The questionnaires cover Tu Bon's production and operation conditions, restrictions on their products and markets, preservation and development efforts from the business and government agencies.

Figure 3. Artisan Le Ba Linh
(owner of Tu Bon business)

(Source: Tu Bon business)

III. RESULTS

A. Preservation challenges

Preserving the cultural heritage of Tuong Binh Hiep village faces several challenges. The availability and retention of skilled artisans emerge as a crucial concern (Le, 2021). The limited number of skilled craftsmen and the absence of a formal training process pose a risk to the transfer of traditional techniques and craftsmanship to future generations (Ly, 2020; Le, 2021). To address this challenge, initiatives have been taken to attract and train young individuals, ensuring the continuity of the craft. Collaborative efforts between government agencies, artisan associations, and educational institutions have been fostered to facilitate the preservation of traditional skills and knowledge. However, the undertaken endeavors have yielded ineffectual results (Le, 2021).

Another challenge lies in the competition from mass-produced lacquerware and changing market demands (Huynh, 2017; Minh, 2020; Le, 2021). First and foremost, there is a notable scarcity of raw materials, leading to elevated prices that squeeze profit margins. Furthermore, the majority of the remaining production facilities are small-scale operations grappling with capital constraints, hindering their capacity to modernize and expand. The various stages of production and processing within the industry also suffer from a lack of synchronization and cohesion among these smaller entities. To compound these challenges, consumer demand is becoming increasingly discerning, with a growing insistence on products of the highest quality.

The small enterprises in Tuong Binh Hiep have been endeavoring to adopt creative designs, expand their range of products, and incorporate modern elements into traditional lacquerware to capture the interest of a broader customer base. However, these efforts have resulted in limited achievements (Huynh, 2017).

B. Government support and collaboration

Government agencies play a vital role in supporting the conservation and development of Tuong Binh Hiep village. Financial assistance, policy frameworks, and training programs demonstrate the government's commitment to preserving the village's cultural heritage and fostering sustainable development (Minh, 2020).

In recent years, Binh Duong province has initiated measures to bolster the growth of the Tuong Binh Hiep lacquer village. This includes the implementation of a tourism development project closely intertwined with the lacquer village, involving the establishment of a collective brand and the provision of financial aid for environmentally conscious production facilities (Huynh, 2017). The recognition of Tuong Binh Hiep lacquer craft as a national intangible cultural heritage further underscores its importance (Huynh, 2017). Acknowledging

the significance of preserving and enhancing this craft, the Provincial People's Committee orchestrated a comprehensive and effective project for the development of Tuong Binh Hiep Lacquer Village (Ly, 2020). This undertaking encompasses key components: creating an integrated craft village, devising plans for a concentrated lacquer production area to address environmental concerns, and establishing a platform for the collective display of artisanal creations (Ly, 2020). In tandem with these efforts, the project entails crafting guided tours, designing scenic routes, and showcasing the craft village's offerings to both domestic and international tourists, thereby fostering growth and recognition (Ly, 2020).

However, there is a need for continued collaboration between government agencies, local communities, and businesses to effectively implement these initiatives (Ly, 2020). In addition, more robust enforcement and implementation measures must be put in place to ensure the project's effectiveness.

C. Recommendations for conservation and development

Based on the analysis and discussion, the authors have compiled and suggested several recommendations to guide the conservation and development of Tuong Binh Hiep village. These recommendations include strengthening artisan training, fostering design innovation, supporting technological advancements, exploring sustainable materials and practices, and strengthening international connections. Especially, strategic marketing and branding efforts, both domestically and internationally, are essential to promote the unique qualities and cultural significance of Tuong Binh Hiep's lacquerware products (Le, 2021).

Sustainable development in Tuong Binh Hiep village also requires collaborative efforts among various stakeholders. Local businesses, artisans, government agencies, educational institutions, and the wider community must work together to address common challenges, capitalize on opportunities, and ensure the long-term viability of the village's lacquerware industry (Ly, 2020). Knowledge sharing, capacity building, and fostering a supportive ecosystem that encourages innovation, product diversification, and design excellence are key elements of such collaborations (Le, 2021).

Tuong Binh Hiep village needs to strike a balance between preserving traditional techniques and meeting contemporary consumer preferences. By fostering strong partnerships, sharing resources, and aligning efforts, stakeholders can maximize the impact of government support and drive the conservation and development of Tuong Binh Hiep Village.

IV. CONCLUSION

Tuong Binh Hiep village, with its rich cultural heritage and traditional lacquerware craftsmanship, stands as a testament to Vietnam's artistic excellence and cultural identity. Throughout history, the village has been a center of lacquerware production, showcasing the skills and creativity of its artisans. However, the conservation and development of Tuong Binh Hiep village present both challenges and opportunities that require strategic planning, collaboration, and innovation.

The research conducted on Tuong Binh Hiep Village sheds light on various aspects of its conservation and development. Conservation efforts, led by government agencies and local stakeholders, aim to preserve the village's artistic

legacy and promote sustainable development. Initiatives such as policy frameworks, financial support, training programs, and cultural promotion contribute to the preservation of traditional skills, knowledge, and the cultural identity of the village.

The case study of Tu Bon business provides valuable insights into the challenges and aspirations of a local enterprise in Tuong Binh Hiep village. The experiences of Tu Bon business highlight the importance of product diversification, design innovation, marketing, and strategic partnerships in navigating the competitive landscape. The case study offers lessons that can inform recommendations for other businesses within the village, emphasizing the need for a balance between tradition and innovation. Preserving the traditional lacquerware craftsmanship, attracting younger generations to the craft, embracing innovation, and expanding market reach will ensure the village's cultural heritage thrives while meeting the demands of a changing world.

The state of conservation and development of Tuong Binh Hiep village is not only crucial for the preservation of Vietnam's cultural heritage but also for the sustainable livelihoods of the artisans and the economic vitality of the local community. By working together, government agencies, local stakeholders, businesses, and the wider community can foster an environment that values tradition, innovation, and collaboration. Through these collective efforts, Tuong Binh Hiep village will continue to shine as a center of artistic excellence, cultural preservation, and economic growth for generations to come.

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SUPPLY CHAIN RESILIENCE DURING MACRO UNCERTAINTY: AN EMPIRICAL EVIDENCE IN BINH DUONG

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Abstract: This study aims to explore dimensions (agility, robustness, disruption orientation, and resource reconfiguration) of supply chain resilience (SCR) in the context of a developing country facing macro uncertainties. The research model, developed based on previous studies, is tested in manufacturing companies through survey questionnaires and analyzed using SPSS. The findings reveal strong relationships between Supply Chain Agility, Supply Chain Robustness, Supply Chain Disruption Orientation, Resource Reconfiguration, and Supply Chain Resilience. These insights contribute to supply chain resilience knowledge, benefiting academia and industry professionals, particularly in emerging economies dealing with macro uncertainties.

Keywords: *supply chain resilience, supply chain agility, supply chain robustness, supply chain disruption orientation, resource reconfiguration, macro uncertainties*

I. INTRODUCTION

The concept of supply chain resilience has become a crucial field of investigation and implementation due to the growing intricacy and unpredictability encountered by corporations in the present interconnected and globalized commercial atmosphere (Christopher & Peck, 2004; Pettit et al., 2010). The notion of resilience in the supply chain pertains to the capacity of a supply chain to endure, adjust, and recuperate from disruptive occurrences and macro uncertainties, which may have extensive implications on operations and performance (Ponomarov & Holcomb, 2009). These uncertainties may emerge from diverse origins, including economic recessions, geopolitical conflicts, natural disasters, technological interruptions, and alterations in consumer conduct.

In the past few years, macro uncertainties, such as the COVID-19 pandemic, trade wars, and climate-related disasters, have brought to light the susceptibility of supply chains. The global events have emphasized the vulnerability of supply chains (Free & Hecimovic, 2021). Given the current COVID-19 crisis, scholars and industry experts are increasingly focused on the need to shed lighter on how supply chains can enhance their resilience from this perspective (Choi, 2021; Ivanov and Das, 2020; McKinsey, 2020. According to Barroso et al. (2011), supply chain resilience refers to the capability of promptly responding to unfavorable impacts resulting from disruptions that may arise at any given time, with the goal of upholding the objectives of the supply chain.

As Vietnam continues to integrate itself into the global supply chain, it is becoming

more and more vulnerable to a range of macro uncertainties, including economic fluctuations, geopolitical tensions, and disruptions in international trade flows. The escalation of uncertainty within the global value chain has the potential to endanger a firm's financial sustainability due to potential interruptions in its critical supply sources (Lee, 2021).

The outbreak of the COVID-19 pandemic in January 2020 has resulted in significant global losses in the economic, cultural, social, and human spheres. This unprecedented event has exerted immense pressure on the production capacity and supply chains worldwide (Cuong & Tien, 2022). The pandemic has had extensive effects on logistics, transportation, and workforce availability. This has highlighted the importance for Vietnamese companies to establish robust supply chains that can endure and recuperate from unforeseen disruptions.

In the past few years, enterprises and logistics firms in Binh Duong have been compelled to reconsider their supply chain and operational strategies as a result of mounting traffic congestion, escalating land expenses, and consequently storage costs, as well as restricted room for prospective growth. According to the World Bank (2019), Vietnam, including Binh Duong, confronts a variety of difficulties associated with trade tensions, changes in regulations, and global economic dynamics, which have the potential to impact the supply chain network.

While there have been numerous valuable studies conducted on the topic of supply chain resilience, a noticeable gap exists in the existing research specifically focused on investigating supply chain resilience within the context of macro uncertainties. The objective of this study is to bridge this knowledge gap by presenting empirical evidence and insights that are tailored to address the challenges posed by macroeconomic and political uncertainties, particularly in the distinct environment of Binh Duong, Vietnam. We acknowledge the utmost significance of examining supply chain resilience in the face of economic and political uncertainties, and our research endeavors not only to provide valuable guidance but also to outline a roadmap for organizations to enhance their resilience. The findings derived from this study present businesses with an opportunity to strengthen their capabilities and ensure long-term sustainability and success in a constantly evolving and uncertain business landscape.

II. LITERATURE REVIEW

A. Review of previous studies

Kähkönen et al. (2021) specifically examined the impact of the COVID-19 pandemic in Italy and Finland in 2020 on the resilience of the medical device supply chain. Their findings contributed to a better understanding of the effects of dynamic capabilities on supply chain resilience, specifically supply chain management during global pandemic disruptions. Similarly, Juan et al. (2021) aimed to explore the interconnectedness of the five key components of supply chain resilience: visibility, velocity, flexibility, robustness, and collaboration. Moreover, they intend to analyze the impact of these factors on supply chain performance during times of disruption. This research reveals that SC collaboration is an exogenous driver of SC resilience; it has a direct impact on visibility, velocity, flexibility, robustness, and SC performance under disruption. Furthermore, the flexibility of the supply

chain is the sole factor in determining its agility during times of disruption. This trait is directly and indirectly influenced by the supply chain's visibility and velocity. The latter, in turn, is affected by the supply chain's visibility, which is a crucial component of its agility. It enhances the supply chain's velocity and robustness. Ramanathan et al. (2021) explored elements causing the initial disruption in supply chains and made recommendations to businesses based on existing practices and theories. Moreover, Ruel and Baz (2021) examined the impact of supply chain disaster readiness on SC resilience and robustness, as well as the following impact on firm financial performance in the context of the COVID-19 outbreak. Their research emphasizes the importance of SC catastrophe readiness in laying the foundation for resilience and robustness. Furthermore, the results show that SC resilience has a beneficial influence on financial performance; however, the benefits of SC robustness on performance are not established. Modgil et al. (2021) conducted how organizations use AI and considers how AI may improve supply chain resilience by enhancing visibility, risk, sourcing, and distribution capabilities. The conclusions of the study emphasize five crucial domains in which AI can enhance the resilience of the supply chain: transparency, guaranteeing the delivery of the final mile, providing personalized solutions to all parties involved in the upstream and downstream supply chain, reducing the impact of disruptions, and facilitating a flexible procurement strategy. Another research carried out by Queiroz et al. (2022) investigated the antecedents of supply chain resilience revolve around the focal point of supply chain alertness, which plays a crucial role in supporting resilience. The research reveals several conclusions, both expected and unexpected. Among these is evidence that supply chain disruption orientation has a significant positive influence on supply chain alertness. Furthermore, supply chain alertness has a significant favorable impact on resource reconfiguration, supply chain efficiency, and supply chain resilience. They also discovered that resource reconfiguration has a partial mediation impact on the link between supply chain alertness and supply chain resilience. Surprisingly, it appeared that supply chain resilience had a large influence on supply chain efficiency, whilst supply chain efficiency had no effect on supply chain resilience.

Queiroz et al. (2021) pointed out five some dimensions, namely agility, robustness, disruption orientation, and resource reconfiguration, are crucial for the SCR to navigate through the unprecedented disruption in the Brazilian supply chain context. Due to the analogous nature of unpredictable occurrences, such as the COVID-19 pandemic, this model is applicable in showcasing the impact of various enablers on the SC resilience during uncertain times.

B. Key concepts

Supply chain resilience

Supply chain resilience is defined as the collection of strategies and abilities that businesses utilize to withstand and counteract environmental disturbances to facilitate their recovery and reinstate normal operations (Ivanov, 2021). Tukamuhabwa et al. (2015) elucidated that supply chain resilience encompasses the ability of a supply chain to adapt to and overcome disruptions, by timely and cost-effective recovery, ultimately progressing towards a post-disruption state

of operations that is ideally better than the previous state. According to Yao and Meurier (2012), supply chain resilience refers to the capacity to recover swiftly from disruptions and effectively adapt and respond to evolving circumstances in a lasting manner.

Supply chain agility

Supply chain agility is the capacity to quickly adapt to short-term changes in supply or demand and fluidly deal with outside disturbances (Lee, 2004). Jain et al. (2008) determined that supply chain agility is the ability to endure and prosper through rapid and effective market adaptations. It is concerned with change, uncertainty, and unpredictability in its business environment and responds appropriately to change. According to Dubey et al. (2018), supply chain agility refers to the ability of a supply chain to detect short-term, transitory changes in the supply chain and market environment and respond flexibly and quickly to these changes.

Supply chain robustness

As per the definition given by Asbjørnslett and Rausand (1999), supply chain robustness refers to the capacity of a system to withstand an unforeseen incident and resume its intended function while preserving the same stable state that existed prior to the incident. In the context of SC, robustness is defined as the capacity to endure or withstand disturbances without necessitating any modifications to the configuration of the system controller. This is accompanied by consistent performance, both prior to and after the disruptive incident (Fabbe-Costes, 2021). Kitano (2014) emphasizes supply chain robustness as the supply chain's ability to function in the face of internal or external disturbances.

Supply chain disruption orientation

Supply chain disruption orientation pertains to a company's proactive measures in anticipating potential disruptions, bolstered by its knowledge, and understanding gained from past supply chain disruptions (Ambulkar et al., 2014). Bode et al. (2011) suggest that companies can enhance their ability to manage supply chain disruptions by fostering a robust orientation towards such events.

Resource reconfiguration

Resource reconfiguration is a crucial factor in supply chain management, particularly in difficult circumstances (Wei and Wang, 2010). A company's ability to adequately and efficiently adjust its resources to react to environmental disturbances and impacts in a suitable manner is referred to as resource reconfiguration capability (Queiroz et al., 2021). Reconfiguration involves enhancing the synergy among all stakeholders in the supply chain (Chandra and Grabis, 2009). Ambulkar et al., (2014) argued that resource reconfiguration is a crucial factor in developing resilience during supply chain disruptions.

C. Theoritical backgrounds

Theory of Resource-Based View (RBV)

Barney (1991, 2001) and Wernerfelt (1984) are esteemed scholars, who have emphasized the significance of Resource-Based View (RBV) as a theoretical foundation for understanding and clarifying the influence of organizational attributes, including management strategies and competencies, on the long-term growth of corporations. According to the resource-based view theory, a firm's valuable, rare, inimitable, and non-substitutable resources play a crucial role in determining its ability to

enter specific markets and the level of profit it can anticipate (Wernerfelt, 1984). The primary emphasis of the Resource-Based View (RBV) is that a company's competitive advantage is derived from its internal resources, according to Boxall (1996) and Wright et al. (2001). In an environment that is marked by uncertainty and unpredictability, it becomes imperative for firms to possess distinctive capabilities that can help them better leverage their resources, especially when the advantages from these resources are not immediately apparent (Wang and Ahmed, 2007). Due to the fact that resilience is often interconnected with external stressors and/or catalysts such as the Russia-Ukraine war, the RBV - which is a stationary theory - is insufficient in revealing the complex nature of resilience, which encompasses both its precursors and consequences (Do et al., 2022). Adequately managing various categories of resources can empower organizations to enhance their business operations, attain efficacy, and accomplish resilience, primarily when confronted with disruptive occurrences within the context of the supply chain (El Baz and Ruel, 2021).

Theory of Dynamic Capabilities (DC)

The concept of Dynamic Capabilities (DCs), introduced by Teece et al. (1997) and Teece and Pisano (1994), refers to an organization's ability to effectively leverage both its internal and external competencies for the purposes of integration and reconfiguration, while effectively responding to various environmental changes. Dynamic Capabilities (DC) emphasizes fundamental matters such as the firm's competencies and performance, but from a dynamic standpoint (Easterby-Smith et al., 2009). The deployment of DC is influenced significantly by the environmental context, which is regarded as a crucial factor (Yao & Meurier, 2012). Moreover, Eisenhardt and Martin (2000) scrutinize the function of DC in moderately dynamic and highly dynamic environments. They expound that the deployment of DCs in these types of environments differs. For the former circumstance, DC entails uncomplicated routines with steady, thorough, and analytical procedures, whereas in the latter, DC encompasses exceedingly experimental processes with unforeseeable outcomes. As companies operating in various sectors grapple with supply chain disruptions and navigate through crises and uncertainties, it becomes imperative to examine the distinct mechanisms by which dynamic capabilities are developed within specific industries (Su et al., 2022).

D. Hypothesis development

The relationship between supply chain agility and supply chain resilience

Supply chain agility displays the capacity of a company to gather the right mindset, intelligence, and quick processes across the supply chain organization to promptly respond to any uncertain environmental changes (Fayezi & Zomorrodi, 2015). Supply chain agility is considered a crucial element of resilience and can profoundly influence the financial performance of companies (Li et al., 2017). In situations of uncertainty, the ability of the supply chain to be agile is a valuable capability for firms to have in their response (Li et al., 2009). Companies in Pakistan's manufacturing sector are enhancing their supply chain agility to effectively adapt to the constantly changing market conditions and unpredictable environmental factors (Aslam et al., 2020). Therefore, we can hypothesize that:

H1: *Supply chain agility has a positive relationship with supply chain resilience during macro uncertainties.*

The relationship between supply chain robustness and supply chain resilience

Supply chain robustness pertains to the capability of a company to effectively sustain and manage its operational plan amidst any possible disruptions (El Baz and Ruel, 2021). Tang (2006) suggests the implementation of robust supply chain tactics, which would allow a company to execute associated contingency plans efficiently and effectively during a disruption, thus bolstering the supply chain's resilience. Consequently, it contributes to SCR. Therefore, this study proposes the following hypothesis:

H2: *Supply chain robustness has a positive relationship with supply chain resilience during macro uncertainties.*

The relationship between supply chain disruption orientation and supply chain resilience

Supply chain disruption orientation is defined by a company's ability to identify and acknowledge potential disruptions, as well as their capacity to analyze and derive knowledge from past disruptions (Bode et al., 2011). When confronted with disruptions in the supply chain, companies can act by renovating or adjusting their risk management infrastructure and drawing on previous disruptions to reduce risks and capitalize on new prospects. Through such efforts, companies can cultivate a robust orientation towards managing supply chain disruptions (Ambulkar et al., 2014). Bode et al. (2011) suggest that organizations have the potential to enhance their ability to respond to disruptions by fostering a robust orientation towards managing supply chain disruptions. This statement suggests that companies with a strong focus on managing supply chain disruptions have the capability to implement proactive measures to expedite the stabilization of their business. Therefore, the next hypothesis is developed:

H3: *Supply chain disruption orientation has a positive relationship with supply chain resilience during macro uncertainties.*

The relationship between resource reconfiguration and supply chain resilience

Resource reconfiguration refers to a firm's ability to modify, restructure, and rearrange their resources to accommodate changes in the external environment surrounding the firm (Marsh and Stock, 2006). Resource reconfiguration plays a pivotal role in shaping the resilience of a firm (Zhang et al., 2022). By gaining insights from the external environment, companies can effectively reconfigure and adjust their resources and procedures to cultivate competencies that grant them enduring advantages in the wake of a crisis (Ongkowijoyo, 2020). Therefore, the author introduces the following hypothesis:

H4: *Resource reconfiguration has a positive relationship with supply chain resilience during macro uncertainties.*

The study utilizes the theory of resources-based view (Barney, 1991, 2001; Wernerfelt, 1984) and the dynamic capabilities theory (Teece et al., 1997; Teece and Pisano, 1994), incorporating four independent variables and one dependent variable as follows:

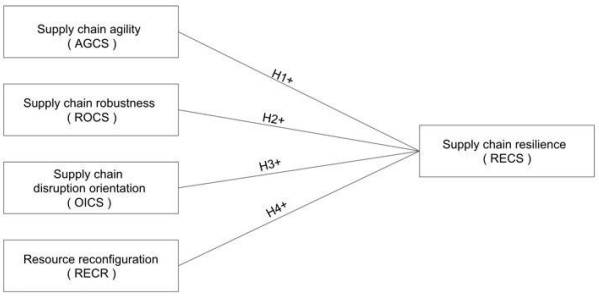

Figure 1. Research model adapted from Queiroz et al. (2021)

III. METHODOLOGY

A. Sampling method

The study employs a quantitative descriptive approach with a cross-sectional research design to examine and assess the impact of certain factors that contribute to supply chain resilience. This research uses conviniece sampling method. The sample size of this topic is calculated using the following formula:

n=m*5 (Hair et al., 2006)

n: sample size

m: number of questions

Applying the above formula, this study's sample size will be 105 samples (5*21= 105). The professionals who completed the questionnaire were provided with a comprehensive understanding of the study's purpose before they filled it out. It was expressly stated that the gathered empirical data would serve solely an academic function and remain anonymous.

B. Methodology

Data collection was conducted through the utilization of self-administered online questionnaires. The questionnaire utilized Google Forms as its structure. We gathered information from June through July of the year 2023. The study's aim and the specifics of participation were clearly stated in 181 participant information sheets. Ultimately, this was done to ensure complete transparency and understanding among all parties involved.

This research employs the research scale of Queiroz et al. (2021). The questionnaire every item was thoroughly scrutinized by proficient researchers in order to ascertain its content validity for this particular study.

The questionnaire including 2 parts:

- Part 1: The questionnaire utilized a 5-point Likert scale, wherein the endpoints were defined as "strongly disagree" and "strongly agree". To obtain the opinions of individuals on 5 dimensions, responses were encoded from "1" to "5".
- Part 2: The demographic information of the respondents includes their gender, current level of education and work experience.

After completing the necessary tasks of data entry, rigorous data cleaning, and conducting meticulous accuracy audits, SPSS was utilized for data analysis. A probability < 0.05 was deemed to be statistically significant for all the tests. Reliability was tested using Cronbach's alpha, while exploratory factor analysis (EFA) was conducted to investigate the independent and dependent variables with the aim of refining the research model and scales. The analysis of the correlation among the different perceived levels of supply chain resilience was conducted through the utilization of Pearson. Multiple regression analyses were conducted with the objective of determining the various degrees of supply chain resilience.

IV. RESULTS

A. Demographic profile

The questionnaire was completed by 181 participants. 45.9% of the participants are males, the remaining are females and others. 33.1% of participants are under 30, 16.6% are from 30 to under 40, 24.9% are from 40 to under 50, 17.7% are from 50 to under 60 and 7.7% are over 60. For education level, 26% are undergraduate, 53% are graduate and the remaining are postgraduate. In terms of work experience, 34.3% had experience of less than 5 years, 11.6% had experience between 5 to 10 years, 16.6% had experience from 10 to 15 years, 17.1% had experience from 15 to 20 years, while the remainder had more than 20 years of experience.

B. Reliability test

Table 1. Reliablity test

Variable	Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Resource reconfiguration	RECR1	10.62	5.593	.586	.814	0.828
	RECR2	10.66	5.458	.626	.796	
	RECR3	10.69	5.382	.654	.783	
	RECR4	10.71	4.975	.756	.735	
Supply chain robustness	ROCS1	10.37	5.012	.636	.753	0.808
	ROCS2	10.42	4.934	.625	.758	
	ROCS3	10.66	5.049	.598	.771	
	ROCS4	10.59	5.011	.635	.754	
Supply chain agility	AGGS1	10.94	5.075	.603	.724	0.784
	AGGS2	10.88	5.174	.585	.733	
	AGGS3	10.86	5.209	.578	.737	
	AGGS4	10.97	5.083	.592	.730	
Supply chain disruption orientation	OICS1	14.62	7.393	.597	.806	0.830
	OICS2	14.65	7.673	.661	.787	
	OICS3	14.59	7.188	.648	.791	
	OICS4	14.78	8.026	.566	.813	
	OICS5	14.69	7.606	.679	.782	
Supply chain resilience	RECS1	11.31	5.259	.603	.727	0.785
	RECS2	11.38	4.948	.611	.722	
	RECS3	11.35	5.339	.571	.742	
	RECS4	11.41	5.043	.582	.737	

Reliability was tested using Cronbach's alpha and Corrected Item-Total Correlation results. A high value of Cronbach's alpha, which usually falls between 0 and 1, indicates that the items on the scale are significantly linked and dependable when assessing the construct. On the other hand, a low alpha value implies that the items may not reliably measure the same idea (Taber, 2017). For corrected items to be approved, it is necessary that the correlation be equal to or exceed 0.3; otherwise, the item will be eliminated (Nunally, 1978). The results of the reliability analysis indicate that all scales exhibit high quality, as evidenced by alpha values > 0.7, which is a strong indicator of reliability. The Corrected Item-Total Correlation of independent and dependent variable are ranged from 0.566 to 0.756, therefore all items are approved.

C. Exploratory factor analysis

Table 2. KMO and Bartlett's test

		Independent variable	Dependent variables
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.824	.791
Bartlett's Test of Sphericity	Approx. Chi-Square	925.885	189.333
	df	105	6
	Sig.	.000	.000

0.5<KMO=0.824<1, the research was conducted with appropriate sampling, as demonstrated by the results. The score of Sig. Bartlett's Test of Sphericity was a mere 0.000, clearly below the threshold of 0.05. Bartlett's Test of Sphericity confirmed that the items within a component are equivalent, and that the data used for factor analysis was both acceptable and appropriate.

According to the table's Kaiser-Meyer-Olkin Measure of Sampling Adequacy, the dependent variables' items show a strong association of 0.791. As all requirements are met, factor analysis is a suitable approach for this dataset. Additionally, the Sig Bartlett's Test of Sphericity (0.000) confirms the appropriateness of factor analysis for this research.

D. Correlation

Table 3. Correlation analysis

		RECS	RECR	ROCS	AGGS	OICS
RECS	Pearson Correlation	1	.636**	.572**	.476**	.544**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	181	181	181	181	181
RECR	Pearson Correlation	.636**	1	.386**	.372**	.381**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	181	181	181	181	181
ROCS	Pearson Correlation	.572**	.386**	1	.319**	.365**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	181	181	181	181	181
AGGS	Pearson Correlation	.476**	.372**	.319**	1	.301**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	181	181	181	181	181
OICS	Pearson Correlation	.544**	.381**	.365**	.301**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	181	181	181	181	181

Based on the Pearson correlation analysis results, it can be concluded that the Sig value is less than 0.05, indicating a high level of significance. It can be deduced that there exists a direct relationship between the independent variables and the dependent variable. A noteworthy correlation of 0.636 is evident between the variable "Resource reconfiguration (RECR)" and the model, while the variable "Supply chain agility (AGCS)" exhibits the lowest correlation level with the model at 0.476. All of the correlation coefficients indicate positivity, which suggests that there is a significant and positive relationship between supply chain resilience and resource reconfiguration, supply chain robustness, supply chain agility, and supply chain disruption orientation.

E. Regression

Table 4. Regression analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics		Adjusted R Square	Durbin-Watson
	B	Std. Error	Beta			Tolerance	VIF		
(Constant)	-.106	.242		-.441	.660				
RECR	.360	.054	.367	6.734	.000	.739	1.353	.605	1.952
ROCS	.287	.054	.284	5.339	.000	.774	1.293		
AGGS	.174	.052	.174	3.342	.001	.809	1.237		
OICS	.263	.056	.249	4.697	.000	.783	1.277		

The model's Adjusted R square value of 0.605 suggests that it is highly significant and well-aligned with the observed variable. This suggests that approximately 60.5% of the variability in the dependent variable, "supply chain resilience", can be explained by incorporating the four independent variables into the model. Durbin-Watson test statistic value is recorded as 1.952, lying between 1.5 and 2.5, thus indicating the independence of residuals and the validity of the model.

Table 5. Result summary

Hypothesis	Std. Coefficient Beta	Testing result	Ranking impact
H1	0.636	Supported	1st
H2	0.572	Supported	2nd
H3	0.476	Supported	4th
H4	0.544	Supported	3rd

V DISCUSSION AND FINDINGS

After processing and computing the collected data with SPSS, the results show that all four independent variables, including Supply chain agility, Supply chain robustness, Supply chain disruption orientation and Resource reconfiguration, have a positive relationship to Supply chain resilience in the context.

It is evident that the foremost crucial aspect with the highest Standardized Coefficient of Beta ($\beta = 0.636$) is the supply chain agility, and the Significant value of 0.000 is undoubtedly acceptable. The prior research of Queiroz et al. (2021), on the other hand, suggested that supply chain agility was not to be a reliable indicator of supply chain resilience in the face of significant disruptions. The literature indicates that supply chain agility is a crucial concept for enhancing competitiveness in a rapidly changing and unpredictable industrial landscape (Brusset, 2016).

Regarding the second hypothesis, we suggested that "Supply chain robustness has a positive relationship with supply chain resilience during macro uncertainties". The result of this partnership received strong approval, thus confirming the importance of a robust supply chain in times of complex disruptions. The literature has also highlighted the significance of supply chain robustness as a crucial proactive ability that enables firms to effectively deal with disruptions, thereby bolstering their operational capacities and ultimately enhancing supply chain resilience (Wieland and Wallenburg, 2012).

In regard to the third hypothesis, we stated that "Supply chain disruption orientation has a positive relationship with supply chain resilience during macro uncertainties". Furthermore, we have discovered a robust correlation within this particular connection. The research confirms that effectively handling supply chain interruptions is crucial during times of major crises. This is mainly because of the substantial influence it has on the supply chains. In this regard, our discovery aligns with the existing literature that underscores the significance of gleaning insights from past disruptions (Bode et al., 2011; Ambulkar et al., 2014).

Finally, in the fourth hypothesis, we proposed that "Resource reconfiguration has a positive relationship with supply chain resilience during macro uncertainties". We found a strong relationship between this factor and supply chain resilience. Hence, the findings validate the significance of resource reconfiguration competence during a major crisis, primarily due to the gravity of its impact on supply chains, leading to scarcity of resources. The literature has also highlighted the importance of resource reconfiguration in the supply chain, especially in the context of disruptions (Wei and Wang, 2010).

VI. CONCLUSION

The main objective of this study is to determine whether there was a relationship between four variables and supply chain resilience in Binh Duong during macro uncertainties. The survey managed to elicit responses from every participant, amounting to a total of 181 responses. According to the demographic data, the majority of the participants are female and primarily fall under the age of 30. All four elements, namely Supply chain agility (AGCS), Supply chain robustness (ROCS), Supply chain disruption orientation (OICS), and Resource reconfiguration (RECR), have positive relationship with Supply chain resilience (RECS). Furthermore, the research found that Supply chain agility has the biggest impact on Supply chain resilience. Firms will be able to provide resilience and sustainability against environment uncertainties with an agile approach.

Upon the implementation of the Regression Model, the following four factors y have the strongest relationships with the resilient of supply chain: Supply chain agility ($\beta = 0.636$), Supply chain robustness ($\beta = 0.572$), Resource reconfiguration ($\beta = 0.544$), and Supply chain disruption orientation ($\beta = 0.476$).

The implications of this research emphasize a crucial practical aspect for businesses and policymakers in Binh Duong and beyond: Supply chain agility emerges as the pivotal factor in strengthening supply chain resilience during periods of macroeconomic and political uncertainty. In a dynamic and constantly evolving environment, the capability

to promptly adapt, reorganize resources, and address disruptions is of utmost importance. Consequently, organizations should prioritize investments and strategies that enhance their supply chain agility. This may entail the implementation of flexible production processes, efficient communication channels, and the establishment of collaborative partnerships with suppliers and logistics providers. Policymakers, on the other hand, should contemplate the creation of a conducive environment that promotes and supports such agile practices within the business community. By prioritizing the enhancement of supply chain adaptability, both corporate entities and governmental officials can engage in cooperative efforts to fortify the robustness of supply chains, thereby guaranteeing their capacity to withstand and thrive in the presence of larger economic and political uncertainties, ultimately making a valuable contribution to the stability and expansion of the region's economy.

It's important to recognize a few limitations in our study. Firstly, because we used a cross-sectional survey and convenience sampling, we cannot say that our findings apply to all supply chain situations or that they show cause and effect. The people we surveyed might not represent everyone in the industry, and our data reflects a specific point in time. Also, our study focused on Binh Duong, so we cannot automatically extend our results to other places with different conditions. In future research, using different methods and looking at changes over time could help address these limitations and give us a broader view of supply chain resilience.

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THE APPLICATIONS OF RECRUITMENT ANALYTICS TO IMPROVE RECRUITMENT PRACTICES FOR ORGANIZATIONS IN VIETNAM

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Abstract: Recruitment is considered as one of the most crucial roles of the strategic HR plan because employing the right people can help that organization thrive. Analytics has been popular and well-set in domains of Marketing, IT, Finance, etc. Its application has traveled in the HR domain and been proved to bring tremendous benefits to companies that utilize its power. The objective of this research is to see how to improve the recruitment practices within organizations in Vietnam by using Recruitment Analytics. The result indicated that Recruitment Analytics allows recruiters to make evidence-based decisions that help the company to cope with recruitment challenges better than those that do not use the analytic technique. Analytic skill gap, underinvestment in technology, and willingness of recruiters to learn analytics are the top three reasons that prevent recruitment analytics become popular in the HR domain. Besides investing in technology to support recruitment activities, it is recommended that companies should get on board with recruitment analytics as soon as possible to gain the full benefits of this approach by preparing themselves in terms of human resource by buying, building, or borrowing depending on specific needs and budget available at the companies. The insights gained in this research will provide a framework for organizations and researchers to offer more solutions to make recruitment analytics become a mainstream adoption in each organization.

Keywords: *recruitment analytics, HR analytics, big data, attrition, data metrics*

I. INTRODUCTION

To win the "war for talent" currently happening in Vietnam, organizations need to better understand the strengths and weaknesses of their Recruiting process to optimize their recruitment practices. Identify and measure the right Recruitment metrics for recruitment is a very efficient way to identify what and where to improve, but Recruitment Analytics practices seem to be underused by companies in Vietnam.

The future of the companies depends on their Human Capital, so the impact of recruitment strategies on the bottom line of an organization is real. With good recruitment strategies and activities, an organization can reap a positive influence of attracting, recruiting the top talent available on the job market that ensures having the right people (knowledge, skills, characteristics, and attitude) for the right job. In one report of BCG Consulting, recruitment was ranked the top important function of HR among 22 other functions because it has the

highest impact on revenue and profit margins of an organization (Kapur, 2020; Sullivan, 2015). On-going improvements in recruitment is a must if an organization wants to keep up with its competitor on the business market as well as the job market. However, it is often vague and hard to decide which part to improve in recruitment when recruiters are blind to their own performance and recruitment impact on the company's performance. Recruitment analytics offer a quantitative approach to quantify necessary insights, enabling recruiters to make operational improvements to achieve higher efficiency, effectiveness, and impact on business outcomes (Deloitte, 2017; Mohapatra & Sahu, 2017).

This study, therefore, seeks to explore how to improve the recruitment practices within organizations in Vietnam by using recruitment analytics. This research is conducted to make HR practitioners work more efficient, effective, and data-based. The main question of this research is to answer "How to improve the recruitment practices within organizations in Vietnam by using recruitment analytics". The main objective of this study is to investigate the current recruitment practices to know whether or not the companies in research using Recruitment Analytics and how Recruitment Analytics can help recruiters make better hiring decisions based on insights gained from data collected throughout the recruitment process and newcomers' performance.

A. Recruiting challenges in Vietnam's context

Vietnam faces skilled and high-tech labour struggle as the economy expands and its direction changes. Vietnam - a country located in Asia is a developing nation with total population of 95,540,395. Political and economic reforms since 1986 have promoted economic development, rapidly turning Vietnam from one of the poorest countries in the world into a low-middle-income country. Since "Doi Moi reform program 1986", Vietnam accelerate its economic strengths in the region thanks to the movement from agriculture to industry and services (Export Entreprises SA, 2020); the Distribution of gross domestic product (GDP) across economic sectors from 2009 to 2019 in Vietnam is clearly illustrated in the bar chart below.

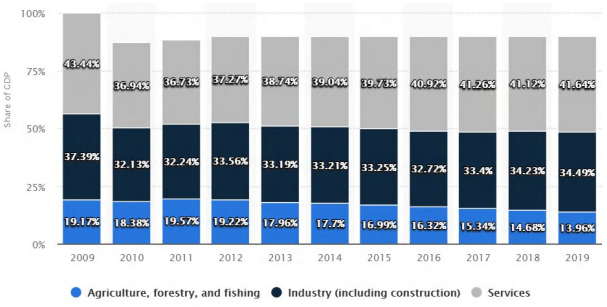

Figure 1. Distribution of gross domestic product (GDP) across economic sectors from 2009 to 2019 in Vietnam

(Source: Statista.com; Vietnam - GDP Distribution across Economic Sectors 2019, 2020)

From 2009-2019, there is also a shift in employment allocations between different job domain, corresponding to the shift from Agriculture to Industry and Services (*Vietnam - Employment by Economic Sector 2009-2019*, 2020).

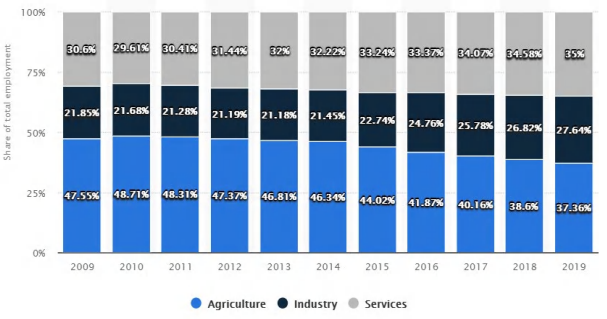

Figure 2. Vietnam: Distribution of employment by economic sector from 2009 to 2019

(Source: Statista.com; Vietnam - Employment by Economic Sector 2009-2019, 2020)

Changing directions for economic development by the government entails high demand for skilled and quality workforce, especially in High-tech and Service industry. According to a report of Vietnamworks 2019 (Iris Data Driven Agency, 2019), Finance / Investment, Banking, Information Technology, Marketing, Construction are currently the five highest-paid jobs in Vietnam. Positions in those industries require candidates with professional knowledge and education, which posts challenges for recruiters compared to just hire manual labor workers. According to Vietnamworks report, foreign-invested companies required highly-skilled workers and senior levels, which explains the growing demand for senior staff at 10-15% over the last few years.

Unlike previous generation who were probably working for the same company for almost their lives, millennials are likely to job-hop every one to three years (Pandey, 2019). According to a report of Gallup in 2016, 36% of the interview reported their willingness to change the organization to look for new opportunities in the next 12 months (Inc, 2016). Talents from one company find it is easy to switch the others thanks to the opportunities available on the job market. While senior staff for positions like IT workers, engineers, and managers was already in shortage, the turnover rate among skilled workers is increasing. As millennial is likely to hold 15-20 jobs during their career (Meister, 2012), it is time for recruiters to apply analytics practices for better analysis of how to simplify and improve the recruitment and hiring process.

To sum up, Vietnam is considered to be a favorable nation for foreign-invested companies and this country is becoming even more attractive to multinational manufacturers thanks to its cheap labor, heavily-invested infrastructure, loosen restrictions for legal requirements, and an emerging market to consume the products. To take the advantage of the favorable conditions, Vietnam need to prepare for the opportunities regarding human resources management especially in recruitment to cope with the future challenges to come.

B. The important roles of Recruitment Analytics

In general, HR metrics and analytics offer critical insights that enable practitioners to make positive actions to improve their work performance. HR analytics relates to people and processes in different HR functions like recruitment, retention, talent management, compensation, etc. the insight gained from analysis help companies shape their strategies and policies that have a long-term and sustainable impact on the business. When apply HR analytics into Recruitment (so called Recruitment analytics), it helps track, measure, collate and analyze candidate and employee data for making better hiring decisions (Koshy, 2016). There are many challenges that recruiters must encounter when they have to fulfill a vacancy position such as lack of a qualified pool of candidates, unmatched applicants, vacancy urgency, or complicated hiring process of a company that likely to drive a good candidate away, etc. Low performance in recruitment can be contributed to many subjective and objective reasons so it is extremely important to conduct data analysis to find out the source of problems, both when the recruitment need is successfully or unsuccessfully filled.

Recruitment practices in Vietnam must change in order to keep up with the opportunities of the new world and of the job market. Doing recruitment in the same way without the help of the strategic application of HR analytics will rob the organization of opportunities of having the talented hired as well as wasting the recruitment budget for unnecessary activities. When making recruitment analysis, recruiters should be able to answer why or why not that they choose to select certain job boards instead of others, internal or external recruitments, etc. When it comes to human, not everything can be measured but there are certain criteria in recruitment that recruiters or hiring managers can measure or evaluation for better management and possible improvements, for example, time for recruitment, the effectiveness of different job board, percentage of a matched CV, profiles are more likely to stay in the positions, etc. Google, Apple, Amazon, or other big names in the business world take their recruitment strategies seriously by investing millions of dollars and a tremendous amount of time to quantify the impact of recruiting by using predictive modeling and algorithm to predict success probabilities of candidates after being hired (Momin & Mishra, 2017; Shrivastava et al., 2018). Looking at Google's army of talents and their impressive expansion over time, it is no doubt that their success in human capital strategies including recruitment and selection contribute to the success of the whole company.

Different from other domains like Marketing, Finance, healthcare, Computing, Telecom, etc., the application of data analysis in the HR domain is not as mature and popular (Ajah & Nweke, 2019; Memon et al., 2017; Sravanthi, 2015). HR practitioners often make sense of the issues and propose solutions based on a hunch and their experience without having any evidence to base their reasoning (Angrave et al., 2016). Compared to the popularity of using HR analytics by companies all over the business world, the adoption of such analytics in Vietnam organizations is considered to be left behind. According to a new report by Grand View Research, the market size for HR Analytics worths $6.29 Billion by 2027 due to the need for companies to attract, retain and develop the right talents (Grand View Research, 2019). Vietnam is off the list from neighboring nations that are adopting HR analytics in the Asia Pacific region, which are Australia, China, Hong Kong, India, Japan, Singapore, and Thailand. However, by recognizing the importance of using HR analytics for competitive advantage, many organizations in Vietnam have begun to use data to understand their personnel, maximize productivity and improve efficiency for the entire enterprise (iELT, 2018).

Fortunately, the trend of analytics increasingly takes organization's attention on two areas: effective recruitment and employee retention, reported in a conference dated 29/05/2018 in Hanoi between the Institute of Economics and International Trade (iEIT) in cooperation with SIFT Analytics Group from Singapore (iELT, 2018). Therefore, the future of recruitment is to use big data and analytics to get insight and improve recruitment practices.

II. METHODOLOGY

To have the insight of current recruitment practices in Vietnam as well as uncover thoughts and behaviors of recruiters about using Recruitment analytics, qualitative research is an appropriate approach. This research is exploratory because there are few studies

conducted to find out the current recruitment problems and challenges in organizations in Vietnam and how HR analytics can contribute to the improvement of recruitment practices. An interview is the most suitable method to get insights directly from recruiters on how they are doing their daily tasks to propose ways to make improvements through Recruitment analytics.

- Problem: Identify and measure the right Recruitment metrics is a very efficient way to identify what and where to improve but applying HR Analytics in recruitment practices seems to be underused by companies in Vietnam.
- Proposition: The application of Recruitment analytics can optimize the recruiter's practices for companies in Vietnam.
- Hypothesis: Recruiters make better decisions by using Recruitment Analytics.
- The scope and boundaries of this research are in Vietnam.

The qualitative approach is taken for this research instead of the quantitative approach because of two main reasons. Firstly, by interviewing one to one with participants, I can dive deeper into current practices of recruitment and the obstacles that come with them. Before proposing the application of Recruitment analytics, it is necessary to know what and where to improve. Conducting interviews allows me to ask to follow up questions and as well as be able to have chances to explain in detail Recruitment analytics definitions and its application in the HR domain, specifically in recruitment. Secondly, the interviewees' perspectives and understanding about HR analytics and its application in recruitment vary from one person to the other, so using qualitative approach is the most suitable one for this research.

To conduct this research, there are two sources of data: (1) the primary data which is directly collected through a semi-structured interview and (2) secondary data from official reports, archives, publications, and previous studies.

The interviews were conducted with 10 HR professionals in companies belonging to 4 fields of IT, Manufacturing, Banking, and HR service. The interviewees are either in charge directly in the whole recruitment process or managers whose duties are to supervise and plan the recruitment in the company. The results will be presented and discussed following the key findings of current recruitment practices and challenges, data collection, recruitment analytics, and perspectives of HR professionals regarding the adoption of Recruitment analytics.

For data analysis, both inductive and deductive approaches employ a pre-determined framework and a pre-identified set of codes to analyze the data. The questions are based on steps of the recruitment process which are often followed by most companies even though small adjustments are possible (including 6 steps starting from Preparing, Attracting, Screening, Selecting, Hiring, and Evaluating). Based on the coding frameworks and through the interviews, NVivo is used to code, build the pattern, categorize, and group the common steps and challenges in recruitment into the themes.

Table 1. Coding for recruitment themes

Theme	Coding
Challenges in Recruitment	Shortage of qualified candidates Fierce competitions Lacking of data
Decision making throughout the recruitment process	Experience Hunch Data-driven
How to improve the recruitment activities	Good planning Diversify sources Combine with other HR function Data-driven decision
Perspective of using analytics in recruitment	Skill-related: Hard to learn, Time-consuming, Complicated, Should not be done by HR professionals Technology-related: expensive, not have specialist Strategy-related: company do not think Recruitment analytics is important

For secondary data, articles regarding "effective recruitment practices" and "HR analytics" are the two key themes of the selected academic articles.

An interview guide is designed to aid the data collection process, which contained a list of 12 key questions with 1 to 3 follow-up questions. The interview will last from 45 minutes to 1 hour and a half. 10 interviewees working in 10 different companies will have a direct conversation in either Vietnamese or English to investigate how they conduct recruitments activities in their companies and to know whether Recruitment analytics is applied. The sample was chosen based on their company scale and industry which required a high volume of recruitment demand.

The interview questions will have two main parts. The first part will be an overview and investigation on which recruiting metrics are most important for the company given their specific recruiting demand while the second part is how recruiters apply analytics in their recruitment practices and challenges that they encounter throughout the recruitment process. The second part of the interview will be more focused on the recruiting steps of different companies to see how they can make improvements by using Recruitment analytics.

III. RESULTS AND DATA ANALYSIS

Table 2. Number of recruitment metrics used by each recruiter

Stages of a recruitment process	Metrics for Recruitment	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
		Talent Acquisition Specialist	Recruiter	HRBP Assistant Manager	Regional Recruitment Manager	Recruiter	Senior talent acquisition	HR Manager	Recruitment consultant	HRBP	Senior Recruiter
Attracting	Cost Per Hire	-	-	x	x	-	x	x	-	x	-
	Applicants per opening	-	x	x	x	-	-	-	x	x	-
	Source of hire	-	x	x	x	-	-	-	-	x	-
Screening	Time to screen 1 potential CV	-	-	x	x	-	-	-	-	x	-
Selecting	Selection ratio	-	-	x	x	x	-	x	-	x	-
Hiring	Interview to Hire Ratio	-	-	x	x	-	-	x	-	x	-
	Time to hire	-	-	x	x	-	-	x	-	x	-
	Offer Acceptance Rate	x	-	x	x	-	-	-	-	x	-
	Time to Fill	x	-	-	-	-	-		-	x	-
Evaluation	Quality of Hire	-	-	-	-	x	x	x	-	x	-
	First-year attrition	-	-	-	x	-	x	x	-	x	-
Others	Employee-related metrics (happiness index, engagement vs performance)	-	-	-	-	-		-	-	x	-
Number of metrics used		**2**	**2**	**7**	**11**	**2**	**3**	**6**	**1**	**12**	**0**

Looking at Table 2, we can see that recruiter position often use 2-3 metrics to evaluate their performance while HRBP position or manager level used at least 6 metrics to make recruitment evaluation. Cost per hire and first-year attrition is used by all HRBP and manager level while being ignored by recruiters. Here are the responses from the interview.

"Actually I don't know how much does it cost to hire one person…" (R1)

I don't know about the cost, my manager will work with outside agency for recruitment. I often collect data and use it to make report to my manager. For example how many CVs and where I found them. (R2)

"My manager just tell me how many people he needs and I just rush into building Booleans and sourcing CV to meet the requirements. Actually I don't know how much does it cost to hire one person because I often search on the job boards provided by the company." (R1)

"Managing many metrics is hard and confusing sometimes but it is important to have the performance measured by metrics, Respondent 4 said."

"Recruitment should be closely integrated with other function of business as well as sub-function in HR like talent management, engagement, C&B etc. Even though it is hard and confusing as too many metrics crossing each other but we must try." (R4)

"There is only one recruiter who confirmed that she does not have any metrics for evaluation and follow the daily instruction given by her manager."

"I just receive request to search CV, I don't have any metrics. My manager tell me what to do." (R 10)

Table 3. The percentage of metrics for recruitment used by the recruiters

Stages of a recruitment process	Metrics for Recruitment	Percentage
Attracting	Cost Per Hire	50%
	Applicants per opening	50%
	Source of hire	40%
Screening	Time to screen 1 potential CV	20%
Selecting	Selection ratio	50%
Hiring	Interview to Hire Ratio	30%
	Time to hire	40%
	Offer Acceptance Rate	40%
	Time to Fill	30%
Evaluation	Quality of Hire	50%
	First-year attrition	50%
Other	Employee-related metrics (happiness index, engagement vs performance)	10%

According to the interview results illustrated in Table 2 and Table 3, 60% the respondents said that they do not engage in data analytics throughout the recruitment process. 40% use data to improve the process (Respondent 3,4,7,9).

"Sure, it you work for projects then you know information is power. How can you make quick decisions without information? We need historical data to make our job faster. Let's say if I do now know which job board to use then I just spend effort equally for all job boards while they are only effective for certain job types." (R3)

"Every data is needed to make decision from the beginning to the end." (R4)

"We actually created an analysis team to do business analysis and we add HR analysis in to get insight of the HR part in the business. We started it long ago but just see how to take advantages of it 3-5 years recently I think. We have run different scenarios and make the most optimum decision with all the collected information at hand." (R7)

"All data must be recorded, we also make feed-back system to collect all kinds of data from candidates, employees, former employees to understand their needs and make improvement." (R9)

Hunch and experience are the grounds in which all recruiters in the research make their decision throughout the recruitment process. The recruiters admitted that sometimes they just know when they talk to the right candidates by experience and make the decision even though there is no clear evidence whether or not the decision made is optimized or effective (Figure 4). 80% of the recruiters shared that they are unaware of the overall strategies of the

company and only need to recruit according to individual KPI assigned by managers monthly, which is excluded from cost-related metrics, business goals, or the reason why their hiring positions are important to the business. That is to say, recruiters may not see their direct impact on the whole performance of the business.

One thing that stands out in the interviews is that only 50% of recruiters made post-recruitment evaluation by using metrics such as quality of hire, one-year attritions to assess the recruitment performance, or financial indicator like cost per hire. In Vietnam, the level that currently has the ability and the access to data analysis remains at the managerial level while recruiters who are directly involved throughout the process do not frequently analyze data to improve the process. They mostly follow instructions of their hiring managers or do the recruitment routinely without reviewing the whole process for improvement.

The data used in the recruitment process are HR-internal data, recruitment historical data, previous internal reports, agency reports. Regarding the data collection process, there are 7 respondents out of 10 said that they either do not collect data or do it manually without the support of the IT system. One respondent shared how the IT system supports him in the data collection process so he can, later on, using the information for analysis.

Looking at Figure 3 below, we can see that in general there are 9 difficulties that recruiters perceived in their job. High competition in the labor market, the high volume of irrelevant CVs, and under budget for recruitment activities are the top three challenges that recruiters perceived in recruitment in Vietnam.

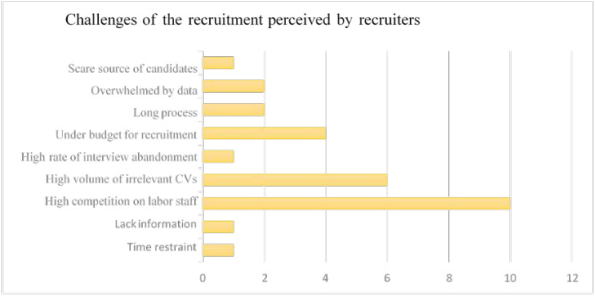

Figure 3. Challenges of the recruitments perceived by interviewees

Among the 10 recruiters, less than half of them using the metrics to evaluate cost per hire, applicants per opening, selection ratio, quality of hire, and first- year attrition. Even though Time to fill and Time to hire is used by around 30%-40% of the recruiters, only 20% interviewer care about the time necessary to find 1 potential candidate while the other care more about the time necessary to process the whole recruitment process.

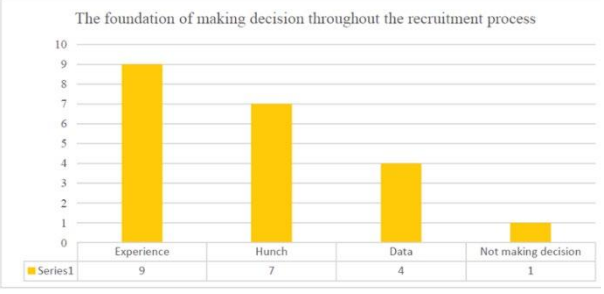

Figure 4. The foundation of making decision throughout the recruitment process

The company that utilizes the power of data analytics believed to finding ease in recruitment stages that other organizations find great challenges. In particular, in the sourcing stage of recruitment, Company B in IT (R6) formed partnership with Bach Khoa University (Technological university of National University) to have potential IT candidates

identified at the very early stage to offer them an internship or Company introduction within the campus so the company find little difficulties in seeking for candidates. Company B has those insights from analyzing their historical data, HR-internal data, and financial data relating to cost for recruitment. By focusing on one good source of the candidate, Company B found fewer difficulties in finding applicants while saving recruitment-related costs in the long-term. Therefore, it is reasonable to believe that data analytics have positive contributions to the efficiency and effectiveness of recruitment by offering valuable insights that help managers make informed decisions.

Regarding the perspectives of HR should learn to do analytics, there are 2 contrasting responses from the 10 interviewees, in which the majority of them agree on the idea that data analytics should be better handled by the experts who have engineer, IT, science-related background. They believed that data analytics is complicated and requires technical knowledge which is neither their strength nor interest. However, there are 2 recruiters show enthusiasm and willingness to learn analytics to improve their performance even though they still admit great difficulties and limitations for HR professionals to get on board with this practice, namely the competencies to process data and the lack of official training for doing so. Coincidentally, the two recruiters support the ideas of learning analytics are having IT and engineering background, meaning that may be having previous training, technical mind-set and competencies enable them to be more willing and open to adopting analytics in recruitments than others HR professionals who come from business management divisions.

Table 4. Correlation between educational qualifications of recruiters in relation to their perspective of learning Analytics

Respon-dent	Educational Qualification	Company industry	Should HR professionals learn Analytics?
R1	MBA HRM	IT	No
R2	MBA International Business	Manufacturing	No
R3	Bachelor of Engineering	HR Service/ Outsourcing	Yes
R4	Bachelor of Business Administration	HR Service	No
R5	Bachelor of HRM	Banking	No
R6	Bachelor of Engineering	IT	No
R7	Bachelor of Business Administration	Banking	No
R8	MBA of Human Resources Management	HR Service	No
R9	Bachelor of IT	Retail	Yes
R10	B Bachelor A of Psychology	Retail	No

The 2 respondents who understand the importance of using data in recruitment and foresee the trend in the future and agree on the suggestion that HR professionals should learn to do analytics are either have Engineering or IT background.

Here are some of the sharing regarding HR professionals learn to do analytics.

"I think the system will do for you, just enter and export the report. You don't have to learn because in the future everything will be automatic". (R1)

"… HR should only responsible for personnel matter, not mathematics or scientific subject. We will hire those doing that better than us." (R2)

"Not at all, if I am good at number I will be a financial staff or number-related jobs. I think human resources and analytics are separate division and should not be crossed." (R5)

"I think finding IT guy who are not too dry and willing to learn HR knowledge can be more helpful than teaching recruiter to do analytics." (R4)

"…In the future, yes but just enough to understand why and what data, about the how to analyze it is better to leave it to the professional like data engineer." (R7)

To sum up, in the mind of the majority of the recruiters, whoever performs analytics must have good skills and mindset for analytics and mathematics, meaning that they come from a technology or science-related background rather than Human resources background. Therefore, most of them believe that it is a good idea to let the professionals in data analytics do the job and recruiters only need to inject the HR knowledge in the analytic equation.

C. Managerial implications

Before applying analytics in recruitment, there are many practical improvements we can make to the current recruitment practices.

Firstly, recruitment managers should conduct meetings with their staff frequently and assign clear metrics so that individuals can follow and self-evaluate their performance. When being informed about the business strategies, recruiters will act as an active force to gauge the direction in which the company is moving towards and make sure they find the right talent for the right positions.

Recruitment should not be a separate part of other HR functions because all personnel-related data contain underlying information that helps improve recruitment strategies. The problems HR wants to solve should come from the inside out of their organizations, focusing on handling the most resource-consuming and inefficient in the organization.

Thirdly, as HR profession is now moving to more strategic roles, candidates for the HR department including recruitment functions should be more open to innovation and analytic roles. Like it or not, understand and be able to learn a coding language, data analysis will bring allow HR practitioners to interpret data and extract information that has a valuable impact on companies. Therefore, company leaders should consider building a team of HR who are technology literate and competent at learning new modern techniques for long-term development.

Finally, the company should make actionable plans and constantly measure their effectiveness and start adopting recruitment analytics in their recruitment process. There are 3 ways an organization can follow to start taking recruitment analytics in their organization which are to buy, build, or borrow Human resources for analytics.

- Build: Equip recruiters the data analyzing skills so that they can collect and examine the data necessary to improve their performance. Companies can consider to train existing staff rather than recruit externally to this new position. However, it is a challenge to add data-analytics competency in the HR staff due to their analytic ability, career interest, and willingness to learn.
- Borrow: If it is more difficult to train HR practitioners to do analytics then it is better to borrow analytic experts from other

departments to help HR professionals translate HR data into actionable insights.

- Buy: Not every company has a business analytics department or if it is difficult to ask financial analytics or IT deportment to make sense of HR data then buying software that embedded the function of machine learning or predictive analytics is another option even though certain training must be conduct so that HR practitioners can run the software themselves.

Above all, companies should analyze and focus on their real and immediate problems in recruitments rather than solving general problems. We can see that even, the applied policies of each organization varies from one company to the other so they all encounter different difficulties in their recruitment. Different organizations value different kinds of data so it is important that recruiters pay attention to the data that help to solve the problems of their own organization rather than doing analytics of common issues like turnover rate for example.

By choosing the right data and metrics to track, recruiters can benefit from measuring the competencies that they are focusing on as well as following up with the cost and time associated with each hiring option. To determine what matters most to the company, it is helpful to review and see what are the hiring problems and bottlenecks that recruiters and their co-workers are frequently facing and to ask what kind of data they can use to investigate further the issue to make improvements.

Hiring budget, recruitment data, and HR-related data should also be shared with recruiters, so they can make improvements and all in the information should be stored in one place to ensure the that relevant people can easily get access to it. A source of HR data such as internal survey data, individual performance, an exit interview can help the recruiters determine what is currently value by most candidates, whether it is salary, career opportunities, or training program that matters, so recruiters and companies can work together to make policies and salary more competitive. With the knowledge of the labor market, the recruiters can advise how long it takes to get the right person on board and if it is possible to put new business strategies into practice on time.

Finally, in order for HR practitioners to understand and value the data as well as, technological support should be present to at least assist the recruiters in collecting data at first. It is noticeable that companies that adopt analytics in recruitment come from heavily-invested technology such as Banking and IT. So analytical resources and tools should be supported and made available, or else the benefits offered by recruitment analytics cannot be fully explored.

To sum up, to adopt analytics in recruitment, preparing competent staff alone is not enough. Knowing the problems of a specific company, investing technological tools or software to collect, consolidate, and generate reports automatically should be focused on for HR professionals get the best out of this approach.

IV. CONCLUSION

Working in human resources management is all about making decisions and hiring decision are one of the most important calls that HR professionals have to make. The application of analytics in Recruitment is just a tip of the

iceberg of what data analytics can do in the HR domain such as talent management, workforce planning, employee turnover analysis, etc. Even though the term and definitions of data analytics and its sub-function is still in discussion among researchers due to its complication and various techniques, successful cases of using analytics in HR have been proven by reality.

The study reveals the current challenges and common practices of recruitment in Vietnam and what should be done to make recruitment analytics become more popular in Vietnam. This research urges recruiters to pay attention to the power of data analytics not only in recruitment function but also in all HR-related domain. From the information gain from the interview, it can be concluded that HR professionals in Vietnam are in the early stage of recruitment analytics adoption and they still have a long way ahead to go. In the beginning, recruiters should be supported by analytical experts who can help them extract meaningful insights for decision making, and the usage of analytics should be controlled by professionals other than HR because of the competencies and skills needed for analysis. However, in the future, HR professionals should equip themselves with analytical competencies, or else they may lose their jobs to other professions that are better at numeric and analytics.

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THE EFFECTS OF CAPITAL STRUCTURE ON PROFITABILITY IN LISTED COMPANIES ON HO CHI MINH STOCK EXCHANGE

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Abstract: The study examines the linkage between capital structure and firm performance. The quantitative method was applied with linear regression from the data of 290 listed companies on the Ho Chi Minh Stock Exchange. Descriptive statistics indicate that these companies exhibit a preference for equity financing rather than debt in their financing activities. The regression results reveal a negative impact of capital structure on firm profitability across short-term debt, long-term debt, and the total debt ratio. These findings support previous research highlighting the disparity in the relationship between capital structure in developed countries and developing countries. It is crucial for finance managers to recognize the specific context of Vietnam and other developing countries that do not rigidly apply theories developed in mature capital markets. They must be careful to increase debt by potential bankruptcy costs. Additionally, this research undertook a limited investigation into the impact of the COVID-19 pandemic on firm profitability. The analysis revealed that this unforeseen "black swan" event had an adverse effect on firm profitability.

Keywords: *capital structure, debt, equity, firm performance, Vietnam*

I. INTRODUCTION

A company's operations are significantly influenced by its capital structure. To enhance the company's value, managers need to carefully evaluate the ideal balance of debt and equity that minimizes the weighted average cost of capital (WACC). A suitable capital structure helps companies to take advantage of tax shields, reduce finance costs, and minimize agency problems. Moreover, from an investor's perspective, companies with a healthy capital structure may be viewed as attractive investment opportunities due to low finance distressed risk. However, if companies make an inappropriate capital structure selection, it may have negative consequences, such as reduced solvency abilities, and a ruined reputation. Therefore, managers face the challenge of making optimal capital structure decisions that balance the benefits and inherent risks of debt.

In the context of Vietnam, the issue of capital structure and its impact on profitability has garnered significant attention. Particularly, the current matter that Vietnamese corporations are grappling with is the challenges associated with debt financing despite being a common strategy employed by companies to secure capital. Besides that, debt

financing strategy has become increasingly challenging for Vietnamese corporates due to the recent economic crisis triggered by the COVID-19 pandemic. The consequences of this epidemic have placed immense financial strain on businesses across various sectors, resulting in reduced revenues, disrupted supply chains, and increased operating costs. An outcome is that companies have been compelled to rely on debt financing to sustain operations, meet short-term obligations, and navigate through uncertain times. However, lenders have become cautious and risk-averse, making it harder for companies to secure debt financing at favorable terms. As a result, the accessibility and affordability of debt financing in Vietnam have become major bottlenecks for companies, affecting their ability to improve profitability and ensure long-term sustainability. Given the magnitude of the challenges posed by debt financing, it becomes imperative to delve deeper into the effects of capital structure on profitability.

In the well-known examination of the linkage of capital structure on firm values mentioned by the research of Modigliani and Miller (1958). Two authors assumed that under perfect capital market conditions: with no tax, no transaction costs, and investors' homogenous expectations, the capital structure does not impact firm value. Although these assumptions are unrealistic, they form the foundation for much subsequent research on capital structure analysis. The actual context of the capital market, the solvency risk, and tax-deductible interest contribute to the concept of an optimal capital structure, which is a balance point between financial distress and tax benefits (Jensen and Meckling, 1976). In other words, additional debt would increase bankruptcy costs beyond the inherent tax-advantaged debt.

The study of the relationship between capital structure and profitability is conducted in developed capital markets, such as the US and Europe, as well as in emerging markets based on the MSCI criteria. In developed nations, several investigations have been conducted on the topic, such as the study of Roden and Lewellen (1995) that utilized data from 107 leveraged buy-out firms in the United States. According to the analysis, the authors concluded that there was a positive correlation between overall debt and profitability. Another study by Gill et al. (2011) explored the link between capital structure and profitability for 272 non-financial companies listed on NYSE from 2005 to 2007. The study results indicated a positive correlation between short-term debt and total debt with profitability, as measured by ROE. Similarly, Margaritis and Psillaki (2010) carried out a study in the United States and France, which revealed that a higher debt ratio was linked to better firm performance. This was attributed to the use of more debt, which reduced the agency costs of equity and encouraged managers to act in the interest of shareholders.

While capital structure theories were developed countries, the positive relationship findings in this research are based on mature capital markets, which may not apply to emerging and frontier countries like Vietnam with inherent risks due to an incomplete capital market. The development history of Vietnam's capital market has been relatively short, spanning only over two decades, and the private economy has only been prioritized by the Vietnamese government for a little over ten years. This is in contrast to other ASEAN countries such as Thailand, Malaysia, and Singapore, which have had a long history of economic development (Hoan, 2019). Ebaid's

(2009) study in Egypt showed that the impact of capital structure on firm performance was negligible or non-existent, based on data from listed firms between 1997 and 2005. On the other hand, Ahmad, Abdulla, and Roslan (2012) conducted research in Malaysia and utilized regression analysis to establish a correlation between capital structure and firm performance. They measured the company's performance through Return on Assets (ROA) and Return on Equity (ROE) as dependent variables, and short-term debt, long-term debt, and total debt as independent variables. The data were collected from 58 industrial companies on the Malaysian stock market from 2005 to 2011. The findings revealed that short-term debt and total debt had a negative influence on ROA, whereas short-term debt, long-term debt, and total debt had adverse impacts on ROE.

As for the Vietnam market, the study of capital structure and firm performance is not a novel topic, as several studies by Nguyen & Nguyen (2020), and Le & Phan (2017) have been conducted. The results of these papers show that debt negatively affected firm performance, contradicting the results of the same topic in developed countries but consistent with some other developing market contexts. Developing countries with inefficient and incomplete capital markets also experience a higher level of information asymmetry, which is the main difference from financial markets in developed countries regarding transparency. Moreover, the unique national capital structure of each country and the business environment in developing countries rapidly change to keep pace with their growth, resulting in changes in capital structure characteristics in different periods. The authors proposed in the Vietnam context, tax benefits could not compensate for enough financial distress costs. However, these studies were undertaken in normal conditions before. With the Covid pandemic and the change of bond issues policy hugely influencing firm performance for two years, the context of the studies may be affected, thus changing the actual result. Therefore, it is necessary to reexamine the relationship between capital structure and firm performance in the "new normal" circumstances.

The research assessed the capital structure among the listed companies on the Ho Chi Minh Stock Exchange and investigated the relationship between capital structure and firm profitability in Vietnam in terms of Short-term debt, Long-term debt, and Total debt to address the following research questions:

1. How does capital structure impact the profitability (ROA) of non-financial enterprises listed on the Ho Chi Minh Stock Exchange from 2014 to 2021?

2. In the context of a developing country, how can managers improve profitability based on the research results?

3. Has the impact of total debt on profitability differed after the Covid pandemic?

Based on the fundamental theories and empirical research, the hypotheses were developed:

H1: *Short-term debt has a negative influence on the firm profitability.*

H2: *Long-term debt has a negative influence on the firm profitability.*

H3: *Total debt has a negative influence on the firm profitability.*

H4: *The outbreak of COVID-19 has had a negative impact on profitability.*

II. METHODOLOGY

The study utilizes a quantitative approach to examine the correlation between capital structure and firm performance through descriptive statistics and regression analysis. The quantitative method establishes a fundamental relationship between empirical observation and mathematical expression. Panel data will be collected for both the independent and dependent variables, allowing the regression approach to identify the relationship between these variables. Regression analysis is widely employed in quantitative research due to its ability to clearly elucidate relationships and it is not too complex for implementation. The regression analysis will use statistical tests to determine the appropriate model for the data set, and the findings will be used to draw conclusions regarding the economic implications. The research used Stata version 14, provided by StataCorp, to analyze the data. The study applied purposive sampling, which is a non-probability sampling method, to select specific enterprises listed on the Ho Chi Minh Stock Exchange as the target sample. This method involves selecting a sample based on specific characteristics that align with the study's objectives.

Table 1 below explains the variable measurement of independent, dependent, and controlled variables which are used to conduct the study.

Table 1. Proxy variables definition

Proxy Variables	Definitions
Dependent variable	
Return on Asset (ROA)	Net income divided by the average assets
Independent variables	
Short-Term Debt (STD)	Short-term debt divided by the total assets
Long-Term Debt (LTD)	Long-term debt divided by the total assets
Total Debt (TTD)	Total debt divided by the total assets
Control variables	
Firm Size (Size)	Natural logarithm of its total assets
Growth Rate (Gr)	Current year's Sales minus previous year's sales divided by previous year's sales

The relationship between debt and profitability is estimated in the following regression models:

$$ROAi,t = \beta0 + \beta1STDi,t + \beta2Sizei,t + \beta3Gri,t + ei,t \quad (1)$$

$$ROAi,t = \beta0 + \beta1LTDi,t + \beta2Sizei,t + \beta3Gri,t + ei,t \quad (2)$$

$$ROAi,t = \beta0 + \beta1TTDi,t + \beta2Sizei,t + \beta3Gri,t + ei,t \quad (3)$$

To expand the research, the dummy variable was also added for the period of COVID-19 to examine whether the COVID-19 could negatively impact the firm performance. However, the research only uses a dummy variable in Total debt model because of limitation research scope.

$$ROAi,t = \beta0 + \beta1TTDi,t + \beta2Sizei,t + \beta3Gri,t + \beta3Dumi,t + ei,t \quad (4)$$

III. RESULTS

A. Descriptive data

Table 2 displayed some statistical characteristics of the data set. Observations did not equal each variable. The reason is that some observations could not be obtained due to data availability at the collected time. The panel is called unbalanced panel data.

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ROA	2,215	0.06391	0.06908	-0.7873	0.7218
TTD	2,280	0.26034	0.16829	0	0.9935
LTD	2,280	0.09474	0.12556	0	0.6721
STD	2,320	0.16274	0.14665	0	0.9935
GR	2,230	0.35780	3.12420	-24.161	77.469
Size	2,267	27.4413	1.68690	23.4406	32.8141

The table depicted the ROA range between -0.787 to 0.722. The average value of ROA was 0.064, and the standard deviation was 0.069. The independent variable was STD LTD and TTD, companies may finance all capital by equity but not all debt, so the maximum debt ratio does not reach 100%. There is no larger than one debt-to-asset ratio that was taken in the analysis because of the cleansing data stage.

The average total debt was 26%, indicating Vietnamese companies prefer using equity to debt in their financing activities. Furthermore, the average of Long-term debt also was 9.47%, while the average Short-term debt was 16%, in the study context. Short-term debt is usually used for working capital, which is popular in developing countries (Le & Phan, 2017), so companies in the study context depend on short-term debt for working capital rather than long-term debt for property, plant, and equipment assets. Among the control variables, the growth rate variable had the widest range of values, from -24 times to 77 times, with a standard deviation of approximately three times. Therefore, this variable may contain the most outliers in the datasets.

Table 3. Correlation matrix

	ROA	TTD	LTD	STD	GR	Size
ROA	1					
TTD	-0.2998	1				
LTD	-0.1729	0.5430	1			
STD	-0.1962	0.6837	-0.2415	1		
GR	0.0432	-0.0386	-0.0084	-0.0373	1	
Size	0.0537	0.0440	0.1100	-0.0447	-0.0003	1

The table presented above illustrates the Pearson correlation between variables in the study. Most pairs of independent variables had a low correlation, except for the two debt variables, which displayed a very high correlation of 54% and 68%. This is because short-term and long-term debt are both components of total debt. Additionally, since the three debt variables were used in separate regression models, multicollinearity between independent variables was prevented. Notably, the highest correlation was found to be between the independent variables (i.e., the debt variables) and the dependent variable (i.e., ROA). This strong correlation may be viewed as a positive aspect of the regression analysis.

B. Statistical result analysis

a. OLS Model

Table 4. Summary OLS estimates

Variable	ROA	ROA	ROA
STD	-0.0947***		
	[-9.38]		
GR	0.000874	0.00102*	0.000774
	[1.70]	[1.97]	[1.55]
Size	-0.00258**	-0.00145	-0.00168*
	[-2.97]	[-1.65]	[-1.98]
LTD		-0.0930***	
		[-7.92]	
TTD			-0.123***
			[-14.45]
_cons	0.150***	0.112***	0.142***
	[6.25]	[4.67]	[6.09]
F	32.89	24.44	73.38

t statistics in brackets

*** p<0.05, ** p<0.01, *** p<0.001**

Initially, the research utilized pool OLS models to investigate the relationship between the independent and dependent variables. Ordinary Least Squares (OLS) is a regression analysis method that is commonly used to estimate the parameters of a linear regression model. In an OLS regression, the objective is to identify the line of best fit that minimizes the sum of squared residuals between the observed and predicted values of the dependent variable.

The table displays that the capital structure (TTD, LTD & STD) had a negative impact on firm profitability, as indicated by the negative coefficients. Furthermore, all the coefficients of the independent variables (i.e., the debt variables) were statistically significant at a p-value of 0.05%. Specifically, the coefficients of TTD, LTD, and STD were -0.123, -0.093, and -0.0947, respectively.

Regarding the control variables, the results varied across the models. The growth variable was only statistically significant at a p-value of 5% in the LTD model (0.00102), while it was not statistically significant in the TTD and STD models. In contrast, the size variable was statistically significant in the TTD and STD models but was not statistically significant in the LTD model. Notably, the impact of both control variables on the dependent variable (ROA) was minor. Moreover, the F-test confirmed the linear relationship between the independent and dependent variables, indicating that the regression fitted the data set. In addition, VIF would be employed to detect Multicollinearity (see Appendix), the result of VIF is low, it means there is no appearance of Multicollinearity.

However, it is crucial to note that OLS models do not consider the time series and cross-sectional characteristics of panel data. Additionally, it is essential to satisfy the assumptions of OLS, such as linearity, homoscedasticity, and normality, for the results to be trustworthy. If these assumptions are not met, alternative regression methods should be employed.

b. Summary FEM estimates

To perform the FEM and REM models, the F-Test and Breusch-Pagan test were used to determine whether fixed or random effects of individual effects were appropriate. Both tests rejected the null hypothesis, leading to the conclusion that the FEM or REM would be more appropriate than OLS. The Hausman test was then conducted (see Appendix), and the results indicated favoring the FEM model over the REM model in all three models because of the rejected null hypothesis.

Table 5. Summary FEM estimates

	ROA	ROA	ROA
STD	-0.138***		
	[-8.02]		
GR	0.00196***	0.00185***	0.00183***
	[4.86]	[4.57]	[4.62]
Size	-0.00840***	-0.00688**	-0.00828***
	[-3.34]	[-2.73]	[-3.35]
LTD		-0.120***	
		[-7.12]	
TTD			-0.145***
			[-11.57]
_cons	0.317***	0.264***	0.328***
	[4.56]	[3.81]	[6.09]
F	31.95	27.36	55.5

t statistics in brackets

*** p<0.05, ** p<0.01, *** p<0.001**

In general, all variables except for the growth variable had a negative impact on

firm profitability. Compared to the previous OLS model, all independent variables were statistically significant at a 5% p-value level. The coefficients of TTD, LTD, and STD were -0.145, -0.12, and -0.138, respectively, which were larger than the coefficients in the OLS model. The control variables were also statistically significant. The Size variable had a negative impact on profitability, while the Growth variable was the only variable that had a positive influence on the dependent variable. The coefficient of the two control variables was quite small compared to the previous OLS model.

To detect autocorrelation and heteroskedasticity, two tests were employed: the Wooldridge test for autocorrelation in panel data and the Wald test for groupwise heteroskedasticity in a fixed-effect regression model (see Appendix). The null hypothesis of both tests was that there was no heteroskedasticity and autocorrelation to be rejected. Heteroskedasticity and autocorrelation are common in financial panel data, and these phenomena can inflate the value of statistical output, making hypothesis testing unreliable. To solve the issue of heteroskedasticity and autocorrelation in the dataset, the Generalized Least Squares (GLS) method was applied.

c. GLS Model

Table 6. Summary GLS estimates

	ROA	ROA	ROA
STD	-0.0670***		
	[-10.85]		
GR	0.00127***	0.00119***	0.00119***
	[4.53]	[4.49]	[4.23]
Size	-0.00259***	-0.00200**	-0.00175**
	[-4.03]	[-3.02]	[-2.80]
LTD		-0.0641***	
		[-9.54]	
TTD			-0.0897***
			[-16.78]
_cons	0.137***	0.116***	0.128***
	[7.62]	[6.34]	[7.35]
t statistics in brackets			
*** p<0.05, ** p<0.01, *** p<0.001**			

The GLS model produced statistically significant results for all independent variables and the intercept at a 5% p-value. Since heteroskedasticity and autocorrelation were corrected, the results are likely more reliable than those of the previous three models. The debt variables still had a negative impact on ROA, with total debt having the largest coefficient of -0.0897. This means that a 1% increase in total debt results in a 1% decrease in profitability (ROA). Short-term debt and long-term debt had similar coefficients of approximately -0.064 and -0.067, respectively.

The Growth and Size variables were significant in the model. They had relatively small, which were consistent with two previous models, indicating that their influence on profitability was somewhat limited.

d. Post-COVID-19 Model

Table 7. GLS regression for dummy variable

ROA	Coef.	Std. Error	t-Statistic	Prob.
TTD	-.091239	.005301	-17.21	0.000
GR	.001209	.000285	4.23	0.000
Size	-.001620	.000626	-2.59	0.010
Dum	-.004983	.001338	-3.72	0.000
_cons	.126629	.017342	7.30	0.000

The GLS model was utilized in the study to assess the effects of COVID-19. It was used to address heteroskedasticity and autocorrelation in the panel data's continuous variables. The findings showed that the dummy variable was statistically significant and had a negative impact on firm profitability, demonstrating the adverse consequences of the pandemic on businesses' profitability. The dummy coefficient was -0.005, indicating that over the two-year period of the pandemic, firm profitability decreased by 0.5%.

IV. CONCLUSION

A. Finding summary

The study examines the linkage between capital structure and firm performance. The quantitative method was applied with linear regression from the data of 290 listed companies on the Ho Chi Minh Stock Exchange. In sum up, the result found that these companies tend to use equity rather than debt in their financing activities because the average total debt ratio was only approximately 26%. The average of Long-term debt also was 9.47%, while the average Short-term debt was 16% in the study context. Short-term debt is usually financed for working capital, which is popular in developing countries (Le & Phan, 2017), so companies in the study context depend on short-term debt for working capital than long-term debt for property, plant, and equipment assets.

In the result of three regression models with short-term debt, long-term debt, and total debt, the regression findings demonstrated that firm profitability is negatively influenced by capital structure in all models, which contradicts previous research conducted in developed countries, including studies by Roden and Lewellen (1995), Gill et al. (2011), and Margaritis and Psillaki (2010). However, this result is consistent with research by Ahmad et al. (2012), Ebaid (2009), and Le & Phan (2017) in the context of developing countries. In general, if companies increase their financing through debt, it may have a detrimental effect on their profitability, particularly for long-term, short-term, and total debt. This outcome can be attributed to the higher bankruptcy costs in developing countries, which may outweigh the benefits of tax shields, as well as the unique characteristics of tax brackets and debt costs in developing countries.

Concerning the control variables, the size of the firm had a negative influence on its profitability, whereas growth had a positive impact. This could be attributed to the fact that firms with a strong growth rate tend to generate higher income. However, both control variables had relatively small coefficients (>0.0026) to ROA (profitability), implying that their effect is noticeable but not substantial.

The test conducted to assess the influence of COVID-19 revealed that the dummy variable was statistically significant and had a detrimental effect on firm profitability, thereby indicating the negative impact of the pandemic on the firm's profitability.

B. Implication

Managers in all companies should carefully consider financing options through debt or equity. The research shows that debt financing has a negative impact on firm profitability, which contradicts the theory of capital structure and results from previous research in developed countries. Since the Vietnamese capital market is immature and underdeveloped, the authorities and managers should refer to finance theories conducted in developed countries to improve the capital system. However, it is important to not rigidly copy these theories and to adapt them to the specific context of Vietnam and other developing countries. Finance managers need to be mindful of the potential bankruptcy costs associated with increasing debt, even if the cost of debt is generally lower than the cost of equity. Maintaining a moderate debt ratio can leverage the tax benefits while also creating additional capacity for future debt to finance growth projects without the burden of excessive interest payments. Furthermore, companies with lower debt ratios tend to be more attractive to investors.

In the case of Vietnam and other developing countries, a faster growth rate in the economy implies a higher interest rate because citizens tend to consume at the moment instead of in the future due to higher income resulting from the higher growth rate. Therefore, it is inevitable.

As for regulation, to decrease the cost of debt, the authorities could improve the capital market, especially the bond market, by supervising it both through government oversight and the development of independent credit rating institutions, in order to increase counterparty trust. This would effectively decrease the counterparty risk premium for bond investing.

Additionally, lawmakers should also improve credit institution laws in terms of collateral asset liquidation, guarantee, and other related fields such as Investing Laws and corporate law to facilitate a favorable capital market for the business development.

C. Limitation and recommendations for further researches

The study solely focuses on the listed companies on the Ho Chi Minh Stock Exchange. Although HOSE has the largest capitalization in the Vietnamese capital market, it may not represent the entire capital system due to the prevalence of SMEs, which constitute a significant portion of the capital market. Thus, the research can be extended to SMEs and the private sector to evaluate the Vietnamese capital system accurately.

Furthermore, the study only considers the debt factor in a pool of companies without taking into account the inherent business operation linkage with debt finance. For instance, industries and manufacturing sectors require long-term debt for long-term asset financing, while service companies need short-term debt for working capital (Gill et al., 2011). This limitation can be addressed by exploring the impact of the different types of debt on firm profitability.

Another limitation of the study is the effect of the COVID-19 pandemic on financial data, which may deviate from the previous inherent characteristics of the data series. However, the research included a dummy variable to account for the pandemic's impact during the study period. It is worth examining the post-COVID-19 period to find solutions to help companies recover from the pandemic's adverse effects.

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APPENDIX

Table 1. VIF Model

Variable	VIF	1/VIF
TTD	1.00	0.996574
Size	1.00	0.99806
GR	1.00	0.998507
Mean VIF	1.00	

Variable	VIF	1/VIF
LTD	1.01	0.987837
Size	1.01	0.987908
GR	1.01	0.999928
Mean VIF	1.01	

Variable	VIF	1/VIF
STD	1.00	0.996611
Size	1.00	0.997998
GR	1.00	0.998606
Mean VIF	1.00	

Table 2. Breusch-Pagan test

a) Total debt

	Var	**sd = sqrt (Var)**
ROA	.0048148	.0693888
e	.0023467	.0484424
u	.0019476	.0441318
Test: Var(u) = 0		
chibar2 = 1532.48		
Prob > chibar2 = 0.0000		

b) Long-term debt

	Var	**sd = sqrt (Var)**
ROA	.0048148	.0693888
e	.0024481	.0494787
u	.0021493	.0463611
Test: Var(u) = 0		
chibar2 = 1630.25		
Prob > chibar2 = 0.0000		

c) Short-term debt

	Var	**sd = sqrt (Var)**
ROA	.0048148	.0693888
e	.002431	.0493051
u	.0020959	. 0457809
Test: Var(u) = 0		
chibar2 = 1596.69		
Prob > chibar2 = 0.0000		

Table 3. Hausman test

a) Total debt

	(b) **fem**	**B** **reml**	**(b-B)** **Difference**
TTD	-.144837	-.1347753	-.0100617
GR	.0018286	.0016611	.0001675
Size	-.0082781	-.0035424	-.0047357
Test: Ho: difference in coefficients not systematic			
chi2 = 18.31			
Prob > chi2 = 0.0004			

b) Long-term debt

	(b) fem	B reml	(b-B) Difference
LTD	-.1197793	-.1090391	-.0107402
GR	.0018479	.0017278	.0001201
Size	-.0068802	-.0030116	-.0038686
Test: Ho: difference in coefficients not systematic chi2 = 10.74 Prob > chi2 = 0.0132			

c) Short-term debt

	(b) fem	B reml	(b-B) Difference
STD	-.1381748	-.1167059	-.0214689
GR	.001958	.0017835	. 0001745
Size	-.0084017	-.004248	-.0041537
Test: Ho: difference in coefficients not systematic chi2 = 17.90 Prob > chi2 = 0.0005			

Table 4. Autocorrelation test

a) Total debt

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F (1, 288) = 24.955
Prob > F = 0.0000

b) Long-term debt

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F (1, 288) = 29.620
Prob > F = 0.0000

c) Short-term debt

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F (1, 288) = 26.003
Prob > F = 0.0000

Table 5. Wald test

a) Total debt

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
chi2 (200) = 3.0e+07
Prob>chi2 = 0.0000

b) Long-term debt

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
chi2 (200) = 1.2e+06
Prob>chi2 = 0.0000

c) Short-term debt

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
chi2 (200) = 9.0e+05
Prob>chi2 = 0.0000

THE EFFECTS OF FINANCIAL DEVELOPMENT ON INCOME INEQUALITY AND POVERTY: EVIDENCE FROM ASIAN COUNTRIES

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Abstract: Asia includes many emerging countries bringing several surprises to the world. The government aims to find out how to achieve national economic growth that closes to or even exceeds their expectations. Financial development is one of the critical, influential factors that generate remarkable changes to any country's economic growth and poverty. This paper aims to examine the interactive impacts of both directions: financial development impacts income inequality, poverty, and vice versa. This study uses diverse regression models, including crisis dummies and income classification for 46 Asian countries from 2000 to 2019. The study's findings reveal that the more liquid liabilities a country owns, the more that country's economy is restrained, whereas market capitalization has the reverse effect. Furthermore, the U-shaped association between financial institutions and income inequality that results aligns with the previous study's findings. The study recommends adopting policies geared towards increasing financial development and economic growth to reduce the high poverty level currently prevailing in Asian economies so that the approach to achieving sustainable development and enhancing people's welfare can be performed.

Keywords: *income inequality, financial development, poverty, economic growth*

I. INTRODUCTION

A. Research context

Long-term issues like poverty and inequality must be addressed. The root causes, socioeconomic effects, and drawbacks of poverty and income inequality have all been well studied by scientists. It is well established that unequal financial access considerably contributes to enduring income inequality and slower economic growth. One body of pertinent evidence suggests that lending regulations that limit access to credit and inconsistencies in the capital markets may have an impact on inequality and poverty throughout economic development. The main causes of poverty, according to inequality and poverty models (see Greenwood and Jovanovic, 1990; Banerjee & Newman, 1993), are enduring financial market inefficiencies. Due to these issues, low-income individuals are unable to invest in their human capital, health, or entrepreneurial endeavors.

The recent global financial crisis and macroeconomic instability have increased attention in the relationship between finance, growth, inequality, and poverty (FGIP). The literature asserts that financial institutions can be crucial in ensuring that economic possibilities

are equitable for all people and that inequities are eliminated in this regard. Therefore, it is crucial to assess the connection between the growth of the financial industry, income inequality, and the reduction of poverty. Fascinatingly, even in cases where the financial system is expanding in size and liquidity (especially in banks and stock markets), this expansion might not help the less fortunate because there is not democratized access to financial services. In other words, financial inclusion will be limited if people who are poor have less access to financial services than the general population.

The goal of the study is to determine the mechanisms via which financial development influences income disparity and poverty as well as to investigate whether innovations in the banking industry, stock markets, and the broader financial sector have helped to reduce income inequality and poverty. Although financial development may have both direct and indirect effects on poverty and inequality, this study largely focuses on the former. In this context, the study empirically investigates the primary pathway via which financial development lessens income inequality and poverty, namely, improved access to banking and stock market opportunities. In other words, the stock market and banks both have simultaneous and independent effects on the relationship between financial inequality and poverty (FIP), which is evaluated in this article. The work makes five significant contributions to the literature. The use of aggregate variables to examine the independent and contemporaneous effects of stock market and bank developments on income inequality and poverty is the first contribution of our study to the literature on FIP. To the best of our knowledge, this is one of the first in-depth studies that examines the simultaneous and distinct effects of two financial sector components, namely the banking and stock markets, on income inequality and poverty reduction by developing aggregate measures to represent the development of the banking and stock markets as well as the development of the entire financial sector. This innovative method of examining the connection between inequality/poverty, stock market development, and those two factors shows how the relationship has changed as a result of taking into account both the independent and concurrent effects of finance as well as the measures of financial development that have been selected.

B. Research problem and objectives

Geographically, Asia includes 50 countries included in the review, then gradually excluding countries that do not provide sufficient information; the remaining 32 Asian countries were included in the sample in the period 2001-2019 of this paper to analyze the impact of financial development on income inequality and poverty.

All data are obtained from the Global Financial Development Database and World Development Indicators published by the World Bank. In addition, the 2001-2019 analysed period was chosen because before 2008, not only economists but also government policy-makers believed that the strong financial development will be an indispensable premise if policymarkers want to get the good economy. Statistics show that, although the financial development of Asian countries is strong, it is still low compared to that of developed economies (Sahay et al., 2015). This implies that Asian countries are still expecting their financial systems to develop further to spur poverty.

C. Literature review

Inequality and poverty are persistent phenomena and fundamental issues of concern. Scientists have put a lot of work into examining the causes, socioeconomic effects, and drawbacks of poverty and income inequality. Unfair financial access has long been seen as a major factor in sustaining income inequality and slowing economic progress. One body of related studies emphasizes how lending restrictions and capital market flaws may have an impact on inequality and poverty during economic progress. In many inequality and poverty models, persistent financial market flaws have been the primary causes of poverty (Greenwood and Jovanovic, 1990; Banerjee and Newman, 1993). People with poor wages are unable to invest in their human capital, health, or entrepreneurial endeavors because of these flaws. The precise effect of financial development on income inequality and poverty reduction has not been well defined in either empirical studies or the theoretical literature, despite the fact that it is well known that absolute poverty has declined over the past 25 years in many countries and income inequality has increased. The recent global financial crises, crisis times, and macroeconomic instability have all raised awareness of the relationship between finance, growth, inequality, and poverty (FGIP). In this regard, it is stated in the literature that financial institutions may play a crucial role in reducing inequality and equating economic opportunities. Hence, relationship between the growth of the financial industry, the reduction of income disparity, and poverty is crucial. It's interesting to note that, even in cases where the size or liquidity of the financial system increases (particularly when it comes to banks and stock markets), this growth may not benefit the less fortunate due to the absence of democratized access to financial services goods. In other words, financial development may not help to reduce inequality and poverty if the poor have limited access to financial services relative to the rest of the population.

The imperfection of a financial market such as informational asymmetries, transactions costs, and contract enforcement costs, is believed to be linked to income inequality and poverty. Poverty is mainly attributable to market failure and financial market imperfection (Jalilian and Kirkpatrick 2002). According to Galor and Zeira (1993), in an imperfect financial market, small enterprises are restricted from borrowing funds for investment and they need to utilize their narrow budget to invest in their business project. As a result, financially restrained entrepreneurs remain in poverty and income inequality. People who are able to provide collateral or who have developed relationships with financial institutions will be given credit (Jalilian and Kirkpatrick, 2005).

Atje and Jovanovic (1993) demonstrate that the development of the stock market has a favorable impact on economic growth. Levine and Zervos (1998) go beyond general financial development by concentrating on whether stock markets promote long-term economic growth. They discover, using data from 47 nations, that a country's economic growth rate and stock market liquidity are positively connected. These results imply that healthy stock markets are, at the very least, a significant predictor of economic production. These findings also lend credence to the endogenous growth theory (Romer (1989) and Pagano (1993)), which contends that efficient markets let a greater proportion of gross saving to flow into capital investment and hence promote economic growth. Finding

out whether or not there is a disproportionate impact on the wealthy compared to the poor from stock market liquidity may be more fascinating than discovering the link between this liquidity and economic growth. Examining this specific question is the primary goal of this investigation. With a huge sample of nearly 100 nations, we specifically investigate whether stock market liquidity affects the degree of income inequality.

The problem of increasing income inequality and poverty requires a view in the nexus between financial development and economic growth. In all economies, the primary functions of financial markets and institutions are to increase the effectiveness of capital allocation, mobilize savings, spur the creation of new capital, control risks, and expedite transactions. There have been many empirical studies supporting the ideas that a developed financial system can facilitates economic growth and reduce poverty. For example, instead of finding that financial development promotes economic growth, Beck and Levine 2004 investigated whether economic growth disproportionately increases the earnings of the poor and reduces poverty. Using a large cross-country sample, they pointed out that by disproportionately increasing the earnings of the poor, financial development lowers income inequality... The same conclusion was seen in older studies (King and Levine, 1993a; Bencivenga et al., 1995). Furthermore, from an empirical perspective, researchers concluded that the linkage between financial development and economic growth is positive. Schumpeter (1911), one of the pioneers of the debate, opinion that financial intermediate affects the distribution of savings, thus enhancing productivity, technological advancement and finally the economic growth. Following available earlier findings, the ideas have been developed in aiding the process of economic growth by analyzing the various functions of financial system, which include mobilizing savings, allocating capital funds, monitoring the use of funds, and managing risk (Levine, 1997; Stiglitz, 1998).

D. Data

This paper uses annual data from 49 Asian countries over the period 2000 to 2019. Data of country level is collected from Global Financial Development Database and World Development Indicators published by the World Bank including GDP growth (annual %); the ratio of liquid liabilities to GDP (%); Number of depositors with commercial banks per 1,000 adults; Private credit by deposit money banks to GDP (%); Number of ATMs per 100,000 adults; Bank deposits to GDP (%); Stock market capitalization to GDP (%); Stock market turnover ratio (%); inflation rate (%); Trade as a ratio of GDP (%); trade to GDP (%), and General government final consumption expenditure (% of GDP); and mobile money service.

This study evaluated two different measures of income inequality to examine the correlation between financial development and income inequality. The initial indicator employed is the Gini coefficient, a widely recognized indicator used to assess inequality in income. This data collects two Gini coefficients related to the household market income and disposable income. These coefficients were obtained via the Standardized World Income Inequality Database (SWIID) (Solt, 2014).

The second indicator of income inequality employs the mean per capita income of the least poorest quintile to measure poverty indicators by determining the quintile the average income of the bottom 20% of the population. The average income is determined by multiplying the income share of the lowest 20% quintile, as obtained from the World Bank's Database, by the average per capita GDP and dividing the product by 0.2.

II. METHODOLOGY

The study employs a dynamic panel data methodology to handle omitted variables and endogeneity from 2001 to 2019, shown in a sample of 49 Asian nations. The empirical portion of this research adopts the system-dynamic generalized method of moments (GMM) technique, as established by Arellano and Bover (1995) and Blundell and Bond (1998). Besides, the research also enhances the explanation of the relationship between financial development about inequality and poverty by including the following variables as control factors: the proportion of government consumption in GDP, the inflation rate, the ratio of trade to GDP, real per capita GDP, and the growth rate of real per capita GDP, mobile money service, and FDI.

This study utilized income inequality and poverty indicators found in previous research. The Gini coefficient measures income inequality that measures deviations from perfect income equality. This measure uses the Lorenz curve, an established standard of income distribution among people living in society. The Gini coefficient is often denoted as a percentage and spans from 0, representing perfect equality, to 1, indicating perfect inequality. Higher values of the coefficient indicate a higher degree of income inequality. The investigation utilizes the growth rate of Gini coefficients for each country over four years as the dependent variable. This study employs a logarithmic transformation to calculate the disparity between the Gini coefficients of the present and preceding time intervals.

The study also used the mean per capita income of the least wealthy quintile to measure poverty indicators by determining the quintile the average income of the bottom 20% of the population. The study employs a methodology that involves multiplying the income share of the lowest quintile (as obtained from the World Bank's Database) by the average per capita GDP and dividing the result by 0.2 to get the average income. Then, the study computes the logarithmic growth rate of the average per capita income for the lowest quintile, as previously elucidated. The dependent variable in our regressions is the average per capita income increase of the poorest quintile. Another poverty indicator is the headcount ratio, which measures the percentage of the population living below US$2.00 a day at 2005 international prices. These statistics are derived from primary household survey data collected by government statistical agencies and World Bank country departments.

The findings of this research used many different kinds of panel regression models to examine the impact of financial development on inequality and poverty indicators, as shown in the model described below:

$$Gini_{i,t} = \alpha_0 + \alpha_1 Gini_{i,t-1} + \beta FD_{i,t} + \gamma Control\_Variables_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $Gini_{i,t}$ is measured by income inequality, is dependent variable of country i at time t, which are defined as i = 1, 2,…, t = 2000,…, 2019. Then,

α_0 denotes the intercept, β and γ are the vectors of coefficients; $FD_{i,t}$ is a matrix of financial development measures; $Control\_Variables_{i,t}$ is a matrix of control variables and $\varepsilon_{i,t}$ captures an error term

$$POV_{i,t} = \alpha_0 + \alpha_1 POV_{i,t-1} + \beta FD_{i,t} + \gamma Control\_Variables_{i,t} + \varepsilon_{i,t} \quad (2)$$

where $POV_{i,t}$ is Poverty, is dependent variable of country i at time t, which are defined as $i = 1, 2, \ldots, t = 2000, \ldots, 2019$. Then, α_0 denotes the intercept, β and γ are the vectors of coefficients; $FD_{i,t}$ is a matrix of financial development measures; $Control\_Variables_{i,t}$ is a matrix of control variables and $\varepsilon_{i,t}$ captures an error term.

III. RESULT

Due to a non-linear relationship between financial development, income inequality and poverty. Table 1 shows sample means of countries in 2000 – 2019. The regression model incorporates a correlation coefficient matrix table, presented below. It is seen that all the correlation values between the variables in the model are below 0.01. The data set employed in this model is suitable, and the utilization of regression panel data is less prone to yield multicollinearity outcomes.

The summary statistics of the variables employed in this study are presented in Table 1. The disparity in poverty rates varies significantly across countries on the continent, with the wealthiest country experiencing a poverty gap of 1.78%. The poorest country exhibits a far higher poverty gap of 61.6%. This observation suggests a significant disparity between the economies of affluent and impoverished Asian nations.

It is essential in this study to consider the significance of two domains within the financial system. To effectively gauge the relative prominence of private external finance and to resolve any disparities in allocation between development banking and the stock market, it becomes necessary to employ two distinct measurements. The section delves into the correlation between financial development and income inequality. As previously discussed, the relationship between financial development and income inequality is theoretically uncertain, as there are valid arguments supporting both positive and negative consequences.

Table 2 provides the correlation output between the primary independent variable, the control variable, and Gini as the primary dependent variable. Table 3 also presents the correlation output of each independent and control variable, with the poverty gap and the headcount index as the dependent variables. The purpose of separating the correlation output is due to the different usage of the dependent variable. Also, in this respect, the paper would like to differentiate the effect of financial development on two other measures of income inequality and the poverty gap.

Table 1. Summary statistics

Variables	Obs.	Mean	Std. Dev.	Minimum	Maximum
gini_disp	920	25.50043	18.38329	0	49.7
SIDSTFRST20	920	1.959022	3.379936	0	10.9
Depth_Priv~t	920	35.71557	42.34907	0	218.944
Depth_liqu~s	920	46.63025	56.79884	0	368.922
Depth_mktcap	920	36.22507	121.1731	0	1098.94
Depth_traded	920	21.68168	71.8555	0	822.317
Depth_bank~s	920	48.22985	46.36916	0	194.8767
GDPpercapita	920	13428.04	17383.86	0	97744.95
Growth	920	4.686663	4.590514	-22.85714	34.46621
Inflation	920	3.879691	5.142458	-18.10863	57.07451
Govermentspending	920	13.64311	16.16874	0	147.7333
Tradeopeness	920	88.52088	74.34878	0	442.62
mobilemoney	920	0.0706522	0.2563823	0	1

Table 2. Full sample of countries

VARIABLES	Model (I)	Model (II)	Model (III)
gini_disp_1	0.506***	0.460***	0.414***
	(0.0429)	(0.0474)	(0.0494)
Depth_Privatecredit	0.0333	-0.0936	0.0376
	(0.0928)	(0.164)	(0.0788)
Depth_liquidliabilities	0.193**	0.452***	0.152**
	(0.0893)	(0.121)	(0.0750)
Depth_bankassets	-0.292***	-0.264**	-0.0277
	(0.0936)	(0.125)	(0.124)
Depth_mktcap	-0.0631***		-0.0512**
	(0.0189)		(0.0216)
Depth_traded	0.0388		0.0288
	(0.0289)		(0.0188)
Depth_Privatecredit_1	-0.00785	-0.0192	0.0306
	(0.109)	(0.124)	(0.0918)
Depth_liquidliabilities_1	-0.116	-0.0950	-0.108
	(0.0913)	(0.102)	(0.0816)
Depth_bankassets_1	-0.0143	-0.0125	-0.0366
	(0.0325)	(0.0293)	(0.0241)
Depth_mktcap_1	-0.00205		0.0181
	(0.0413)		(0.0224)

VARIABLES	Model (I)	Model (II)	Model (III)
Depth_traded_1	0.00197		0.00531
	(0.0312)		(0.0284)
GDPpercapita			-0.00144***
			(0.000358)
Growth			0.232**
			(0.117)
Inflation			0.414***
			(0.132)
Govermentspending			-0.0351
			(0.0743)
Tradeopeness			0.0922**
			(0.0373)
mobilemoney			-3.139*
			(1.661)
GDPpercapita_1			0.000322***
			(8.34e-05)
Growth_1			0.0465
			(0.127)
Inflation_1			0.321**
			(0.136)
Govermentspending_1			0.120*
			(0.0683)
Tradeopeness_1			-0.0797***
			(0.0218)
mobilemoney_1			-2.963**
			(1.486)
Depth_Privatecredit_square		0.000142	
		(0.000930)	
Depth_liquidliabilities_square		-0.00121***	
		(0.000356)	
Depth_bankassets_square		0.000157	
		(0.000946)	
Constant	23.95***	19.56***	22.85***
	(4.753)	(4.286)	(6.909)
Observations	874	874	874
Number of Country	46	46	46

The results from the full panel of countries are reported in Table 2. The empirical results also indicate that the coefficient of inequality is statistically significant in all the specifications. In this model (III), we add other factors expected to affect income inequality. This is growth economic, GDP per capita, inflation, government size, globalization, and mobile money service. Globalization can be depicted by the extent of trade openness, quantified by the ratio of exports to imports. The consideration of government size in this study, defined by the proportion of government expenditure to GDP, is justified due to the government's utilization of certain expenses for redistribution achievement of the economic objectives. In models (I) and (III), we run the regression between income inequality measures and financial development measures (with control variables in model (III)). In both models, we find that the ratio of liquid liabilities has a positive, statistically significant impact on income inequality. The percentage of liquid liabilities to GDP, which is a measure of financial depth also considered a measure of the size of the financial sector (King & Levine, 1993). The findings show that Asian countries, with greater levels of bank development, have exhibited a positive correlation with increased income inequality, as measured by the Gini coefficient. The linear and square-term coefficients of the ratio of liquid liabilities to GDP are substantial. The coefficient of the linear component is optimistic; in contrast, the coefficient of the square term is negative, showing that financial development has a U-shaped impact on income inequality. Thus, financial development exacerbates inequalities in income up to a certain threshold, after which it alleviates the extent of inequality. The threshold manifests when the liquid liabilities to GDP ratio approaches its average value within the given sample. This implies that the threshold at which financial development reaches a significant level before economic growth occurs.

The findings of our study align with the fundamental theoretical framework that explains the relationships between financial development and inequality in income. The positive impact associated with financial development, which implies enhanced accessibility to financial services for those with diminished incomes, provides more significance in economically disadvantaged nations where a substantially more significant proportion of the population lacks access to such services.

In another proxy, deposit money banks' assets to GDP as one of the surrogate indicators of financial deepening indicates a significant and negative effect on Gini. This means the removal of higher reserve requirements mitigates income inequality.

Stock market capitalization negatively and statistically significantly impacts income inequality in models (II) and model (III). In model (II), we use the stock market capitalization to GDP ratio as a proxy for financial development. The estimated coefficient of the linear term of financial development is always negative and significant. This study's findings indicate utilizing stock market capitalization to mitigate income inequality. On the other hand, the relationship between liquid liabilities and GDP is expected to exacerbate income inequality.

Given the significant causal relationship between the financial dimension on income inequality, we argue that directly the stock market capitalization and the removal of high reserve requirements are essential to reduce income inequality.

Model (III) demonstrates a substantial negative relationship between GDP per capita and mobile money service, while GDP growth and inflation rate positively affect income inequality. The outcomes of this study indicate a potential correlation between countries' financial development and income inequality developments during their development. As the finance sector progresses beyond a certain threshold, it has the potential to alleviate income disparity. In advanced countries, the rise of financial institutions rather than economic growth has exacerbated wealth disparity.

The net effects based on conditional and unconditional results are estimated from the interaction between financial development variables.

The research findings indicate that financial institutions have a detrimental effect on income inequality. This conclusion is consistent with previous studies conducted by Gimet and Lagoarde-Segot (2011), Jauch and Watzka (2016), De Hann and Strum (2017), Blau (2018), and Hsieh et al. (2019), which also found a significant positive relationship between financial institutions and income distribution. Rajan and Zingales (2003) argue that individuals with higher wealth can offer collateral and exhibit a higher likelihood of loan repayment. Individuals with low incomes, who do not have this benefit, might need help obtaining loans even in a well-established banking industry.

This positive outcome is supported by the negative and significant estimate, aligning with the findings of Liu et al. (2017), Blau (2018), and Hsieh et al. (2019). These results support the notion that stock markets serve as a beneficial mechanism and possess a distinct advantage in developing tailored financial products that can effectively fund innovative, high-risk, and long-term ventures that rely heavily on intangible resources (Demirgüç-Kunt et al., 2013). This viewpoint is further supported by Levine (1991) and Bencivenga et al. (1995), who posit that an increase in stock market liquidity and lower transaction costs mitigates the negative repercussions associated with long-term investment in projects. This phenomenon may serve as an incentive for companies to undertake such endeavors, hence resulting in a surge in labor demand.

Table 3 presents the results for the relationship between financial development and the growth of the average income of the poorest quintile as the first proxy of the poverty indicator. In the relative measure of poverty, this negatively affects income for the poorest 20% of the population under the total value of all listed shares in a stock market as a percentage of GDP. Nevertheless, our analysis reveals a positive correlation between poverty and the turnover ratio - the overall trading volume on a country's stock market divided by the total number of outstanding shares.

Furthermore, our analysis reveals a positive correlation between financial institutions and poverty in most of our specifications, as observed in the measurements of the poverty gap and the headcount index.

According to the findings in Table 3, there is a positive correlation between GDP growth rate and poverty across several financial development indicators. This suggests that when economies experience higher growth rates, the income allocated to the bottom 20% of the population tends to decrease. This suggests that when economies experience growth, there

is an increase in the share of individuals living below the poverty threshold.

This study finds a negative correlation between poverty and stock market capitalization. This is not surprising considering the high-level stock market capitalization that poverty reduces. A well-developed stock market with high capitalization can indicate a thriving economy with solid business activities and investment opportunities. This can contribute to overall economic growth and job creation, essential to reducing poverty. Although a flourishing stock market can bring prosperity to investors and corporations, it is necessary to recognize that this wealth and its advantages may not be distributed equally among all members of society. In the absence of appropriate policies and regulations, the stock market's growth might disproportionately favor individuals with higher incomes, thereby exacerbating the issue of income inequality.

We also find evidence of liquid liabilities to GDP and higher reserve requirements exacerbating it. A high ratio of liquid liabilities to GDP can indicate a relatively large money supply in the economy. Factors like increased government spending or easy credit availability might drive this. High liquid liabilities may lead to inflation that indirectly hurts poverty. Requiring banks to hold higher reserves can contribute to financial stability by providing a buffer against potential banking crises or runs. This can help maintain public confidence in the banking system. However, higher reserve requirements might also lead to reduced bank lending capacity. This could limit access to credit, particularly for low-income individuals and small businesses, potentially hindering economic growth and poverty reduction efforts.

It is worth acknowledging that the Asian nations may influence the outcomes of our testing. A strong positive correlation exists between the growth rate of per capita GDP and the average incomes of individuals facing poverty. Foreign direct investment (FDI) has been found to impact poverty levels negatively via its influence on international trade. Notably, the findings demonstrate an essential relationship between GDP per capita and FDI with the exacerbation of poverty. The result aligns with theoretical and empirical research that has identified ways FDI can provide negative or insignificant effects on poverty alleviation. Firstly, it is essential to note that FDI does not consistently alleviate poverty in the nations that receive the investment, as it does not necessarily result in job creation and improved wages. In developing countries, numerous multinational corporations possess substantial money, resulting in limited employment opportunities for unskilled laborers within their respective regions. Several empirical studies have been undertaken by Mohey-ud-din (2007), Huang et al. (2010), Ali et al. (2010), Tsai et al. (2007), Akinmulegun (2012), and Ogunniyi and Igberi (2014) to demonstrate the negative impact of FDI on the reduction of poverty.

Table 3. Full sample of countries (POV dependent variable)

POV_20	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Lag of pov20	-.4892009	.0412559	-11.86	0.000	-.5700609	-.4083409
Private credit	.0010272	.0033491	0.31	0.759	-.0055369	.0075913
Bank deposit	.0064935	.0036689	1.77	0.077	-.0006974	.0136843
Liquid liabilities	.0042269	.0012586	3.36	0.001	.00176	.0066937
Stock market capitalization	-.0123916	.0046215	-2.68	0.007	-.0214496	-.0033336
Stock market turnover ratio	.0158961	.0037683	4.22	0.000	.0085103	.0232819
GGDP	.0598694	.013593	4.40	0.000	.0332277	.0865111
INFL	-.0078789	.019269	-0.41	0.683	-.0456455	.0298877
FDI	-.0101839	.0009788	-10.40	0.000	-.0121023	-.0082654
OPEN	.0047859	.0038718	1.24	0.216	-.0028027	.0123746
_cons	4.002801	.4950465	8.09	0.000	3.032527	4.973074

IV. CONCLUSION

This paper investigates how financial development can positively influence income equality and poverty reduction. This is an essential issue for Asian countries, as it presents an opportunity to improve the financial system while addressing the inequality challenge. We approach this topic through empirical analysis to provide insights for policymakers and stakeholders in their efforts to create a more prosperous and equitable society. Theoretically, comprehending the relationship between finance, inequality, and poverty requires more clarification. There are valid arguments to be concerned about the potential effects of financial development on equality. In a context, the advancement of financial development has the potential to enhance the accessibility of financial services for those with limited incomes, hence facilitating their ability to enhance productivity.

Conversely, the development of the financial sector may inadvertently exacerbate inequality if it primarily caters to the affluent segment of society, offering them improved and superior financial services while failing to make substantial strides in ensuring access for the underprivileged. Consequently, this disparity would further widen the gap between the rich and the poor. Hence, financial development's impact on income inequality requires empirical investigation.

The findings presented in this study consistently indicate that the financial market plays a crucial role in alleviating poverty and mitigating the decline in income inequality. These results are in line with the findings of several recent studies conducted by Jalilian & Kirkpatrick (2005), Beck et al. (2007), Odhiambo (2010), and Inoue & Hamori (2011). These studies suggest that the progress of the financial sector positively impacts economic growth and facilitates poverty reduction by establishing a causal link between financial development, income inequality, and poverty reduction.

The findings of this study shed light on the often neglected relationship between financial development, GDP per capita, mobile money services, and government spending in reducing income inequality. However, GDP per capita and FDI aggravate poverty in Asian countries. The results propose an approach for policymakers' decision-making with a thorough assessment of how specific financial system policies and interventions can achieve desirable income distribution and poverty reduction in Asian nations.

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THE RELATIONSHIP BETWEEN MOTIVATION AND JOB SATISFACTION TOWARDS JOB PERFORMANCE OF EDUCATIONAL STAFF IN ENGLISH CENTERS IN THU DAU MOT CITY

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Abstract: Vietnam in general and provinces in particular are on the way to global integration, therefore, the need to learn a second language has become necessary. Most Vietnamese citizens choose to learn English as a second language because they believe that it can help them to change their future in a good way. For this reason, the number of English centres increases rapidly, and the quality of employees tends to be an important part of keeping organisation service. The aim of this research is to identify the work motivations including payment, job security, promotion, supervision, working environment and training have a relationship impact on job satisfaction toward job performance in English Centers, Thu Dau Mot City, in Binh Duong province, Vietnam. The research is based on quantitative data collected from 384 employees working in English Centers, in Thu Dau Mot City. The collected data was then analysed using various statistical techniques, including Cronbach's alpha test, and exploratory factor analysis (EFA) using the Five-Point Likert Scale. Additionally, confirmatory factor analysis (CFA), structural equation modelling (SEM), and the Bootstrap method were applied using Amos Version 24. Among these dimensions, Supervision has the most significant impact on employee satisfaction, consequently driving performance. The results are expected to provide valuable insights for English Centers and can guide future research as well as inspire further research in this field.

Keywords: *motivation, payment, job security, promotion, supervision, working environment, training, job satisfaction, job performance, English Centers, Thu Dau Mot City, Binh Duong Province*

I. INTRODUCTION

One of the extensively researched concepts in the field of human resource development (HRD) is "performance". For Shaughnessy (2017), the employees' performance is the extremely crucial key to the company's success. In Vietnam, the number of English centres increased rapidly due to the increase in parents' need for their children. They believe that as a second language – English can help to enhance their future better. Research about the customer target in English Centers in Vietnam shows that most of them are in the middle class (Pham and Le, 2020). The figure of the middle class in Vietnam increased double to 33 million in 2020 and it will continue to increase until 2030 (Vietnam News, 2021), therefore, the English

education industry becoming a potential market. Hence, improving the morale of employees is also necessary to achieve the best work efficiency to adapt to the development industry. Furthermore, having a closer examination of job performance may help managers identify which motivating factors are related to job satisfaction. Even though the topic of job satisfaction has been actively conducted across a wide range of fields, including industry, business, and education (Schneider & Barbara, 2014). On the other hand, there is no research combining the 3 elements including job motivation, job satisfaction and job performance, especially in the English education system in Vietnam.

II. LITERATURE

A. Motivation

Sansone and Harackiewicz (2000) define motivation as an internal system that directs conduct. This can be thought of as the catalyst for individual workers to improve their productivity and attain organizational performance. The motivation factors that affect job satisfaction are different in many research because they can vary by country, jobs and changes over time, according to the research claimed by Westover and Taylor (2010). The viewpoints of Astrauskaite, Vaitkevicius and Perminas (2011) and Spector (1997) collectively share the opinion that teachers differ from typical employees in various ways. Therefore, the motivation for teachers in the teaching field may not always be captured by instruments that are used to measure typical employee traits like job satisfaction and motivation, such as appreciation, communication, coworkers, outside benefits, job conditions, nature of work, organizations' policies and procedures, pay, personal growth, promotion opportunities, recognition, security, and supervision. However, Sharma and Jyoti (2009) found that supervision, work itself, career growth, and recognition are significant parts of teachers' motivation at work and can be utilized to explore motivation and performance among teachers. So, the motivation facets will be combined between the international and domestic studies which are closer and more suitable for the education employees in English centers including payment, job security, promotion, supervision, working environment and training. They are also considered extrinsic motivation factors for teachers (Gultekin & Acar, 2014; Kumar & Hossain; 2017).

B. Job satisfaction

As shown by Spector (2007), job satisfaction can be defined as a happy emotional state brought on by the enjoyment a worker gets from their work in addition to the affective and cognitive attitudes they have towards different parts of their employment. According to Ayam Olowo (2013), job satisfaction is an emotional reaction brought on by how well an employee feels about their job and workplace. A person is more satisfied at work when they are treated well and given challenging and interesting tasks (Bateman & Organ, 1983). Therefore, senior management should continue to update and rearrange job duties to increase employee interest and satisfaction (Harter, Schmidt & Hayes, 2002).

C. Job performance

Performance is the outcome of the quality and quantity of work completed by a person while performing their job. Performance evaluation is crucial for businesses so that the viability of the enterprise may be ensured (Zhang, 2010). Performance is necessary because its existence

can increase motivation and encourage them to be actively involved in innovative programs, and make it easier to reach the desired goals (Minavand & Lorkojouri, 2013). Furthermore, employee performance is a very important point in the company's efforts to seek the goal (Riva, 2006). Performance management must consist of a series of actions intended to ensure that the organization's performance requirements come from its employees in order to be effective. This is the link between the organizational strategy with the ultimate results by Mathis and Jackson (2010).

D. Hypotheses development

a. Payment and job satisfaction

The wage structure of the company is closely correlated with employee work satisfaction (Greenberg & Baron, 1995). According to Lawler (1981), having an equal and fair compensation system is necessary to promote job satisfaction. Lawler added that factors like bonuses and annual wage increases will boost worker job satisfaction. A report by Lazear (2000) indicated that when their employers' income increases, the majority of employees work attentively on their duties and obligations. On the other hand, McLean et al. (1996) examined the impact of pay on the career perspectives of information system professionals, they discovered that although pay is essential at first, other considerations eventually take precedence over pay. Payment is defined in this study as the amount an employee receives that is sufficient to cover their typical living expenditures. Therefore, as per the above discussion, the subsequent hypothesis is constructed.

H1: *Payment is positively related to job satisfaction.*

b. Job security and job satisfaction

Employee job security, in accordance with Andrew and Postel-Vinay (2019), refers to the degree of security an employee has over the ability to keep their current job and receive a reliable income from it. It also encompasses the belief that they will not be terminated or laid off from their position without just cause. According to Tsui, Pearce, Porter, & Tripoli (1997), depending on the firm's own practices and policies with them, they determine whether employees feel more or less secure about their employment. According to Bakan & Büyükbeşe (2004), an important source of motivation for employees is their expectation that they will not lose their jobs or that they will remain with the same company for as long as they like. Therefore, job security is one of the most significant components of employee happiness due to how it helps the individual's attitude toward his or her job as a whole. If employees feel that they have a facility of job security, the increased level of job satisfaction following that is more commitment and in the end organizational productivity will be increased (Preuss, 2005). Therefore, as per the above discussion, the subsequent hypothesis is constructed.

H2: *Job security is positively related to Job Satisfaction.*

c. Promotion and job satisfaction

The promotion definition by Lazear (1986) is "The movement of an employee upward in the hierarchy of the organization, typically that leads to enhancement of responsibility and rank and an improved compensation package is a promotion". It can be understood that the job of employees become level up with the significance and high compensation. Moen and

Rosen (2005) found that the most significant categories of job satisfaction are pay satisfaction and satisfaction related to job security, not promotion opportunities. However, without promotions and other job improvements like training, there may be a bigger negative impact on job satisfaction than high workloads or poor pay (Shields & Ward, 2001). Furthermore, having training programs, the possibility of growth, and promotion opportunities also positively affect work satisfaction, according to teacher satisfaction research at Universities in Pakistan (Syed, Bhatti, Michael, Shaikh & Shah, 2012). The researchers from Simanjuntak (2015) and Rahayu (2017) found that satisfaction with job promotion has a positive and significant influence on employee performance. Therefore, as per the above discussion, the subsequent hypothesis is constructed.

H3: *Promotion is positively related to Job Satisfaction.*

d. Supervision with job satisfaction

As a part of the supervision process, the supervisor is really necessary to contribute to successful job satisfaction. Supervisors are the assessors who appraise an employee's duties to help them accomplish the organization's goals and objectives (Wahjono, Marina, Perumal and Wardhana, 2016). According to the research of Sargent and Hannum, (2005), the quality of the managers and supervisors influences the working environment of the school. It means that the people who have a higher rank than employees might impact the job environment. Therefore, according to Arnetz (1999), the issues between supervisors and employees in businesses used to come early because supervisors do not treat employees with the respect employees deserve. Previous research has examined the relationships between supervisor support and job satisfaction and reported a positive relationship between supervisor support and job satisfaction (Changetal, 2010). In this research, I am looking at the relationship between supervisor-employees to find out the effectiveness of supervision on job satisfaction. Therefore, as per the above discussion, the subsequent hypothesis is constructed.

H4: *Supervision is positively related to job satisfaction.*

e. Working environment

According to Schultz & Schultz (2015), the working environment or working conditions are all physical working characteristics, occupational psychology, and work policies that may impact workplace satisfaction and productivity. According to the research of Nitisemito (2010), a worker's work environment includes everything in and around him and might have an impact on the way he completes duties. According to Wakhid (2014), a positive work environment provides workers with a feeling of security and allows them to perform at their best. It means that in a suitable work environment that they like, the employees will feel comfortable with their job to use the working time effectively. Furthermore, the workplace has a huge impact on employee satisfaction (KafuiAgbozo, 2017). Research by Saggaf, Nasriyah, Salam, and Wirawan (2018) revealed that a positive work environment and a committed organizational culture will boost teachers' performance in order to hit the set targets, which include producing competent students and reaching the maximum potential of the country's educational system. From that standpoint, it is clear that a good employee's work environment gives them satisfaction

that affects everything around them and the ability to carry out their given responsibilities. Therefore, as per the above discussion, the subsequent hypothesis is constructed.

H5: *Working environment is positively related to job satisfaction.*

f. Training with job satisfaction

Training is defined as the transmission of useful and applicable knowledge, abilities, and skills through teaching in order to successfully complete a task in the actual world (Karlan & Valdivia, 2011). The goal of ongoing training is to improve an employee's performance and knowledge (Mahony, 2002). It has been established that enhanced training programs for employees and train-the-trainer programs for employee trainers have a positive impact on job satisfaction (Hatcher, 1999). Rodriguez & Walters (2017) also argue that training lets employees believe they are making an investment in their own future, they experience higher levels of work satisfaction because they have a role in their organizations. Therefore, as per the above discussion, the subsequent hypothesis is constructed.

H6: *Training is positively related to job satisfaction.*

g. Job satisfaction with job performance

Performance is the outcome of the quality and quantity of work completed by a person while performing their job (Bintoro and Daryanto, 2017). Meanwhile, the performance also assesses the active role of employees in carrying out obligations according to the formal contract given to them by the company (Biswas, 2009).

Due to its beneficial impact on job performance, job satisfaction has received considerable attention in the literature (Lu & Gursoy, 2013) and has also been associated with productivity (Halkos & Bousinakis, 2010). According to Gu and Chi (2009), there is also a strong connection between being satisfied with their job and employees' performance. A worker with a good attitude about their work will be more satisfied with their work and more likely to dedicate themselves to their company, which will improve organisational performance (Wu, Tsai & Fu, 2013). According to studies by Hendra Kurniawan and Arasy Alimudin (2015), employee performance is significantly influenced by job satisfaction. Job satisfaction has a substantial positive association with organisational success, which includes financial performance, service performance, and behaviour performance, according to Shiu and Yu's (2010) research. Therefore, as per the above discussion, the subsequent hypothesis is constructed.

H7: *Job satisfaction is positively related to job performance.*

E. Research model

Figure 1 shows the conceptual model and provides the summary of the variables and the hypotheses that are guided for this paper of study. As could be seen in the model, payment, job security, promotion, supervision, working environment and training represented six different determinants of motivation factors. Moreover, this paper also showed job satisfaction affects employees' performance as the mediator role.

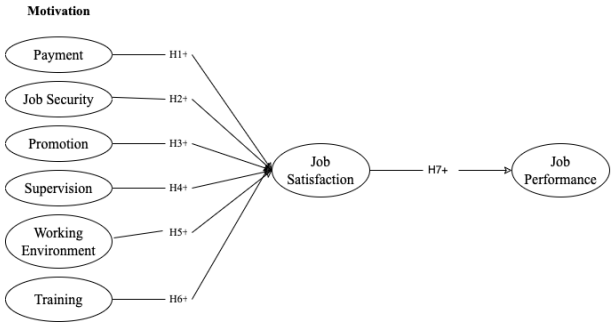

Figure 1. The research model

Based on the model (Figure 1), we propose the following research questions:

RQ1: What motivational factors positively affect the job satisfaction of educational staff in English Centers in Thu Dau Mot City?

RQ2: What is the most significant factor that affects the job satisfaction of education staff in English Centers in Thu Dau Mot City?

III. METHODOLOGY

A. Research process

The quantitative data were obtained through an anonymous online survey. The respondents are Vietnamese citizens who are working at the English Center in Thu Dau Mot City. In this study, the linear structural analysis method (SEM) is applied to investigate the relationship between job motivation and satisfaction to find out the effect of job performance.

B. Sampling method

In August 2023, participants for this study were recruited using Google Forms. This paper yielded a total of 384 valid responses. A total of 66 responses were omitted due to missing data.

The survey contains a demographic section which includes gender, age, education level, work contract and work experience, monthly income and the centre's name in current company are presented in Table 1.

Table 1. Descriptive data

Characteristics		N	%
Gender	Male	127	33,1
	Female	241	62,8
	Other	16	4,2
Age	18 years old	30	7,8
	19 - 25 years old	272	70,8
	26 - 30 years old	27	7
	30 - 35 years old	30	7,8
	Over 35 years old	25	6,5
Level of Education	Undergraduate	263	68,5
	Bachelor	97	25,3
	Master	18	4,7
	Doctorate	0	0
	Other	6	1,6
Type of employment contract	Full time	91	23,7
	Part time	293	76,3
Working Experience	Less than 1 years	65	16,9
	1-3 years	273	71,1
	More than 3 years	46	12
Monthly Income	Less than 10 million VND	296	77,1
	10 million VND to less than 20 million VND	46	12
	20 million VND to less than 30 million VND	20	5,2
	Over 30 million VND	22	5,7
Center	ILA	37	9,6
	Apollo	26	6,8
	VUS	44	11,5
	Nghị Anh	35	9,1
	H123	51	13,3
	Others	191	49,7

As presented in Table 1, there were 127 males, 241 females and 16 others which were 33.1%, 62.8% and 4.2% respectively. Participants were the age of 19-25 which exceeded 70.8% of the total, therefore most of them are in the level of undergraduate students with 68.5% of education level, and because of that their employment contract for part-time employees has the maximum percentage with 76.3% compared to full-time. The number of participants who had 1–3 working experience

was the majority, which exceeded 71.1%. In the salary aspect, the number of participants who had a monthly salary of less than 10 million was the highest which reached 77.1%. With the number of centres, we can see that the "others" option has the maximum number meaning Thu Dau Mot has a lot of English centres besides the popular one.

IV. RESULT

We evaluated the validity of the first-order measurement model by examining internal consistency, as well as convergent and discriminant validity of all factors.

The Corrected Item-Total Correlation, Cronbach's alpha, CR (composite reliability), and AVE (average variance extracted) values are presented in Table 2. According to Taber (2018), Cronbach's Alpha should be higher than 0.5, which means that if it is higher, which means the measurement scale is more credible and in reverse. Furthermore, Corrected Item – Total Correlation scores that are less than 0.50 are unacceptable according to Kim and Stoel (2004). Most of the factors are more loading than 0.5, which are considered to have satisfied the conditions needed. Only items PA2 and JP5 have values lower than 0.5, so they are not valid for the next stage.

Table 2. Variable statistic

Constract	Item	Corrected Item-Total Correlation	Cronbach's Alpha
Payment			0.846
	PA1	0.751	
	PA2	0.494	
	PA3	0.791	
	PA4	0.735	
Job Security			0.926
	JS1	0.809	
	JS2	0.806	
	JS3	0.805	
	JS4	0.805	
	JS5	0.802	
Promotion			0.942
	PR1	0.849	
	PR2	0.861	
	PR3	0.864	
	PR4	0.874	
Supervision			0.919
	SUP1	0.809	
	SUP2	0.810	
	SUP3	0.811	
	SUP4	0.828	
Working Environment			0.93
	WE1	0.848	
	WE2	0.831	
	WE3	0.834	
	WE4	0.834	
Training			0.941
	TR1	0.851	
	TR2	0.867	
	TR3	0.86	
	TR4	0.855	
Job Satisfaction			0.93
	JSa1	0.816	
	JSa2	0.813	
	JSa3	0.821	
	JSa4	0.815	
	JSa5	0.812	
Job Performance			0.846
	JP1	0.625	
	JP2	0.733	
	JP3	0.705	
	JP4	0.667	
	JP5	0.123	

We used the value in Table 3 to examine the convergent validity using the composite reliability (CR) and average variance extracted (AVE) indices. According to Fornell and Larcker (1981), in order to establish convergent validity, the AVE value should be equal to or greater than 0.5, while the CR value should be equal to or greater than 0.7. When assessing discriminant validity, the AVE values should be greater than the Mean Shared Variance (MSV) value.

Table 3. CFA–validity analysis

	CR (0.7)	AVE (0.5)	MSV	MaxR (H)	JSa	JS	PR	WE	SUP	TR	JP	PA
JSa	0,93	0,727	0,4	0,93	**0,853**							
JS	0,926	0,713	0,407	0,926	0,567 ***	**0,845**						
PR	0,942	0,803	0,284	0,943	0,421 ***	0,494 ***	**0,896**					
WE	0,931	0,77	0,4	0,931	0,632 ***	0,494 ***	0,425 ***	**0,878**				
SUP	0,92	0,741	0,348	0,92	0,590 ***	0,418 ***	0,431 ***	0,351 ***	**0,861**			
TR	0,941	0,799	0,435	0,941	0,560 ***	0,559 ***	0,468 ***	0,505 ***	0,499 ***	**0,894**		
JP	0,848	0,583	0,435	0,857	0,570 ***	0,638 ***	0,533 ***	0,488 ***	0,528 ***	0,660 ***	**0,763**	
PA	0,893	0,735	0,265	0,896	0,493 ***	0,515 ***	0,462 ***	0,348 ***	0,358 ***	0,417 ***	0,447 ***	**0,858**

In this table, the results of all variables (JSa, JS, PR, WE, SUP, TR, JP and PA) meet the required conditions which are higher than 0.7 in the CR, and higher than 0.5 in the AVE. Moving to check the MSV, the value of each variable is adapted less than the value of AVE so discrimination is guaranteed. Checking the Fornell and Larcker table, the SQRTAVE value is higher than the value of correlations between it and other factors that meet the criteria.

Table 4. Heterotrait–motitrait (HTMT) radio of correlation

	JSa	JS	PR	WE	SUP	TR	JP	PA
JSa								
JS	0,567							
PR	0,422	0,494						
WE	0,633	0,494	0,425					
SUP	0,588	0,419	0,433	0,348				
TR	0,559	0,56	0,47	0,506	0,499			
JP	0,573	0,638	0,54	0,49	0,54	0,662		
PA	0,489	0,512	0,462	0,345	0,358	0,418	0,453	

The Heterotrait – Monotrait ratio of correlations - HTMT is a relatively modern approach for discriminant validity evaluation, and the value has to be lower than 0.90 to establish sufficient discriminant validity (Henseler et al., 2015). In that case, an HTMT value above 0.90 would suggest that discriminant validity is not present. According to Table 4, the values shown in the table are from 0.345 to 0.662 meaning that each item has a distinction. In other words, these values mean that the constructs from variables are not having problems and the respondents' perceptions are not confused.

Next, the researcher included all observed variables and the latent variables that were tested earlier in the analysis into a linear structural equation model (SEM) and tested the hypotheses, allowing us to test the research hypotheses we formulated. In Table 5, the focus is on the p-value column and the Estimate column. Interestingly, most of the independent variables have a positive value effect on the mediator variable (Job Satisfaction), only the relationship between the Promotion variable and Job Satisfaction has a negative relationship with the estimated value is -0,051 and the p-value is 0.222 (>0.05). Furthermore, the relationship between Job Satisfaction and Job

Performance is also positive with a value equal to 0.488. The results reveal that satisfaction with their job can thus an employee to well perform if the employee is motivated enough to work.

Table 5. SEM–regression weights

	Estimate	S.E.	C.R.	P
JSa <--- PA	0,162	0,047	3,426	***
JSa <--- JS	0,164	0,055	2,98	0,003
JSa <--- PR	-0,051	0,042	-1,22	0,222
JSa <--- SUP	0,296	0,043	6,86	***
JSa <--- WE	0,256	0,034	7,601	***
JSa <--- TR	0,089	0,042	2,122	0,034
JP <--- JSa	0,488	0,044	11,012	***

The Standardized Regression Weight is a table used to assess how strongly a factor influences another factor in a causal relationship.

Table 6. Standardised regression weights

			Estimate
JSa	←	PA	0,162
JSa	←	JS	0,156
JSa	←	PR	-0,057
JSa	←	SUP	0,321
JSa	←	WE	0,364
JSa	←	TR	0,108
JP	←	JSa	0,604

It is clear that the independent factor that affects the mediator factor (Job Satisfaction – JSa) including Payment (PA), Job Security (JS), Supervision (SUP), Working Environment (WE), and Training (TR) by their positive values. The highest value means the strongest impact, therefore, the strongest factor influencing JS is WE, followed is SUP, next is PA, lower is JS and the lowest is TR. Meanwhile, Promotion (PR) has a negative value of -0.057, meaning that the independent variable PR has a negative impact on the mediator variable, and as the value of the independent variable changes, it tends to produce opposite changes in the mediator variable. For the dependent variable – Job Performance (JP) and mediator variable – JSa also has a high effect with an estimated value of 0.604. According to the findings of this study, which focused on the mediation role of job satisfaction, the working circumstances at an organization can help to improve employees' performance by raising their levels of satisfaction.

Table 7. The results indirect effect of the variable

Hypo -thesis	Indirect Path	Indirect		Result
		Standardized Estimate	Sig. (< 0.05)	
H1	PA → JSa → JP	0.098	0,001	Accepted
H2	JS → JSa → JP	0.094	0,006	Accepted
H3	PR → JSa → JP	-0.034	0,16	Unaccepted
H4	SUP → JSa → JP	0.194	0,001	Accepted
H5	WE → JSa → JP	0.22	0,001	Accepted
H6	TR → JSa → JP	0.065	0,028	Accepted

As suggested by Hair et al., (2010), it is crucial to employ Bootstrapping to validate the results obtained from mediation analysis. Many studies have utilized the bootstrap method proposed by Preacher and Hayes (2008) to test the role of intermediate variables in mediation analysis. The results in the table above show the significant mediating relationships among the variables in the model. With the value above, the relationship through H1, H2, H4, H5, and H6 is accepted due to having a significant value, while H3 will be denied because of the invalid value. The valid values explain the hypothesis that:

H1: Indicating that Job Satisfaction (JSa) acts as a mediating factor in the relationship between Payment (PA) and Job Performance (JP). The fact that the confidence interval's upper and lower limits do not include the value

0, and the P-value is 0.001 < 0.05 supports this conclusion. Furthermore, it is mentioned that the standardized effect coefficient for this relationship is 0.098, which suggests a significant positive effect of payment on job performance through the mediator of job satisfaction.

H2: The relationship between Job Security (JS) and JP has an intermediary role of JSa due to the value of confidence interval, upper and lower limits do not include the value 0, and the P-value is 0.01 < 0.05. The standardized estimate's value also gives a large support for this relationship with the number reaching 0.094.

H3: The value in this hypothesis is not significant, because the P-value is reached at 0.177 higher than 0.05, the value of lower is negative with -0.059 and the standardized effect's value is negative too with -0.034, so the relationship between Promotion (PR) and JP is unacceptable even though having the participation of mediator variable – JSa. This factor, the fact is because the career path for employees in education industries can be too short and far, or also does not have many chances for them to develop, therefore, if organizations are interested in this factor, the organization can face many struggles for solutions.

H4: The proposes that the relationship between Supervision (SUP) and JP with acts from mediator variable - JSa has been confirmed. This relationship is accepted and significant with the upper and lower limits not including the value of 0 and the P-value is 0.001 < 0.05. This means that JSa plays an intermediary role in the relationship between SUP and JP. Additionally, the standardized effect coefficient for this relationship is 0.194 which signifies a large positive effect of the performance. As the person has more opportunities to contact with employees compared to others, the role of supervisors should be noticeable to support and increase employees' satisfaction and performance by providing necessary support, carrying out mental health, supporting work-life balance, and so on.

H5: This hypothesis has been checked, showing that JSa mediates the association between the Working Environment (WE) and Job Performance (JP). The P-value is 0.001<0.05 and the upper and lower boundaries of the confidence interval do not include the value 0. Therefore, it can be said that the relationship between WE and JP is mediated by JSa, with a standardized effect coefficient of 0.220. This result, suggests that firms must make sure that their workers are working in a favorable and welcoming atmosphere because of the growing competition and the dynamic, demanding nature of the business environment. This is necessary for them to perform to their greatest capacity.

H6: Has been supported, demonstrating that the association between Training (TR) and Job Performance (JP) is mediated by JSa. The upper and lower boundaries of the confidence interval do not include the value 0, and the P-value is 0.03 < 0.05. Therefore, it can be inferred that the impact of TR on JP is significantly mediated by the JSa, and the standardized effect coefficient for this relationship is 0.065. Therefore, organizations can invest and improve in the training programs for employees which can have a positive effect on job satisfaction

V. FINDING AND DISCUSSION

Table 8. The summary of hypotheses results

	Standardised Estimate	P < 0.05	Result	Impact Ranking
H1: Payment is positively related to Job Satisfaction.	0.162	0.000	Supported	4^{th}
H2: Job Security is positively related to Job Satisfaction.	0.164	0,003	Supported	3^{rd}
H3: Promotion is positively related to Job Satisfaction.	-0.051	0,222	Rejected	6^{th}
H4: Supervision is positively related to Job Satisfaction.	0.296	0.000	Supported	1^{st}
H5: Working Environment is positively related to Job Satisfaction.	0.256	0.000	Supported	2^{nd}
H6: Training is positively related to Job Satisfaction.	0.089	0,034	Supported	5^{th}
H7: Job Satisfaction is positively related to Job Performance.	0.488	0.000	Supported	

A. Finding

The study found a significant positive relationship between Payment (PA), Job Security (JS), Supervision (SUP), Working Environment (WE), Training (TR) and Job Satisfaction (JSa). On the other hand, Promotion (PR) had a negative relationship with JSa. The relationship between mediator – JSa and Job Performance (JP) had a positive relationship. The relationship between PA and JSa was p-value 0.000 < 0.05 and the Standardized Estimate value was 0.162 this factor had a ranking at 4^{th}. The relationship between JS and JSa had a p-value is 0.003 < 0.05 and the Standardized Estimate value for this causal relationship is 0.164, therefore, H2 about the positive relationship between Job Security and Job Satisfaction is acceptable with rank 3^{rd}. Promotion which had the p-value = 0.222 > 0.05, and Standardized Estimate value = -0.246 also showed a negative relationship with the satisfaction. Therefore, this hypothesis is not rejected. For H4, the relationship between Supervision and Job Satisfaction had a strong positive impact with the value reaching at top 1 as p-value = 0.000 and the Standardized Estimate value = 0.296. The 2^{nd} belong to the Working Environment with the p-value = 0.000 and the Standardized Estimate value = 0.256, meaning that their relationship was significant and positive. Training motivation has a value with the p-value = 0.034 < 0.05 and the Standardized Estimate = 0.086, this value helps H6 has been demonstrated and to attend at top 5^{th}. H7 in this research is not the motivation factor that determines the rank, therefore, this hypothesis does not have the rank but the relationship in this hypothesis is as positive as the proposal.

B. Discussion

The result for pay satisfaction is particularly surprising. Some researchers agree that payment is a strong predictor of job satisfaction (Heneman, 2002) but in this research, it is not. The results of this review suggest that earning is weakly satisfying job satisfaction in the English Center working environment in Binh Duong. However, in the context of the economy and job search opportunities in 2022–2023 are facing many difficulties due to an economic recession after the Covid-19 pandemic, workers are trying to find a job to cover their lives, so they tend to be satisfied with the salary rather than demanding a high salary. Thus, businesses can use wages as a motivating factor, inspiring teachers to invest extra effort in their roles, develop innovative teaching approaches, and engage in continuous professional development.

In this research, the result shows that security in a job has a higher rank compared to payment, therefore, the job security of academic staff must be taken seriously. With the huge number of employees who can use English and the consumers' needs nowadays, becoming an English teacher is becoming easier than ever, therefore, paying attention to job security has a significant impact on the organizational commitment of employees (Iverson, 1996) and their performance (Lambert, 1991). Thus, the business must have a suitable strategy to secure

the employees' job about their interests such as mental health, benefits, commitment and so on which can induce employee commitment in any work situation. Teachers who perceive the safety of job security would put in their best for the achievement of institutional goals and objectives and would take their jobs seriously.

In much research, the relationship between promotion and job satisfaction is positive on many levels. However, with this research result, their relationship is negative, meaning, promotion does not significantly increase the job satisfaction level as we normally perceive. It can be from many reasons that come from the job, themselves, external agents and so on. However, many researchers have confirmed that the motivation factors are different due to the industry, demographics, geography and so on. Hence, the promotion factor is not suitable to study in the case of the research.

The ranking of Supervision with Job Satisfaction is in top 1 which is on the top, which means that the supervisor factor greatly influences job satisfaction; the research from Tickle et al. (2011) makes the same argument, furthermore, they also find out that teachers' supervisor support greatly influences their intention to stay in the educational environment. As this is the first important factor, the business can attend to it by training the supervisor to behave thoughtfully and friendly towards the teachers, to show personal interest, to value them, to empathize with them, to listen to and to support their opinions. The satisfaction of supervision will be reflected in job performance positively and will serve to improve the success and efficiency of businesses, furthermore, it builds a strong commitment between educators and centers.

With nature binding the people within the community of the working environment, businesses should have a healthy impact on it to make a good and conducive working environment, which can make the employee comfortable and have the spirit to do each of his or her duties (Chandrasekar, 2011). Organization can start from the organization's culture because culture is also important for teachers to create a conducive and focused work environment. A culture needs time to establish but it will be a core strategy valid for the long term. A good working environment and a dedicated organizational culture will increase the teacher's performance to achieve the designated target, which is to create qualified students and to achieve a full national education goal (Saggaf et al., 2018).

Even the ranking of training motivation is attended at the low top, however, with the positive relationship, it cannot be denied the necessary. Businesses must have training suitable programs to help them enhance their functional area expertise and also prove helpful in improving their classroom delivery as a faculty. Training the necessary skills not only improves employee's performance but also for the business. Moreover, having training programs can enhance the satisfaction of employees because they can feel the company's attention and personal development for their career path ahead.

Playing as a full mediator, job satisfaction has a significant role in the relationship between educators' motivation and job performance. Besides that, the research findings of Price (1997) and Rose (1991) reported that job satisfaction is a predictor of organizational commitment. Following that, businesses can

increase a high level of job satisfaction by attending to the most interested or necessary of their employees, which can lead to a high level of job commitment and performance. However, if academic staff experience job dissatisfaction they would become frustrated, and apathetic, and their morale would sag. This would be affected by the commitment and performance of both. In conclusion, job satisfaction plays a central role in institutional efficiency and commitment.

VI. CONCLUSION

This paper examines the impact of working motivation on employees' performance in the English Center in Thu Dau Mot City with the participation of job satisfaction as a full mediator. Based on those results, we conclude that motivation on the job can increase employee satisfaction, and the mediating role of employee satisfaction which in turn increases their performance. We found that all relationships in the structural model were statistically significant, where the relationship between Supervision, Working Environment and Job Security are in the top 3 which were found as most important followed by the relationship between Payment and Training with Job Satisfaction.

Having a strong relationship between employees and their supervisors can enhance employees' performance, in this way, satisfaction with the job can increase, and the organization can prioritize this item. To make it successful, Purcell's research (2009), also suggests that when promoting or hiring for manager positions, organizations should be more discriminating and look for applicants with a real interest in human rather than just technical knowledge. Furthermore, having a good working environment can increase employee loyalty, level of commitment, efficiency & effectiveness, and productivity, and also develops a sense of ownership among employees which ultimately increases organizational effectiveness as well as reduces prohibited costs emerging as a result of dissatisfied employees. Regarding job security, even though education is a sustainable industry, employees want to have a fair and guarantee in their job such as fair treatment, clear payment, health protection which are essential for them to believe and work for your business. Money is a good motivator, actually, all employees work for money. Employees need money, and a good salary and good compensation are key factors in satisfying the employee. In the research, even if payment is not the top motivation factor of employees, however, they still have a certain interest in their salary at work. Therefore, we can deliberate to increase the employee salary and compensation to motivate the employee. Good payback can be one of the key factors affecting job satisfaction, also in this way one can increase service quality and organizational performance. Last but not least, training was demonstrated to be the element which had an effect on the satisfaction of staff. In practice, training helps employees have a lot of opportunities to learn and enjoyable experiences on issues related to their work. Hence, an organisation should have training policies or training sessions periodically for employees, which might help them feel less dissatisfied with their work, destroying the feeling that the organisation only wants to squeeze their available knowledge and experience.

The relationship between Promotion and Job Satisfaction is found to be the least important and with a negative sign, suggesting a negative effect, meaning that in the English

education environment especially in Thu Dau Mot City, the career path is unclear or does not have, this phenomenon is not totally clarified. However, as a determinant of job motivation, it does not significantly affect total job satisfaction to make a noticeable difference.

The result of this study relating to the mediating role of job satisfaction suggests that a company's work motivation assists in improving the performance of the employees by increasing the employee's satisfaction levels.

VII. LIMITATIONS AND FUTURE RESEARCH

Several limitations might be present in this study, though every effort was made to ensure the integrity of the research. Firstly, the direct relationship between the independent variable – job motivation and the dependent variable – job performance has not been accredited to compare the similarities and differences with the relationship having job satisfaction as a full mediator. Second, as the English Centers are popular in Thu Dau Mot City in particular and Binh Duong Province in general, however, they have differences such as teaching styles, teaching purpose, source materials, types of main teachers, and so on, with the difference that they have, therefore, the research's results only have a relative because it cannot suitable for almost business. Finally, it is a limit to the generalizability of the findings to other regions or markets due to data that was collected solely in Thu Dau Mot City, Binh Duong Province. So, it cannot extend the support to improve the quality of the English Center Organization in the context of Vietnamese citizens having a significant interest in learning English more to cultural integration. Future research should continue the research on the direct impact of Motivation on Job Performance to have a clear evaluation of this relationship and the relationship having Job Satisfaction as a mediator variable. Having deep research to choose the suitable and potential motivation factors for this research object such as rewards and co-work. With the popularity of English Centers nowadays, uniformity about the type of business which helps to focus on the research to have a homogeneity sample. Then, expanding the scope of the study to include a larger and more diverse sample from multiple regions would enhance the generalizability of the findings.

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THE RELATIONSHIP BETWEEN PORT SERVICE QUALITY (PSQ) AND CUSTOMER SATISFACTION IN BINH DUONG

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Abstract: This study examines the relationship between port service quality (Resource, Outcomes, Process, Management and Image and Social responsibility) and customer satisfaction. These relationships are examined using a sample of 172 respondents - customers or staff who have already used port service in Binh Duong which was obtained through online survey and then using SPSS for hypothesis testing. The research findings indicated that among five attributes of innovation there are four factors, including Resource, Outcomes, Process and Management that have a positive impact on port service quality on customer satisfaction. Meanwhile, Outcomes is the most significant determinant influencing port service quality on customer satisfaction. Additionally, this paper also provides further findings and recommendations which will not only contribute to the literature on logistic research but also assist ports in Binh Duong become more developed and improve their services and customer's reliability to meet their customers' satisfaction.

Keywords: *Port service quality (PSQ), customer satisfaction, Resource, Outcomes, Process, Management, and Image and Social responsibility, theory of SERVQUAL and ROPMIS*

I. INTRODUCTION

Seaports serve as crucial hubs for both inbound and outbound transportation in this regard product flow outward. Ports were first primarily thought of as platforms, having connectivity with other ships where cargo is being loaded or unloaded, travel methods (Neil, 2013). Nowadays, ports play a bigger role in the efficient management of goods movements and information sharing. Therefore, any unexpected incidents, such as accidents or delays in the loading and unloading of cargo, may stop those movements, which could lead to performance failures in other phases of the global supply chains. Other stakeholders, such as shipping lines, shippers, and logistics service providers, would undoubtedly be unhappy with an inefficient ports management outcome given the potential repercussions (Bishal & Ravi, 2021). Seaports have assumed an increasingly significant role in Vietnam in recent years. When compared to other seaports in the region, Vietnam's seaports have recently demonstrated significant and constant growth in terms of throughput. Vietnam's seaport infrastructure is expanding quickly, with throughput growth in the years 2010 to 2015 reaching 11.8%, more than twice the global average. According to data from the Vietnam Seaports Association (2018), the country's seaports handled 12,930,071 TEU in 2018, indicating a large trade in containerized cargo.

In fact, Binh Duong plays an essential role in the seaport system planning program, contributing to reducing traffic pressure on the inner-city areas and developing trade in the near area of Ho Chi Minh City, Dong Nai, and Ba Ria-Vung Tau. Nowadays, Binh Duong has a lot of ports such as Binh Duong Port, Thanh Phuoc Port, An Son Port, Thai Hoa Port cluster or Thuong Tan Port (Huong, Tai & Tuong, 2019). In order to meet the transportation needs of more than 8 million tons of freight and more than 3 million people by 2020, Binh Duong is working to begin building its port and wharf system. Water transportation contributes for 15% of the province's transport needs. The province is expected to finish the system by 2025, with an aim to move over 40 million tones of cargo and serve 8 million passengers by 2030. Relevant Binh Duong agencies are revising and classifying the current local port and wharf system to create appropriate investment plans in line with the socioeconomic development of the province (Binh Duong calls for investment in port, wharf construction, 2018). Besides that, despite extensive planning for ports on the Dong Nai and Saigon rivers, no sizable port has actually been constructed, hence the transportation burden has not been reduced. There is now only one train station in Song Than, and it only offers North-South rail service, thus there isn't a lot of transportation accessible. Road connections is very restricted, and there is no link to the waterways. Currently, there are no comprehensive logistics facilities and a modest storage and distribution system. To meet the transportation demands of businesses, the ports and ICDs were not constructed in a coordinated manner. Transport responsibilities, let alone a bottleneck from Binh Duong to Ho Chi Minh City, are too much for the ports of the important economic zone like Cat Lai and Cai Mep to handle. It is now unavoidable to build an international standard logistics chain as a result of all the issues (Hung, 2021).

Service quality is regarded as a determinant in market share, return on investment, and cost in a competitive context (Noor, Nadia & Amir 2019), greatly influencing ports' success. It is essential for Vietnamese seaports to thrive and be competitive that they understand the factors that affect consumer satisfaction with their services (Thai, 2017). A study on port service quality (PSQ) and customer satisfaction will thereby contribute to the body of knowledge on PSQ management, particularly in the context of developing countries. Academic study on how to improve the quality of maritime services is clearly quite limited, especially in the context of Vietnam in general and Binh Duong in particular, aside from major investment in enhancing infrastructure and facilities.

Yeo, Thai, and Yeon (2015) previously conducted research on the relationship between port service quality and customer satisfaction: The Case of Korean Container Ports. In 2016, Thai conducted research on the impact of port service quality on customer satisfaction: the Singapore scenario. Port logistics service quality and customer satisfaction in Vietnam: Empirical data (Duc, Hong, & Phuc, 2019). Tien et al. (2020) conducted an exploratory study of container ports in Vietnam to examine port service quality (PSQ) and customer satisfaction.

Therefore, the purpose of this research is to identify what factors of port service quality (PSQ) affect customer satisfaction on port in Binh Duong. Because this study focuses at what PSQ contains and how it affects customer satisfaction, even if the maritime industry, of which ports are an important component, is critical to the national economy. Additionally, the study will also help to determine the factors of service quality affecting customer satisfaction

that will help ports in Binh Duong become more developed and improve their services and customer's reliability to meet and exceed their customers' satisfaction (My, 2021).

II. LITERTURE REVIEW

A. Review of previous studies

According to Yeo, Thai, and Yeon (2015), it is claimed that the author has examined a wide range of documents and material from newspapers, journals, the Internet, as well as domestic and international study findings, in order to understand the content and research techniques. Research data was collected from 313 members of the Korean Port Logistics Association (KPLA). The study through online surveys revealed port service quality is found to be a five-factor construct, and its management, image and social responsibility factors have significant positive effects on customer satisfaction. With the aid of the SmartPLS 3.2.1 program, partial least squares structural equation modeling (PLS-SEM) was carried out to verify the port service quality dimensions and investigate how they relate to customer satisfaction. According to this study, all independent variables positively affect the dependent variable; however, the port service quality component connected to image and social responsibility had the biggest impact on customer satisfaction.

The study of Thai (2016), the model's reliability is first examined through interviews with top executives employed by different Singaporean container shipping companies, and then it is confirmed through a survey of 175 Singapore Shipping Association and Singapore Logistics Association members. The port service quality concept is validated and its relationship to customer satisfaction is investigated using a confirmatory factor analysis, multiple regression, and multiple testing through online surveys. It is discovered that port service quality is a four-dimensional construct and there is a positively significant correlation between port service quality and customer satisfaction. Customer satisfaction is specifically impacted favorably by the port service quality aspects of outcomes, management, process, image, and social responsibility. The port service quality scale, which port managers may use to gauge customer happiness and utilize to support investments in port service quality as a relational marketing tool, is one way that this study advances management practice.

The findings of the study by Duc, Hong, and Phuc (2019) were obtained through focus group discussions and one-on-one interviews with 212 respondents who worked for companies that had used the port logistics service offered by Cat Lai Port in Ho Chi Minh City, Vietnam. The study uses both qualitative and quantitative methods. After that, the structural equation modeling (SEM) technique is used to examine survey data using multivariate analysis. Findings show that five elements, including responsiveness, certainty, reliability, tangibles, and empathy, favorably influence the quality of port logistics services. Additionally, customer satisfaction is positively impacted by the quality of the port logistics services. The tangibles component of the port logistics service industry most obviously shows how technology developments seem to improve service quality, which ultimately pleases clients.

Tien et al. (2020) did an exploratory research of container ports in Vietnam to look at port service quality (PSQ) and customer satisfaction. The online survey for the study was first written in English before being enhanced through a process of translation and back-

translation to ensure that there were no language discrepancies. The survey involved 200 members of the Vietnam Shipowners' Association, the Vietnam Logistics Associations, and the Vietnam Shippers' Council. By the deadline, 108 surveys had been submitted. According to the study's findings, improved port service quality will have a positive impact on customer satisfaction, with the outcomes of port service performance and its image having the greatest impact.

B. Key concepts

Service quality

From the unique characteristics of the service, it is important to consider its distinctive qualities. Specific criteria, such as features, durability, qualities, and so on, are used to evaluate the quality of tangible objects. However, because the service is invisible, the quality of the service is likewise hidden. As a result, the process of utilizing the service and the interactions between businesses and customers are how the quality of the service is evaluated. Lehtinen and Lehtinen (1982) also assert that there are two ways to evaluate the quality of a service: the first is service value, and the second is service outcome. Service quality, according to Parasuraman et al. (1988), is the degree of discrepancy between the expectations of consumers for services and their assessments of the results of those services. Numerous researchers have used and evaluated the SERVQUAL model developed by Parasuraman et al. (1988) in a variety of service sectors and marketplaces, including audit services in Bojanic (1991), dry cleaning services in Cronin and Taylor (1992), and retail services in Dabholkar (1996). In short, the general definition of the quality of service at each level is as follows: service quality is related to client expectations and perceptions of the service. Each client will perceive service quality differently according to their own perspectives and demands (Hoang, 2019).

Fitzsimmons and Sullivan (1982) said "Service quality is generally viewed as the output of the service delivery system, especially in the case of pure service systems". Furthermore, service quality is linked to consumer satisfaction. For example, customers are questioned about their satisfaction with the service they received when they leave a restaurant or hotel. If they respond "yes", we tend to conclude that the level of service was high. These service providers are aware of the practical impact that service quality has on customer happiness, including the fact that bad customers' moods and feelings can alter if the quality of the service is good (Duffy, 1998). Jain and Gupta (2004) defined the term of service quality as Quality is now understood to be a strategic instrument for achieving operational effectiveness and enhanced corporate performance. Both the products and services industries are affected by this. However, because services have innate qualities that set them apart from goods, the challenge with managing service quality in service organizations is that quality is not simply identified and measurable (Jain & Gupta, 2004).

Customer satisfaction

In any field, a company's satisfaction is heavily influenced by how well it serves its customers (Kotler, 2001). A business must satisfy its customers' needs if it wants to keep growing in a very competitive market, especially for enterprises that provide services. Business reality shows that if a company adds 5% more devoted clients, its profit will increase by 25-85% since long-term connections between customers and service providers depend on

customer happiness. A delighted customer, on the other hand, will often suggest the business's products and services to 5 additional individuals, whereas a dissatisfied customer will typically complain to 9. Because of this, when a company does not satisfy its consumers, it not only loses its current customers but also a significant number of potential customers (Kotler & Keller, 2016). Oliver (1997) asserts that customer satisfaction is a feeling people have after using certain goods and services. As an alternative, consumers' responses to estimates of the discrepancy between prior expectations (or performance criteria) and the actual manifestation of the product when using it are referred to as their level of satisfaction (Tse and Wilton, 1988).

According to Oliver (1980), customer satisfaction is specifically referred to as an effect of service quality, which indicates a positive relationship between it and the caliber of goods or services offered to the customer. Along with an increase in the perceived quality of the good or service, it is also thought that the level of consumer satisfaction is boosted. Customer satisfaction is seen to be an intrinsic feature that accounts for repeat business and post-purchase behaviors of consumers of goods and services. Customer's satisfaction is defined as a level of service quality that meets the customers' expectations (Wang, 2000). Customer evaluations of the service provider, the service core, or the overall service organization are referred to as service quality. Perceived quality is a global judgment relating to the superiority of a product. Defining service quality as a measure of excellence in terms of perceptions is not sufficient according to Langevin (1988). It is evident that the most important problem and factor in determining service quality is comprehending client expectations and meeting customer needs (Jun & Cai, 2001).

The relationship between service quality and customer satisfaction

According to Pitt et al. (1995), the relationship between satisfaction and service quality is a crucial factor in determining how well customers are treated. Additionally, Bhatnagar et al. (1999) highlighted the importance of client happiness for the caliber of logistics services.

According to Brady and Cronin (2001), "rational quality", "result quality", and "physical environmental quality" are three components of service quality. The "exogenous quality" refers to the volume of cargo flows, hinterland, and size of free trade zones (FTZ), while the "relational quality" refers to port sales, customer relations, and distribution network (Cho, Kim & Hyun, 2010). Ha (2003) listed a number of port service quality elements, such as "ready information availability of port-related activities", "port location", "port turnaround time", "facilities available", "port management", "port expenses", and "consumer convenience". A few subsequent studies focused on the efficiency and service quality of Korean ports (Yeo et al., 2015) and Vietnam ports (Tien, Thai & Thao, 2020) have utilized these frameworks and evaluated customers' reaction to various factors of service quality.

According to other researches like Zeithaml and Bitner (2000) and Parasuraman et al. (1988), client satisfaction affects the quality of the services provided. However, Cronin and Taylor (1992) contend that service quality is what drives customer satisfaction because it can only be measured after a client utilizes the service. If enhancing service quality is not driven by consumer desire, it will not fulfill that demand. Overall, there is a causal link between customer satisfaction and service quality. When the degree of service quality is

excessively high, expectations are exceeded. Customers are pleased and satisfied with the high level of service quality and expected degree of satisfaction. In contrast, if the service quality is poor and the level of satisfaction is lower than what was anticipated, the consumer will be dissatisfied. Customer satisfaction is a generic term that refers to how happy a customer is with a service they have received. Service quality, on the other hand, only pays attention to certain aspects of the service (Zeithaml & Bitner, 2000).

C. Theories

Theory of SERVQUAL

Using the SERVQUAL model, Hopkins et al. (1993) assessed the cognitive service quality in the logistics industry and determined that the primary condition for customer satisfaction was the fulfillment of their expectations. The extent of the customer experience is compared to the degree of the customer's expectation of service quality as defined by Rushton et al. (2014), which is a different strategy that is considerably more frequently used. The SERVQUAL model, which includes the five dimensions of tangibles, reliability, responsiveness, assurance, and empathy, was one of the first and most widely used instruments to measure service quality (Parasuraman, Zeithaml & Berry, 1988).

Table 1. Dimensions of SERVQUAL model of Parasurman et al., (1988)

No.	Dimensions	Definition
1	Reliability	Express the ability to deliver timely and consistent services.
2	Responsiveness	Express through eagerness to help customers and quickly resolve problems when errors or unexpected situations occur.
3	Assurance	Express through ability to build customer trust through professionalism, politeness, respect for customers, communication skills and attentive attitude to do the best support for our customers.
4	Empathy	Express through the style of services of employees through attention, care, ability to understand the needs and create feelings of secure and safety for customers.
5	Tangibles	Express through the appearance of facilities, equipment, staff uniforms, items and materials used for performing the services.

According to empirical studies of Duffy (1998), there are five dimensions: tangibles - actual buildings, furnishings, and personal appearance; reliability - the capacity to carry out the desired service consistently and correctly; responsiveness, which is the capacity to assist clients and render prompt assistance; assurance - the ability of employees to instill confidence and trust by their knowledge, kindness, and other qualities; empathy - compassionate and individualized service from the personnel (Duffy, 1998). On the other hand, according to Ha (2003) listed a number of port service quality elements, such as "ready information availability of port-related activities", "port location", "port turnaround time", "facilities available", "port management", "port expenses", and "consumer convenience" (Ha, 2003). A few subsequent studies focused on the efficiency and service quality of Korean ports (Yeo et al., 2015) and Vietnam ports (Tien, Thai & Thao, 2020) have utilized these frameworks and evaluated customers' reaction to various factors of service quality.

Theory of ROPMIS

The ROPMIS model, as opposed to SERVQUAL, is better suited to the maritime sector because it takes into account the very important image and social responsibility factors. Despite the model's intended general applicability to maritime transport services, the author claimed that its components could easily be altered for particular sub-sectors, such as ports. As a result, we use this model here and update operationalized measurement items relevant to the port industry. The idea of service quality in port was investigated by Thai (2008), who also created and validated a measurement model (ROPMIS) with six dimensions: "resources", "outcomes", "processes", "management", "image", and "social responsibility". This model included both recently established components, like managerial image and social responsibility, as well as a thorough examination of the numerous service quality dimensions and determinants from prior studies. There are three factors that make the ROPMIS model the most suitable. First, the model is a theoretical synthesis of numerous other theories. Second, the development of the original ROPMIS concept is put into practice within the unique framework of the Vietnamese transport sector. ROPMIS model application is acceptable because it closely matches the scope of the quality of freight forwarding research, whereas other models are typically tested in other industries. Finally, research using the ROPMIS model has produced promising findings despite its limited use. ROPMIS model has been used in a few empirical studies, including those by Tran (2010), Nguyen and Do (2013), and most recently, Yuen and Thai (2015), which are all directly related to research (Hoang, 2019).

D. Hypothesis development

Resources-related PSQ

According to Tien et al. (2020), resource-related PSQ is the infrastructure condition, cargo track and trace convenience, infrastructure readiness and availability. Moreover, Thai (2007) believed that the resources-related quality component is concerned with the availability of physical resources, financial resources, the state of facilities and equipment, as well as location and infrastructure. Besides that, resource means having equipment, facilities and infrastructures such as berths, yards, warehouses, distribution centers, hinterland connection networks and having good financial stability (Duc, Hong & Phuc, 2019). Customer satisfaction is impacted by the resource element, which includes infrastructure, information technology applications, and software for service delivery (Tran, 2010). Therefore, if ports make good outcomes, customers will be satisfied and have a close relationship for a long time with them (Thai, 2007). The study of Thai and Grewal (2007) on services in Vietnam revealed that resources are readily available in terms of equipment elements, equipment conditions, the capacity to track commodities, and the infrastructure. Resources were found to have a strong favorable impact on the ability to deliver logistics services in Yang et al. (2009) earlier study, which improved the company's financial performance in the long term.

Based on the previous findings, in this research, the researcher hypothesizes the following:

H1: *Resources-related PSQ positively influences customer satisfaction.*

Outcomes-related PSQ

Outcomes-related port service quality includes the products and core service received by the customers, for example, service accomplishments like the timely delivery of a shipment, the cost of a service offered, just-in-time service provision, consistency of service performance (time of delivery and acceptance), homogeneity of service supplied, assurance of cargo safety, accuracy of documents, and diversification of service (Thai, 2007). If ports make good outcomes, customers will be satisfied and have a close relationship for a long time (Thai, 2007). This gives managers knowledge of the logistics service quality issues to address in order to improve customers' perceptions of their expectations based on the outcomes they utilized in ports (Thao, David & David, 2019). Outcome of service is demonstrated by upholding contractual obligations, preventing errors, guaranteeing the safety of the items, document correctness, and satisfying customer requests (Buttle, 1996). In addition, service capacity which is indicated in the study by Thai and Grewal (2007) includes service dependability, speed of service, guaranteeing the safety of goods, document accuracy, variety, and service accessibility. Parasuraman et al. (1985) suggested that the service capacity demonstrates to professionals the ability of a certain organization to provide services.

H2: *Outcomes-related PSQ positively influences customer satisfaction.*

Process-related PSQ

This enabler focuses on how committed the organization is to creating and putting into practice a comprehensive methodology to plan, carry out, and create work systems for all of the organization's activities (Shanmugapriya & Subramanian, 2015). The process-related quality dimension primarily focuses on aspects of interactions between employees and customers, employees' attitudes toward serving customers, employees' interactions with customer needs, employees' professional awareness of customer inquiries, for instance, how customers perceive staff behavior in handling customer requirements, staff knowledge of customers' wants and needs, as well as staff's use of technology in better serving the customers. Therefore, customers can evaluate the quality of products or services they use in ports through the process of service of employees (Tien et al., 2020). Besides that, process-related uncertainty like the necessity to handle wrong, missing or damaged parts as well as process disruption can occur within a short time which shows professional attitude and behavior in meeting customer's requirements of the port's staff (Sarah & Franziska, 2018). In this study, the researcher has put up the following theory considering previous findings:

H3: *Process-related PSQ positively influences customer satisfaction.*

Management-related PSQ

According to Tien et al. (2020), besides resource, outcome or process, making careful to study human management. Application of technology in operations and management, performance in those areas, comprehension of client demands, and continual improvement focused on meeting those goals. To meet or exceed customers' needs and expectations, it means allocating resources as effectively as possible. It also means that employees must possess the necessary knowledge, skills, and professionalism to comprehend and transform customers' needs and requirements into what they want. This also connects to the customer feedback system as fresh inputs for the new cycle of quality management and continuous

improvement as recommended by numerous quality gurus, which led to increased customer reliability. This indicates that port operations and administration are highly efficient. In addition, the management in the port we use consistently demonstrates good expertise and competence, including the capacity to handle incidents. As a result, the port works to continually enhance its customer-focused management and operation procedures, which can greatly increase customer satisfaction (Yeo, Thai & Yeon, 2015). According to Tran (2010) and Huynh (2013), a shipping company's managerial capability has the greatest impact on how satisfied customers are with the caliber of its delivery services. Thai and Grewal (2007) state that management capacity factors such as the use of information technology in management and operation, effectiveness in management and operation, knowledge and skills in troubleshooting and accident prevention, understanding of customers' needs and requirements, and relationships with suppliers (ports, shipping lines), among others, have an impact on customer satisfaction.

H4: *Management-related PSQ positively influences customer satisfaction.*

Image and social responsibility-related PSQ

Reputation- and image-related: Reputation for dependable service and positive relationships with other supply chain partners. It refers to how clients see the service organization generally and finally achieved customer satisfaction. Associated with social responsibility - refers to an organization's ethical stance and operations in a socially responsible manner, safe and environmentally responsible operations, and social obligation fulfillment (Thai, 2007). Corporate reputation is a crucial intangible asset that affects a company's success and, consequently, its long-term presence. Corporate reputation has attracted interest from a wide range of academic fields. It is also gaining attention from the corporate world and the media. It affects how various partners continue to support a firm, such as staff retention, customer happiness, and consumer loyalty (Victor, 2018). As a result, companies should focus aggressively on enhancing the value of the corporate reputation dimensions if they want to guarantee the stability of business outcomes, or in other words, their customers' positive opinions (Victor, 2018). Therefore, ports have positive relationships with other ports and land transportation service providers, and they also have a high reputation for dependability in the market, which helps them draw in more and more clients over the coming period of time (Duc, Hong & Phuc, 2019). The prior findings, in this investigation, the researcher hypothesizes the following:

H5: *Image and social responsibility-related PSQ positively influences customer satisfaction.*

Based on the five hypotheses development above, a conceptual framework in this study is proposed to demonstrate the independent and dependent variables as follows:

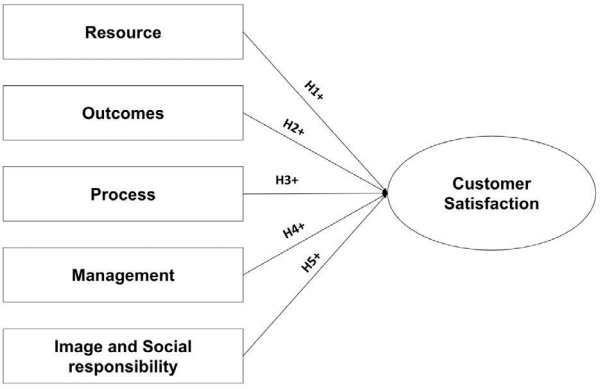

Figure 1. Research model adapted from Yeo et al. (2015)

II. METHODOLOGY

A. Sampling method

This study's sample will consist of Binh Duong Province customer's port who have used and purchased products of Binh Duong port. The sample size is computed using the following formula devised by Comrey and Lee (2013):

n=5*m (Comrey & Lee, 2013)

n: is the sample size.

m: is the number of questions.

Applying the above formula, this study's sample size will be 170 samples (n=5*34=170). In addition, 170 questionnaires will be delivered both offline and online in an effort to weed out inappropriate and incomplete ones. To make sure that each survey question is simple to comprehend, a pilot study with 10 participants will be conducted. If not, we will alter the survey questions to make them simpler to comprehend in light of the pilot study's suggestions, comments, and feedback. Other responders will be able to fully comprehend the questionnaire as a consequence.

B. Variable measurement

The structure of the questionnaire has two sections consisting of:

Section 1: Filter question

* A compulsory question to confirm whether the participants are suitable for this study.

Q.1. Have you ever used port service in Binh Duong?

- Yes.
- No.

If respondents click "YES" to go to the next page, you understand they have already used port service quality in Binh Duong. On the other hand, if respondents click "NO" to stop this survey, which means they have not already used port service quality in Binh Duong.

Section 2: Demographic Information

Table 2. Demographic Information

No	Items	Code	Scale
Demographic Information (DI)			
1	What is your gender?	DI1	1. Male 2. Female 3. Others
2	How old are you?	DI2	1. Under 20 2. From 20 to 29 3. From 30 to 49 4. Over 50
3	Your level of education	DI3	1. High school 2. College students 3. University 4. Others

Section 3: Main part

Table 3. The list of variables

No	Name of Independent Variables	Code	Adopted from
Resources-related PSQ (RESOU)			
1	The port that we are using always has available equipment and facilities to meet our requirements.	RESOU1	(Yeo et al., 2015)
2	The equipment and facilities of the port that we are using are modern and always function properly.	RESOU2	
3	The port that we are using has strong and stable financial stability.	RESOU3	
4	The port that we are using has excellent shipment track and trace capability.	RESOU4	

No	Name of Independent Variables	Code	Adopted from
5	The port that we are using excellent physical infrastructure such as berths, yards, warehouses, distribution centers, and hinterland connection networks.	RESOU5	
Outcomes-related PSQ (OUTCO)			
6	The port that we are using always provide fast service.	OUTCO1	(Yeo et al., 2015)
7	The port that we are using always provide service in a reliable manner.	OUTCO2	
8	The port we are using always provide service in a consistent manner.	OUTCO3	
9	The port that we are using always ensure safety and security to our ships/ shipments.	OUTCO4	
10	The port that we are using always produce error-free invoice and related documents.	OUTCO5	
11	The port that we are using always offers competitive price of service.	OUTCO6	
12	The port that we are suing can always meet our service requirements anytime and anywhere we want.	OUTCO7	
Process-related PSQ (PROCE)			
13	The staff in the port that we are using always demonstrate professional attitude and behavior in meeting our requirements.	PROCE1	(Yeo et al., 2015)
14	The staff in the port that we are using always respond quickly to our enquiries and requests.	PROCE2	
15	The staff in the port that we are using always demonstrate good knowledge our needs and requirements.	PROCE3	
16	The level of ICT applications in customer service. The port that we are using is comprehensive.	PROCE4	

No	Name of Independent Variables	Code	Adopted from
Management-related PSQ (MANAG)			
17	The level of ICT applications in port operations and management at the port that we are using is comprehensive.	MANAG1	(Yeo et al., 2015)
18	The port that we are using demonstrates high level of efficiency in operations and management	MANAG2	
19	The management in the port that we are using always demonstrates good knowledge and competence, including incident-handling capability.	MANAG3	
20	The management in the port that we are using always demonstrates good understanding of our needs and requirements.	MANAG4	
21	The port that we are using always collects our feedback about their services and reflect on their improvement.	MANAG5	
22	The port that we are using continuously improve their customer-oriented operation and management processes.	MANAG6	
Image and Social Responsibility-related PSQ (IMAGE)			
23	The port that we are using demonstrates good relationship with other ports and land transport service providers.	IMAGE1	(Yeo et al., 2015)
24	The port that we are using possesses positive reputation for reliability in the market.	IMAGE2	
25	The port that we are using always emphasized on operations and work safety.	IMAGE3	
26	The port that we are using demonstrates good record of operations and work safety.	IMAGE4	
27	The port that we are using fulfills good social responsibility to their employees and other stakeholders.	IMAGE5	

No	Name of Independent Variables	Code	Adopted from
28	The port that we are using always emphasizes on environmentally responsible operations.	IMAGE6	
29	The port that we are using has in place the environmental management system.	IMAGE7	
Customer Satisfaction (SATIS)			
30	Overall, we are satisfied with the facilities, equipment and other infrastructures of the port that we are using.	SATIS1	(Yeo et al., 2015)
31	Overall, we are satisfied with the management and employees of the port that we are using.	SATIS2	
32	Overall, we are satisfied with the service quality of the port that we are using.	SATIS3	
33	We will refer service of the port that we are using to our business partners.	SATIS4	
34	We will continue using services of the port we are using.	SATIS5	

C. Methodology

The six main stages of data collecting are as follows:

Step 1: A survey of the customers using the ports in the province of Binh Duong will be conducted using the origin questionnaire. Additionally, the survey will be translated into both English and Vietnamese, with the translation being assured to have the same meaning as the original.

Step 2: Next, the surveys in Vietnamese and English will be imported into a Google Form.

Step 3: Prior to distributing the content to clients in other areas, a pilot study with 10 participants (a convenience sample) will be conducted to ensure that the content is simple and easy to understand by customers in Binh Duong Province.

Step 4: Compile comments from the pilot study and alter the survey questions as necessary to ensure that future respondents can understand the questions fully.

Step 5: The surveys will be delivered to the intended respondents in 170 soft copies.

Step 6: To examine the data, it was then transferred from Excel to the Statistical Package for the Social Sciences (SPSS) program.

- Descriptive data
- Cronbach's alpha reliability analysis
- Exploratory factor analysis
- Correlation test
- Multiple regression analysis

III. RESULTS

A. Result

Result summary

Table 4. Summary of hypotheses testing

Hypotheses	Hypotheses result	Impact ranking
H1: Resources-related PSQ positively influences customer satisfaction.	Supported	3rd
H2: Outcomes-related PSQ positively influences customer satisfaction.	Supported	1st
H3: Process-related PSQ positively influences customer satisfaction.	Supported	2nd
H4: Management-related PSQ positively influences customer satisfaction.	Supported	4th
H5: Image and social responsibility-related PSQ positively influences customer satisfaction.	Not supported	-

B. Discussion

The core of this study is to discover key elements that affect port service quality impact on customer satisfaction. Accordingly, not all port service attributes have significant effects on port service quality toward customer satisfaction. In fact, these attributes not only have different impacts but also have different degrees of influence of port service quality toward customer satisfaction. In more details, among five attributes there are four DVs which are Resources, Outcomes, Process and Management that have significant effects (with positive direction) on customer satisfaction to use port service in Binh Duong. It can be observed that Outcomes is the most significant factor with the highest Standardized Coefficient of Beta ($\beta = 0.391$) and Significant value is 0.000 which is obviously acceptable.

The first finding reveals the most significant factor influencing consumer satisfaction in Binh Duong to use port service quality - Outcomes. Outcomes' Beta value is the highest ($\beta = 0.391$) and the Significant value is 0.000 ($0.000 < 0.05$). In fact, previous research of Thai (2016) conducted in Singapore also resulted as Outcomes-related PSQ is the strongest factor affecting their respondents' intention to use this innovation with the Beta value at 0.310 and Sig. 0.001 (Thai, 2016). Besides that, previous research of Tien et al. (2020) conducted in Vietnam also resulted as Outcomes is the strongest factor affecting their respondents' intention to use this innovation with the Beta value at 0.538 and Sig. 0.000 (Thai, 2016). Moreover, many previous research on intention to adopt innovation indicated a positive relationship between Outcomes and customer satisfaction as well (Yeo et al., 2015 and Duc, Hong & Phuc, 2019).

The second finding is about the second significant factor which positively affects port service quality and customer satisfaction - Process. The data result as its Standardized Coefficients Beta equal to 0.297 and the Significant value is 0.000 signifies. Process is also a strong influential factor (after Outcomes) affecting port service quality and customer satisfaction in Binh Duong. According to Tien et al. (2020), the process-related quality dimension primarily relates to variables of interactions between employees and customers, employees' attitudes toward serving customers, employees' interactions with customer demands, employees' professions, and employees' awareness of consumer inquiries; this is also one of the crucial variables impacting customer psychology and resulting in customer satisfaction.

The third finding is about the next determinant which has a positive impact on port service quality and customer satisfaction - Resource. In more details, Compatibility has the Standardized Coefficients Beta value is 0.270 and the Significant value is obviously acceptable ($0.000 < 0.05$) is clearly acceptable. Therefore, resources have equipment, facilities and infrastructures such as berths, yards, warehouses, distribution centers, and hinterland connection networks. Following this can improve service reliability, more personalized trains created in collaboration with the customer, and other technological advancements will be part of this future trend and create customer satisfaction over the long time (Roy, 1993).

The Management, which was identified as the fourth finding and the least significant influence on port service quality and customer satisfaction, produced an intriguing discovery

(with a positive Beta value of 0.181 and Sig. value of 0.002). Allocating resources as efficiently as feasible requires the use of technology in operations and management, performance in those areas, understanding of client wants, and continuous development centered on meeting or exceeding customers' needs and expectations (Tien et al., 2020). Because it also has a beneficial effect on increasing customer satisfaction and reliability, the factor of Management needs to be created and enhanced daily.

The Image and Social responsibility, which was identified as the last finding and no influence on port service quality and customer satisfaction, with the Significant value is exceeding limitation (Sig. value of 0.7 > 0.005). Whereas, the influence of this attribute could result in different directions as well with the Image and Social responsibility factor, have the strongest influence on customer satisfaction (with a positive Beta value of 0.276 and Sig. value of 0.009) (Yeo et al., 2015).

Vietnamese delivery companies must compete with foreign businesses in the context of global economic integration because Vietnam has expanded its service industry. In fact, 25 of the top 30 delivery businesses in the world are already operating in Vietnam, holding a market share of 75%, mostly in high added value sectors. However, with around 25% of the market being small and tough to capture, local businesses must take every chance. Additionally, because Vietnamese delivery companies cannot match the level of services provided by foreign companies, their capacity is constrained (Hoang, 2019). Shipping lines and cargo owners might be negatively impacted by the failure or unreliability of port services, which will decrease their satisfaction (My, 2021). Moreover, Vietnam is a popular production base for multinational companies and has become a hub for the global supply chain. As a result, more attention has been paid to the service quality of ports in order to accommodate the rising demands on transportation and to satisfy customers' intricate requirements (Hoang, 2019).

However, the definition of port service quality (PSQ) and how it affects port customers' satisfaction have lacked more attention in research. Therefore, this research analyzes and identifies management practices in addition to academics because port managers can use the port service quality scale to gauge client satisfaction and justify investments in the quality management of port services (Yeo et al., 2015). As a consequence, this study will concentrate on the quality aspects that promote customer satisfaction with port services, as well as the specific assessment items that consumers appreciate. This study's objective is to identify what factors of port service quality (PSQ) affect customer satisfaction on port in Binh Duong. On the basis, this empirical quantitative research will propose some factors which help port in Binh Duong improve port service quality, contributing to better understanding their customer satisfaction and achieve more reliability in the future field of port in Binh Duong.

The research framework after analysis is illustrated as below:

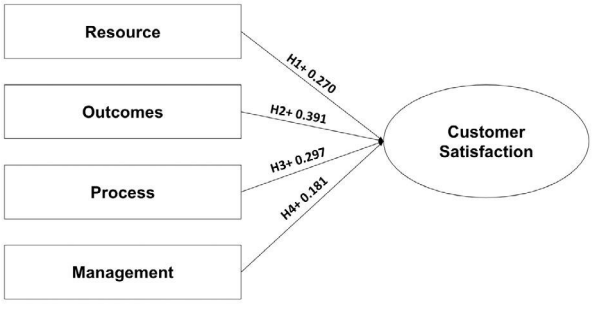

Figure 2. Research framework (after analysis)

IV. CONCLUSION

This study aims to discover factors affecting port service quality on customer satisfaction in Binh Duong as well as to detect the level of significance between five attributes of port service quality and customer satisfaction. The study was able to identify four key determinants, including Resources, Outcomes, Process, and Management, which have a positive impact on Binh Duong customer satisfaction when using port service quality, thanks to the participation of 172 survey respondents and the support of SPSS with conducting statistical analysis. Importantly, the study found that Outcomes has the biggest impact on customers' satisfaction with port service quality. Customers will not use port services unless they perceive positive results from service accomplishments such as timely shipment delivery, cost of service, just-in-time service delivery, consistency of service performance (time of delivery and acceptance), homogeneity of service provided, assurance of cargo safety, accuracy of documents, and service diversification (Thai, 2007).

Following the application of the Regression Model, the results show that among the five attributes of the Innovation Diffusion Theory, four attributes of Resource, Outcomes, Process, and Management can explain changes in customer satisfaction with use of port service quality (PSQ). More specifically, the following four characteristics of port service quality have the strongest relationships with customer satisfaction: Outcomes ($\beta = 0.391$), Process ($\beta = 0.297$), Resource ($\beta = 0.270$), and Management ($\beta = 0.181$).

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THE RELATIONSHIPS BETWEEN PERCEIVED INCSR, AFFECTIVE COMMITMENT AND TURNOVER INTENTION: EMPIRICAL EVIDENCE FROM VIETNAMESE BANKING INDUSTRY

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Abstract: This paper investigates the relationships between perceived internal corporate social responsibility (perceived InCSR), affective commitment, and turnover intention in the Vietnamese banking industry. The study utilizes a questionnaire-based survey to collect data from 271 baking employees from Southeast provinces in Vietnam through convenience and snowball sampling techniques. By using Partial Least Squares-Structural Equation Modeling (PLS-SEM), the findings reveal that a positive perceived InCSR positively influences employees' affective commitment, while affective commitment, in turn, reduces turnover intention. Additionally, the study indicates that affective commitment mediates the relationship between perceived InCSR and turnover intention. The study contributes to the existing literature by advancing the understanding of the factors influencing turnover intention based on social exchange and social identity theories. Furthermore, the study provides managerial implications for the Board of Directors of banks, suggesting appropriate governance policies and effective human resource development strategies. Our recognized limitations from the number of samples collected and the method of sample collection are the premise to overcome for future studies.

Keywords: *perceived internal corporate social responsibility, affective commitment, turnover intention, Vietnam banking industry*

I. INTRODUCTION

Executives and managers across various corporate sectors have increasingly turned their attention to the concept of turnover intention as a means of successfully managing their workforce. This surge in interest stems from its growing prominence in management literature (E. Chang, 1999; Li et al., 2019; Shukla, 2014; Tett & Meyer, 1993). Employee turnover is recognized for its adverse effects, including the depletion of social and human capital (Hausknecht & Trevor, 2011) and the substantial financial burdens it imposes on companies (Brown, Thomas, & Bosselman, 2015). In the wake of the COVID-19 pandemic, Vietnamese enterprises, particularly in retail (29.7%), non-banking financial enterprises (22.9%), and consumer goods (17.7%), along with banking firms, have experienced a significant surge in turnover (Hoang, 2021). This escalation, with 450 employees leaving organizations compared to the previous year, is partly attributed to overwhelming workloads in the banking sector

(General Statistic Office, 2020, 2021). Contrary to misconceptions, banking positions demand professionals who can thrive under pressure, endure regular overtime, and maintain a relentless work ethic, especially during peak financial periods (VnExpress, 2021). Furthermore, intense workplace competition has fostered a "toxic" atmosphere, where colleagues resort to unsupportive behavior and even underhanded tactics (Chi et al., 2022; Nakamura, 2015; Nhue, 2022) resulting in adverse consequences for employee well-being and their connection with the organization (Morrison, 2005). This silence perpetuates employees' emotional disengagement (Rasool et al., 2021), erodes cohesion, and weakens their dedication (Carmeli & Weisberg, 2006; Pinder & Harlos, 2001).

According to Meyer & Herscovitch (2001), affective commitment has been linked to a wide range of outcomes related to absenteeism, organizational behavior and job performance. Through emotional commitment can reduce employee absenteeism, improve organizational effectiveness (Meyer & Allen, 1991). Moreover, the post-pandemic landscape has reshaped perspectives on life and career choices. The banking sector, while demanding, offers access to an information-rich environment, serving knowledgeable and affluent customers. Bank employees can broaden their career horizons by leveraging this opportunity instead of enduring unwarranted pressure (Minh Duc, 2021). Identifying the factors contributing to job turnover and enhancing job retention is paramount for banking organizations to reduce operational costs (Aida, 2014; Lu & Gursoy, 2016).

Drawing upon social identity theory (SIT), past research has shown that CSR practices can influence employees' in-role actions and enhance self-concept, self-esteem, and psychological capital (PsyCap) (Leal et al., 2015; Youssef & Luthans, 2007). Additionally, according to Social Exchange Theory (Blau, 2017), employees' responses are rooted in reciprocity. InCSR fosters reciprocity norms between employees and employers, increasing employees' perception of organizational support. This, in turn, motivates employees to reciprocate by contributing their best efforts. Consequently, firms that promote employees' physical and psychological well-being through CSR initiatives generate positive emotions and reduced turnover intentions among their workforce. The paper explores these theoretical foundations and their implications for organizations aiming to enhance employee retention and foster sustainability.

Various studies have been undertaken to determine the predictors of employee turnover intention, and multiple characteristics, including emotional intelligence, have been uncovered (Da et al., 2015; Trivellas et al., 2013), perceived CSR and affective commitment (Papacharalampous & Papadimitriou, 2021), and a few others (Bande et al., 2015; Boyar et al., 2003). However, the correlations between these three factors in the banking sector have not been examined in Vietnam. Moreover, there is no empirical evidence that confirms the relationships of perceived InCSR, affective commitment, and turnover intention in one model. Since COVID-19 alters people's perspectives, the study is conducted to see whether link between the three variables altered or not. In addition, specific to the financial sector, bank employees and key stakeholders are greatly ignored (Akhouri & Chaudhary, 2019). They can determine the effectiveness of CSR programs and act as CSR ambassadors for their companies (Bauman & Skitka, 2012). There have been several effects of the COVID-19 pandemic

on workers' physical and emotional well-being, including the aforementioned causes of high turnover intention (Meyer & Allen, 1991). Due to these two gaps, the researchers have decided to undertake this study to examine the interactions between perceived InCSR and affective commitment and then investigate the turnover intention of bankers in Southeast Vietnam areas such as: Binh Duong, Binh Phuoc, Ho Chi Minh City, Dong Nai, … in order to contribute to manage turnover intention issue in the banking industry.

Our research questions are: (1) "What determinants affect the turnover intention of bank employees in Vietnam?" and (2) "What are the relationships between these determinants including perceived InCSR, affective commitment and turnover intention of bank employees in Vietnam?"

II. LITERATURE REVIEW

2.1. Review of the previous studies/ theories

2.1.1. Perceived InCSR

Carroll's definition in 1979, which has been most frequently cited in other literature, comprehensively referred 4 aspects of CSR comprising Economic, Ethical, Environmental and Philanthropic, and those responsibilities are not mutually exclusive (Carroll, 1979). One of the pillars of modern CSR, which integrates those responsibilities of business (Ashrafi et al., 2018), is the interest in employees (Shin & Hur, 2020). Internal CSR (InCSR) refers to company management activities focusing on internal members as they play an important role in the company (Chang et al., 2021).

In general definition, many scholars argued that perceived InCSR seems to be self-focused because InCSR practices are able to provide necessary clues to meet employee demands, which shows they are cared by their organizations (Chang et al., 2021; Hameed et al., 2016). Referencing the Social Exchange Theory (Yasmeen et al., 2021), which claims that reciprocity is what motivates employees' responses. Employees who see their company as being helpful will be more anticipated to return the favor by giving their all. Therefore, it is proposed that if businesses assist their employees' professional, psychological, and physical growth, it improves their perception of the company and leads to higher performance (Turker, 2009a). In accordance with this reasoning, InCSR improves the norms of reciprocity between employees and employers, increasing the perception of organizational support among employees. Employees will not care about the company's other operations if they are unaware of its InCSR practices or cannot perceive them (Chang et al., 2021; D. E. Rupp et al., 2013).

Following the logic, in the field of Human Resource Management, InCSR has been developed for the last 2 decades. The practices are primarily intended to promote training and development programs for employees, create diverse and equal opportunities in line with the advancement of technology and talent, and support the physical and mental well-being of employees by offering healthy and safe working conditions, safeguarding employees' interests, being more collective cohesion, and ensuring a balance between work and life (Ramos-González et al., 2022; Shen & Jiuhua Zhu, 2011; Turker, 2009a; Vuontisjärvi, 2006).

However, for the banking industry, although it still guarantees the 4 aforementioned responsibilities, InCSR is different from other industries in integrating more into philanthropic responsibilities (B. Sengeh, 2021).

Philanthropic responsibilities are corporate acts that exceed society's expectations, such as donating to support the disadvantaged, sponsoring scholarships, making financial and labor contributions to community projects (Himmelstein, 1997). Nevertheless, most of the previous papers only studied how implementing CSR affected on affective commitment and turnover intention as a whole instead of breaking it down, analyzing and measuring its InCSR. Therefore, examining and measuring affective commitment and intention to remain reactions towards the dimension of CSR is the motive for this study.

2.1.2. Affective commitment

A strong psychological attachment that binds individuals to an organization is known as organizational commitment (Walumbwa et al., 2018), often highlighted in good attendance, high work performance, strong connections with a company, intentions to stay, the sharing of institutional values, and work pride (Mowday et al., 1979). One of the three elements of organizational commitment, apart from continuation and normative commitment, respectively, is affective commitment (Allen & Meyer, 1990; Chun-Chen Huang, 2011). A significant identification with a corporation as well as organizational commitment, which is present when there is a strong emotional or psychological linkage, are both incorporated into the concept (Allen & Meyer, 1990). The "gold standard" for employee commitment, according to most studies, is emotional ties to an organization and faith in its principles (Olafsen et al., 2020). Such that strongly emotionally committed employees remain in the organization because they want to enjoy membership of the organization. Some employees might have a strong desire to remain in the company but have no need or need to do so; in other circumstances, employees may believe they have an obligation to stay but do not want to, and so on (Mowday et al., 2013). Since every organizational commitment component has conceptual variations, (Allen & Meyer, 1990) proposed that each component has its own antecedents. Hence, for the purposes of this study, affective commitment is treated as an individual construct, and is the degree to which employees feel strongly connected to a company based on perceived InCSR.

2.1.3. Turnover intention

In general, turnover intention refers to an individual's subjective appraisal of his or her likelihood of leaving an organization in the near future (Griffeth et al., 2000; Jung & Kim, 2012; Tett & Meyer, 1993). According to Steel (2002), the biggest predictor of actual turnover is employees' turnover intention. In the realm of human resources, turnover intention is defined as a withdrawal cognitive process that consists of three stages: considering leaving a company, looking for another job, and lastly having the simple intention to depart (Carmeli & Weisberg, 2006; Cho et al., 2009). Every business will experience turnover, which is split into two types: voluntary and involuntary turnover (Dess & Shaw, 2001). First, voluntary turnover occurs when individuals are dissatisfied with their current employment and are willing to hunt for another job in another place (Dess & Shaw, 2001). Second, involuntary turnover occurs when employees are discharged by their organizations (Shaw et al., 1998).

In the modern business world, either voluntary or involuntary turnover has negative effects on the organization. Such effects include challenges with finding a replacement, challenges with hiring, training, and development, socialization costs, and customer perceptions of the quality of the organization's services (Chan

& Ao, 2019; Hausknecht et al., 2009; Schneider & Bowen, 1993; Shaw et al., 1998).

2.1.4. Theoretical framework

This research uses social exchange theory and social identity theory as theoretical frameworks to develop the research hypotheses.

Incorporating social exchange theory and social identity theory into our research framework will enrich our understanding of employee dynamics in banking. Social exchange theory, with its emphasis on reciprocity and cost-benefit analysis, provides a lens through which we can explore the complex web of relationships in the workplace job. By applying this theory, we anticipate uncovering insights into how bankers evaluate exchange fairness and how this perception impacts satisfaction and commitment in their work.

Additionally, social identity theory is seen as an additional tool to explain the behavior and communication among employees based on their inherent value to membership in the organization. Thereby, they want to see their particular social groups in a positive light. This desire can lead to prejudice and conflict between them and the organization (Mahmood et al., 2021; Paruzel et al., 2020). Integrating social identity theory allows the paper to delve into the complexities of group dynamics, shedding light on how individuals categorize themselves and others within banking. We hypothesize how bankers will identify themselves as whether or not their bank promotes CSR programs. By shedding light on the interaction between these two theories, our study aims to contribute to a more comprehensive understanding of the interactions of employees of banking organizations.

2.2. Hypothesis development

2.2.1. Perceived InCSR and affective commitment

The relationship between employee CSR perception and affective commitment has been investigated in earlier studies (Bouraoui et al., 2019; Brammer et al., 2007; Khaskheli et al., 2020; Turker, 2009a). Turker (2009a) and Stites & Michael (2011) discovered that several metrics of CSR activities were related to higher organizational commitment. Using a large sample of business professionals employed at a financial services firm, Bouraoui et al. (2019) and Brammer et al. (2007) discovered comparable conclusions. Furthermore, the association between the variables was further supported by data from (Collier & Esteban, 2007; Ditlev-Simonsen, 2015), particularly when corporate ethics and values coincide with employees' norms and values. Scholars in the micro-CSR literature appear to agree that SIT is an important angle for understanding employee responses to CSR (Ashforth & Mael, 1989; Paruzel et al., 2020; D. Rupp & Mallory, 2015; Turker, 2009a).

According to SIT, people frequently work to strengthen their so-called "self-concept" and cultivate a positive view by associating with the positive traits of favored groups (Brammer et al., 2007). It can be suggested that the organization's CSR activity is a significant contribution for employees to meet the need for self-identity and integration into the organization is explained positively (Ashforth & Mael, 1989; Rupp & Mallory, 2015; Turker, 2009a). Moreover, The social exchange theory by Blau (2017) posits that benefits are what individuals gain from connections, such as enjoyment, friendship, companionship, and social support. Therefore, employees consider CSR participation to bring

about a sense of pride in the organization, which has been shown to some extent affect employees' affective commitment to the organization later on. (Brammer et al., 2007; Turker, 2009a). Based on the aforementioned findings and following SIT, it is assumed that employees' affective commitment is influenced by positive InCSR perception. The first hypothesis is presented:

H1: *Perceived InCSR of bank employees relates positively with their affective commitment.*

2.2.2. Perceived InCSR and turnover intention

Previous studies have also found that numerous measures of corporate social responsibility are linked to higher candidate job pursuit intentions, individual identification with and attachment to an organizational commitment, and lower turnover intentions (Glavas & Radic, 2019; Mowday et al., 2013; D. E. Rupp et al., 2013; Tett & Meyer, 1993). Corporate social responsibility was shown to be adversely correlated with involuntary turnover and favorably correlated with job retention in studies of (Meng et al., 2013; Shaw et al., 1998). According to Ellis (2009), ignoring CSR and its implications might have a detrimental effect on employees' motivation and organizational performance. The achievement of organizational goals is morally risky (Fritz et al., 2013; Kolk, 2016), which can reduce perceptions of CSR that may have a positive correlation to turnover intention. Evidence from Sobhani (2021), by implementing CSR into human resource management identified similar findings using a large sample of commercial banks in Bangladesh. As a result, HRM employing CSR practices may increase employee enthusiasm and understanding of CSR, as well as encourage social involvement through volunteer work and contributions (Shen & Zhang, 2019; Voegtlin & Greenwood, 2016) to reduce turnover intention. The following hypotheses are therefore presented:

H2: *Perceived InCSR of bank employees relates negatively with their turnover intention.*

2.2.3. Affective commitment and turnover intention

Employee emotional attachment to, identification with, and engagement in the organization is referred to as affective organizational commitment (Meyer & Allen, 1991). Allen and Meyer (1991) developed a model of commitment with three commitment dimensions as affective, continuous, and normative. Since Meyer & Herscovitch (2001) found that affective commitment has stronger influence on employees' retentions than normative and continuous commitment, various studies have demonstrated that a lack of organizational emotional commitment has negative consequences, including an increase in turnover rate and intention to leave (Elisabeth et al., 2021; Jenkins & Paul Thomlinson, 1992; Lee & Bruvold, 2003). However, the studies focused only on affective commitment and its effect on turnover intention (Z. X. Chen & Francesco, 2003; Meyer & Herscovitch, 2001).

In contrast, a majority of the studies have found organizational commitment reduces employees' intention to leave the organization (Firth et al., 2004; Lee & Bruvold, 2003). Some scholars even suggested not to retain only affective commitment because the three-dimensional commitment model is a mash-up of attitudes and outcomes as the construct and leave out the normative and continuous commitment components (Bergman, 2006; Solinger et al., 2008; Somers, 1995). In other words, only affective commitment is inefficient to reduce turnover

intention (Gellatly et al., 2006). The following hypotheses are assumed that:

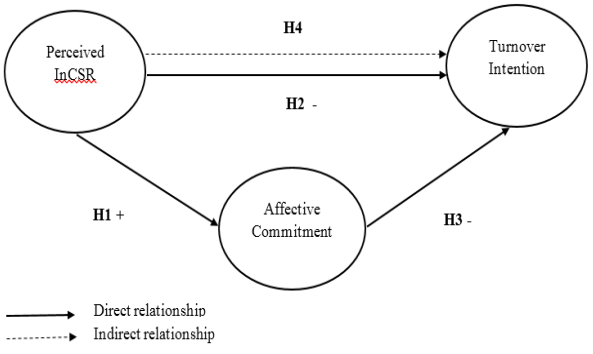
H3: *Affective commitment of bank employees relates negatively with their turnover intention.*

2.2.4. The mediating role of affective commitment on the relationship of perceived InCSR and turnover intention

This study looked at the magnitude of perceived InCSR and turnover intention, while also considering the mediating function of affective commitment in the relationship. According to the above stated research review, perceived InCSR is associated with affective commitment, which is also related to turnover intention. According to social identity theory (Ashforth & Mael, 1989), organizational identification referred to how closely connected and emotionally driven employees perceive to a company. The individuals classify themselves and other people into numerous groups based on an evaluation of their own conventional traits and those of others around them. Mael & Ashforth (1992) emphasized the social identity theory that if their organization is respected by others or appreciated by the public, they would think favorably of it. It also suggested that organizations enhance employee engagement levels by obtaining feedback from the public and society about their operations and then realizing whether others and they feel about the same things or not (Luhtanen & Crocker, 1992; Tyler, 1999; Wagner et al., 1986). Additionally, it was also alluded as an enrollment in an organization by the representatives (Zaman & Nadeem, 2019). Organizations should concentrate on creating a culture of respect and dignity through CSR efforts in order to improve employee identification. (Bouraoui et al., 2019).

Additionally, by applying the social exchange theory (Blau, 2017), firms may be able to encourage favorable employee outcomes including emotional commitment and staff retention. Collier & Esteban (2007) examined the case based on the social exchange theory that employees' loyalty to the company will depend on how much value they see themselves receiving as members. In other words, In other words, when employees' commitment and involvement in CSR are examined from the perspective of behavior beyond the contract, the benefits are considered as part of the organization. (Bakker & Schaufeli, 2008). The level of employee engagement with CSR will reflect the level of positive feeling to commit and turnover intention to their organization (Kim et al., 2016). Based on previous findings and the social exchange theory, the following hypothesis is formulated:

H4: *Affective commitment mediates the relationship between perceived InCSR and turnover intention.*



III. METHODOLOGY

3.1. Research process

The evaluation of prior literature and its use in this study during the first phase helped to explain the factors. Following that, the literature study is used to construct the theoretical framework. After discussing the

connections between the variables, hypotheses are then put forth. The theoretical framework is constructed. The items for each variable are carefully gathered from prior pertinent research once the variables and the framework had been defined, and a draft questionnaire is then being created. Next, a pilot test is used to evaluate the questionnaire's validity and reliability. The final questionnaire is created and disseminated once the required revisions were made after viewing the results. Data was entered into and analyzed in SmartPLS after being gathered via the questionnaire.

3.2. Data collection, sampling method, and statistical strategies

A pre-test is necessary to see whether the items are acceptable and to make changes before the final survey is sent (Malhotra, Nunan, & Birks, 2017). In order to assess the language and structure of the questionnaire, ensure logical consistency, suitability to the context, readability and content value, the survey is applied back translation method to translate from Vietnamese into English and vice versa by two different people. The survey, then, was sent to a number of parties, including university professors and several subject matter experts. The questionnaire will be revised based on their feedback, suggestions and criticisms. Finally, the questionnaires will be sending to 20 to 30 random participants to identify any issues that may arise during surveying use and improve the overall quality before being officially submitted for reliability testing.

According to Hair et al. (2013), the minimum sample size to use EFA is 50, preferably 100 or more. Some other researchers suggest that the ratio of observations to an analytic variable should be 10:1 (Arrindell & Van Der Ende, 1985; Jackson, 2003). Therefore, the sample size is calculated as below:

$$N = 10 * m$$

Where:

N is the sample size;

m is the numbers of questions.

Hence, the questionnaire of this study contains at least 150 responses. However, the research collected a total of 300 responses (online and paper self-administrative surveys) during the period from December, 2022 to March, 2023, using convenience sampling and snowball sampling method to eliminate error responses and ensure the reliability. Employees working at banks in Southeast Vietnam area such as: Binh Duong, Ho Chi Minh City, Dong Nai, Long An, Tien Giang… are among the study's target population. After the screening of all the responses for usability and reliability by SPSS 26.0, 271 responses are accepted and valid for the analyzing process, resulting in a response rate of approximately 90.3%. This high response rate reduces the likelihood of response bias. After that, SmartPLS 3.3.9 uses the data to access hypotheses with the Partial Least Square technique. PLS-SEM was employed since it is suitable for complicated structural models and enables researchers to pinpoint the critical model components.

3.3. Variable measurement

This part is divided into two sections including two factors affecting on turnover intention and demographic questionnaires.

3.3.1. Three factors: Perceived InCSR, affective commitment and turnover intention in the banking industry in Vietnam

According to Jr & Fowler (1995), employing questions from previous research to

enhance questions in a questionnaire study is a good method. The questions, however, should be revised and tailored to the present study. The following sections provide details on how the questions were gathered and produced. The questionnaire includes three main constructs: (1) employee's perception of InCSR with 6 items adopted from Turker (2009), and (2) affective commitment- a six-item scale adopted from Allen & Meyer (1990) and (3) turnover intention with three items (Mobley et al., 1979). All of the items are measured by a five-point Likert scale, with "Strongly Agree = 5," "Agree = 4," "Neutral = 3," "Disagree = 2," and "Strongly Disagree = 1".

Table 1. Independent and dependent variables and its measurement items

Measurement items	Code	Source
Perceived InCSR	***PIC***	(Id Bouichou et al., 2022; Turker, 2009b)
Our bank encourages us to participate in the voluntarily activities.	PIC1	
Our bank policies encourage us to develop their skills and careers.	PIC2	
The management of our bank primarily concerns with our needs and wants.	PIC3	
Our bank implements flexible policies to provide a good work and life balance for us.	PIC4	
The managerial decisions related with us are usually fair.	PIC5	
Our bank supports us who want to acquire additional education.	PIC6	
Affective commitment	***AC***	(Allen & Meyer, 1990; Yukongdi & Shrestha, 2020)
I would be very happy to spend the rest of my career in this bank.	AC1	
I really feel as if this bank's problems are my own.	AC2	
I do not feel like "part of my family" at this bank I.	AC3	
I do not feel "emotionally attached" to this bank I.	AC4	
This bank has a great deal of personal meaning for me.	AC5	
I do not feel a strong sense of belonging to this bank I.	AC6	
Turnover intention	***TI***	(Khalida, 2018; Mobley et al., 1979)
I often think of leaving the bank.	TI1	
I intend to look for a new job within the next year.	TI2	
If I could choose again, I would not work for this bank	TI3	
R: reversal items		

3.3.2. Demographic questionnaires

Table 2. Demographic questions

Demographic	Category
1. What is your gender?	a. Male
	b. Female
2. What is your age?	a. Less than 25 years old
	b. 25 – 34 years old
	c. 35 – 44 years old
	d. More than 44 years old
3. Marital status	a. Marriage
	b. No marriage
4. What is your current position?	a. Sales
	b. Client Adviser
	c. Risk Manager
	d. Operation Officer
	e. Internal Audit Officer
	f. Others
5. Employment years with current bank	a. Less than 5 years
	b. 5 – 10 years
	c. 11 – 15 years
	d. More than 15 years
6. Educational background	a. Diploma
	b. Bachelor's degree
	c. Master's degree
	d. Professional degree
7. Monthly salary	a. Less than 15 million VND
	b. 15 - 25 million VND
	c. 26 – 35 million VND
	d. More than 35 million VND
8. What bank are you working at?	a. Vietcombank
	b. BIDV
	c. VIB
	d. Others

IV. DATA ANALYSIS, FINDINGS AND DISCUSSION

4.1. Profile of respondents

After categorizing these collected questionnaires, 271 responses were accepted for further analysis. The table below shows a summary of that respondent's information using SPSS 26.

Table 3. Profile of respondents

		Frequency	Percent
Gender	Male	65	24%
	Female	206	76%
Age	Less than 25 years old	89	32.8%
	25 – 34 years old	152	56.1%
	35 – 44 years old	29	10.7%
	More than 44 years old	1	0.4%
Marital status	Marriage	86	31.7%
	No marriage	185	64.2%
Current position	Sales	134	49.4%
	Client adviser	36	13.3%
	Risk manager	3	1.1%
	Operation officer	60	22.1%
	Internal audit officer	8	3%
	Other	30	11.1%
Employment years with current bank	Less than 5 years	165	60.9%
	5-10 years	103	38%
	10-15 years	3	1.1%
	More than 15 years	0	0%
Educational background	Diploma	0	0%
	Bachelor degree	255	94.1%
	Master degree	14	5.2%
	Professional degree	1	0.4%
Monthly salary	Less than 15 million VND	114	42.1%
	15 – 25 million VND	141	52%
	26 – 35 million VND	15	5.5%
	More than 35 million VND	1	0.4%
What bank are you working at?	Vietcombank	34	12.7%
	BIDV	15	5.5%
	VIB	62	22.8%
	Other	160	59.5%

(Source: Results of data analysis)

4.2. Outer Model Evaluation

The outer loading value in SmartPLS is the correlation coefficient between an observable variable and a latent variable (also known as a factor or structure) expressed as a reflective scale. The outer loading value indicates the magnitude and direction of the relationship between the observable and concealed variables. If an observation has a low outer loading, it might be demonstrated that the variable contributes minimally to the associated factor and can be removed from the model.

Some experts (Hair Jr et al., 2021; Hulland, 1999) recommended the outer loading value for a well-meaning observable variable to be 0.7 or higher. Therefore, during the reliability test, the expression variable AC4, AC6 and CSR6 was excluded because it did not pass the threshold of 0.70.

In Table 4, the results of measurement model evaluation including external weights, composite reliability (CR), Cronbach's alpha (α), and average variance extracted (AVE) should be benchmarked greater than 0.60 (Churchill, 1979; Gerbing & Anderson, 1988; Wong, 2013).

The table below shows that while CR values varied from 0.879 (Affective commitment) to 0.787 (Turnover Intention), the α values of affective commitment, perceived InCSR and turnover intention all exceeded the required value of 0.60 by 0.833, 0.818, and 0.624, respectively. This means that all three components tested with numerous reflecting indicators obtained internal consistency confidence.

The convergent validity is examined through the AVE measures in which AVE must exceed 0.50 (Fornell & Larcker, 1981; Hamid

et al., 2017). Our AVEs range from 0.551 (Affective Commitment) to 0.553 (Perceived InCSR and Turnover Intention), surpassing the recommended threshold of 0.50. This indicates that convergent validity is achieved.

Table 4. Measurement model evaluation results

Constructs	Code	Outer loading	CR	α	AVE
Affective commitment (AC)	AC1	0.719	0.879	0.833	0.551
	AC2	0.770			
	AC3	0.873			
	AC5	0.812			
Perceived InCSR (CSR)	CSR1	0.795	0.869	0.818	0.533
	CSR2	0.773			
	CSR3	0.819			
	CSR4	0.709			
	CSR5	0.771			
Turnover intention (TI)	TI1	0.710	0.787	0.624	0.553
	TI2	0.754			
	TI3	0.764			

(Source: Results of data analysis)

To achieve discriminant validity, the AVE square root measure for each structure should overcome the estimated correlations between the structure and other structures in the model. The following table shows that Correlation, AVE and Heterotrait-Monotrait Ratio (HTMT) values meet the condition of discriminant validity because the square root of their AVE measures exceeds the squared correlation of all other constructs.

Table 5. AVE square root measurement

	AC	CSR	TI
AC	0.742	0.591	0.367
CSR	0.560	0.730	0.349
TI	-0.297	-0.276	0.743

(Source: Results of data analysis)

4.3. Inner model evaluation

To confirm hypothetical relationships, the inner model undergoes evaluation alongside the outer model. The path coefficients for all variables and R-squares are illustrated in the picture below.

As seen above, the path coefficients reflect the strength of the structure's association, and the R-squared values represent the percentage of variance of the structures in the model to aid in forecasting the structural model's accuracy.

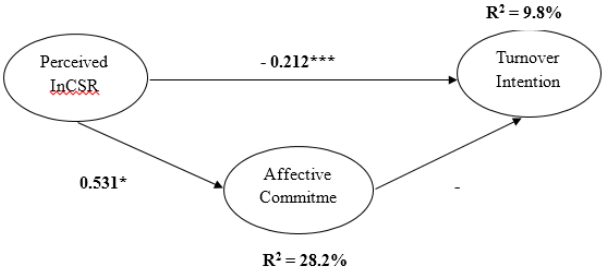


Figure 2. Hypothetical relationships

The results in the figure above explain 28.2% of variance in Affective commitment (R-square = 0.282) and 9.8% of variance in Turnover Intention (R-square = 0.098), which means that the value is moderate and weak respectively (Chin, 2010). From these pieces of information, it suggests that the experimental results confirm the explanatory power of this study's model at a moderate level.

F-Square is an index proposed by Cohen (1988) to evaluate the importance of independent variables in the SEM structural model. Employing Cohen's effect metric, known as the f^2. Cohen (1988) proposes a standard for testing the value of f^2 = 0.02 as "small effect", 0.15 as "medium effect", and 0.35 as "large effect" of the external structure on an internal structure. The table below evaluates the

strength of impact between variables based on each model structure. Hence, table shows that AC for TI indicates a small effect, while CSR has a large effect on AC. Remarkably, the f-square of CSR for TI less than 0.02 means that the regression equation does not fit the data well.

Table 6. Measurement of variables strength

	f-square	Effect size
AC → TI	0.036	Small
CSR → AC	0.392	Large
CSR → TI	0.017	Very small

(Source: Results of data analysis)

Bootstrapping Results

On the experts' recommendation to ensure the requirements of testing the linear structural model (Hair Jr et al., 2021), this study additionally was performed a series of 5000 samples to confirm the statistical significance of the hypothesized relationships (Henseler et al., 2016; Wong, 2013). It is suggested that the t-value should be more than 1.96 (5% significance level) and 2.57 (1% significance level) such that the path coefficients of the variables have a significant difference from 0 (Hair Jr et al., 2021; Henseler et al., 2016). Therefore, the table below illustrates that all potential associations are statistically proven, since all p-values are less than 0.05.

Table 7. Bootstrapping results

Relationships	Path Coefficient	Observed T-value	P value	Results
AC → TI	-0.212	3.473	0.001	Supported
CSR → AC	0.531	9.844	0	Supported
CSR → TI	-0.144	2.008	0.045	Supported
CSR → AC → TI	-0.112	3.227	0.001	Supported

(Source: results of data analysis)

4.4. Hypothesis test results

Hypothesis test results show that the relationship of InCSR with affective commitment to turnover intention in banking sector is statistically significant, which emphasizes the appropriateness of the proposed model.

For the hypotheses about the relationships of aspects of CSR with variables such as affective commitment and turnover intention are supported. Comparing the impact of the CSR aspect on those variables shows that, respectively: H1 is fully supported with impact coefficient $\beta = 0.531$, $p = 0$ while H2 has $\beta = -0.144$ and $p = 0.045$. At the same time, the results of hypothesis testing also show that the hypothesis about the relationship between various aspects of CSR on the dependent variable Turnover Intention through the mediating factor affective commitment is also accepted. As a result, this shows that CSR has a direct positive impact on employees' affective commitment to their organization. However, the impact of CSR on turnover intention was negative ($\beta = -0.144$). Besides, the analysis results also show the opposite effect of affective commitment on turnover intention ($\beta = -0.212$).

V. CONCLUSION

5.1. Hypothesis test results

In conclusion, the research results show that all the paths of this model are statistically significant and all hypotheses are proven. First, the internal CSR perception significantly related to affective commitment among banking employees. It was strongly supported by recent studies (Dung, 2020; Wang et al., 2020). Second, Affective Commitment related negatively Turnover Intention. The results are confirmed by Joarder et al. (2011). Third,

Perceived InCSR related negatively Turnover Intention (Y.-P. Chang et al., 2021; Low, 2015, 2017). Additionally, our findings indicate the mediating role of Affective Commitment in the relationship between Perceived InCSR and Turnover Intention (X. Chen et al., 2023; Joarder et al., 2011; Low, 2017). This means that Perceived InCSR affects indirectly Turnover Intention via Affective Commitment.

The above hypothetical results show that employees perceive CSR at banks in some provinces in the Southeast region, which has a positive impact on employees' affective commitment. Simultaneously, a turnover intention was followed, but may not have had an impact on reducing their intention to leave. This result gives governance implications: An ethical business not only knows how to polish its name through CSR programs, but also knows how to implement CSR with their employees first. CSR programs should become a recurring activity of the business. This will help employees feel proud of the company.

5.2. Research implication

As a result, the study proposes a number of governance implications to help the bank's Board of Directors develop appropriate and effective governance policies in order to improve the cohesion of the bank employees through deploying some solutions for HRD.

(1) Developing and implementing a full and standard CSR implementation organization.

It could be attributed to several ongoing key steps. To begin, the organization's leadership must demonstrate commitment and vision by articulating a clear CSR purpose that is consistent with its values and long-term goals. Engagement with stakeholders is critical for understanding their expectations and concerns. Following that, the firm should establish a dedicated CSR team managed by an experienced manager and give them with the resources they require. A complete CSR evaluation assists in identifying key areas for change. To track success, goals and KPIs should be established, and CSR should be integrated into core company activities. Collaboration with external partners, openness through frequent reporting, and employee involvement are all necessary for success. Continuous development and flexibility to changing conditions guarantee that the organization's CSR activities are effective and long-lasting.

(2) Develop organizational policies, especially employee policies, that enhance employee emotional commitment.

2.a. Employee Volunteerism and Community Engagement Policy:

Employees are supported and encouraged to participate in volunteer activities and community engagement programs. They might be provided with paid time off to engage in charitable initiatives and contribute positively to the communities.

2.b. Green Initiatives and Sustainability Policy:

Employees are urged to make a commitment to lowering their environmental impact and encouraging sustainable practices in the workplace by saving energy, eliminating trash, and supporting eco-friendly projects.

2.c. Employee Feedback and Engagement Policy:

Employee feedback is acknowledged and respected, as actively soliciting their opinion through frequent surveys, town hall meetings, and open-door policy. Employee engagement

efforts are put in place to foster a healthy work environment and guarantee that employees' perspectives are heard and included in decision-making processes.

(3) Let employees self-propose to execute social activities.

They intend to sponsor, but these initiative rights need to be within the framework of the charter and allowable budget of the business. When employees have the right to take the initiative, they will feel that they are an important part of the business, the business's job is also their own. As a result, employees will feel proud, engaged and want to stay longer with the business so that they can work together to complete positive projects for the society.

5.3. Limitations and future studies

First of all, the data were collected from roughly 300 respondents due to time and financial restrictions; hence, the validity of results outside of the Southeast may be restricted. As a result, more research in other cities in Vietnam may be undertaken to extend the sample size, analyze the influence of these variables, and offer a clear path to tackle this problem, assuring a more representative population sample.

Secondly, since this research used the convenience and snowball sampling methods, respondents were chosen based on their availability and desire to engage; some people choose to participate while others do not. This might result in skewed and ambiguous findings. As a result, future research should employ accurate sampling methods such as random sampling or probability sampling to reduce sample bias and boost sample representativeness. Moreover, the sample size limits the scope of this investigation. Further research in diverse sectors, geographic, and cultural contexts could potentially be done to generalize the relationship between the antecedents, procedures, and effects of InCSR perception, as well as the attitudes, actions, thoughts, and affections of employees in the organization.

Finally, the study also employed cross-sectional data, thus only a snapshot perception at a certain time point was collected. They cannot be used to examine behavior over time or to identify long-term patterns. To address this drawback, future research should employ longitudinal data to quantify within-sample change over time, measure event length, and record the timing of multiple occurrences

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THE TREND IN APPLYING AGENT-BASED MODELING IN ECONOMICS AND FINANCE STUDIES: A BIBLIOMETRIC ANALYSIS

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Abstract: This article presents a bibliometric study that reviews the current trends in applying agent-based modeling in economics and finance studies. The study examines the level of interest within the research community regarding this topic. The Scopus database was used to retrieve English literature on applying ABM in economics and finance studies published between 1995 and 2023. A total of 1,294 relevant articles were identified and analyzed. The findings include information on the top journals publishing these articles, the research topics covered, and an analysis of publication trends over the years. Through quantitative analysis, valuable insights were extracted. This paper provides a concise and informative overview of the current trends in the field, serving as a helpful introduction for researchers and practitioners interested in this area of study.

Keywords: *agent-based modeling, network analysis, bibliometric analysis*

I. INTRODUCTION

Agent-Based Modeling (ABM) is a computational simulation technique used to study complex systems by creating individual agents, each representing an autonomous entity with specific characteristics and behaviors. These agents interact with each other and their environment to observe emergent system-level behaviors that arise from the interactions of the individual agents.

ABM has found application across a variety of research domains, including but not limited to social sciences (Axelrod & Tesfatsion, 2006; Borawska & Łatuszyńska, 2021; Grinberger & Felsenstein, 2023; Li et al., 2023; Li et al., 2021; Parviero et al., 2022; Qie et al., 2022; Stolz, 2023), ecology (Akopov et al., 2017; McLane et al., 2011; Peck, 2014), economics (Alexandre et al., 2023; Nicola-Gavrilă, 2023; Polyzos et al., 2023; Purba et al., 2022; Sadeghi & Gerami-Seresht, 2023; Wang et al., 2021), transportation (Bastarianto et al., 2023; Sahin et al., 2023; Wilson et al., 2023), and computer science (Bastarianto et al., 2023; Richmond et al., 2023; Vijaya Chandrakala & Kiran, 2023; Wu et al., 2023). ABM provides a flexible and intuitive approach to exploring and understanding complex systems, especially when detailed individual-level interactions are important for the system's behavior. However, designing agent-based models can be challenging, and validating the models' accuracy and predictive capabilities is crucial for their effectiveness.

The initial study related to ABM was done in 1972. The number of studies annually

increased gradually over time, reaching 8533 studies by 2022. On July 4th, 2023, the total cumulative number of research is 109,030 documents.

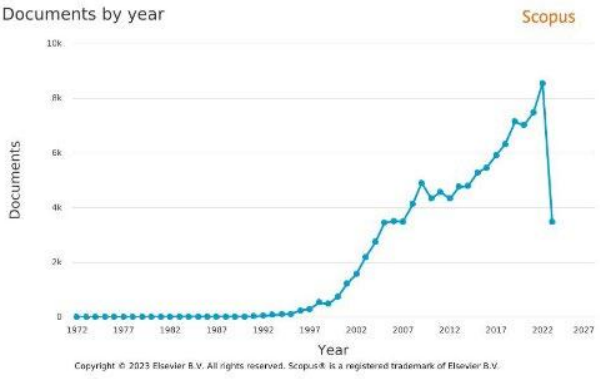

Figure 1. Trend of research on ABM

Studies related to ABM have covered many subjects, in which Computer Science, Engineering, and Mathematics mostly contributed with proportions of about 35%, 24%, and 16%, respectively. The proportion of Economics, Econometrics, and Finance subject area is only 0.873% with 1770 studies.

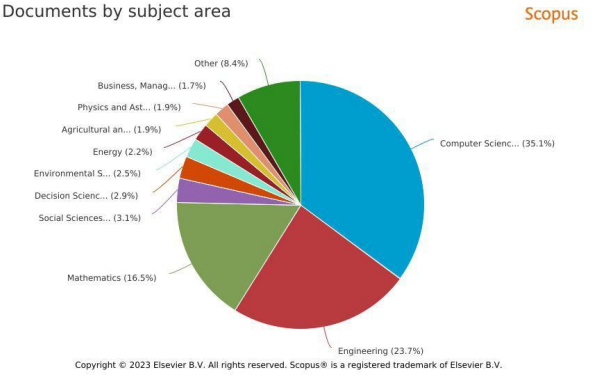

Figure 2. Fields of research on ABM

The large number of documents can inhibit the determination of current research points and research gaps within the field. Therefore, employing bibliometric analysis offers a quantitative means to assess the available database documents, facilitating the identification of research trends for future reference. This study's objective is to illustrate the allocation of ABMEF research articles concerning authorship, countries, and institutions. Results from this study are expected to provide a valuable resource for researchers and institutions seeking insights into the forthcoming prospects and possibilities within this field.

II. METHODOLOGY

We use both bibliometrics analysis and network analysis to explore the global trend in applying agent-based modeling in economics and finance studies. In this section, firstly, the data collection strategy is introduced. Secondly, network analysis bibliometrics analysis, and network analysis are applied to investigate the trend of study outputs, publication sources, high-level scientific research countries, and institutions. The approach used in this research was based on the methodologies proposed by Md Khudzari et al. (2018), Wang et al. (2021), and Purba et al. (2022).

A. Data collection

The database used in this study is collected from the Scopus database on July 4th, 2023, covering documents on ABM in economics and finance studies (ABMEF) published from 1995 to 2023. The search query employed was: TITLE-ABS-KEY ("agent-based model" OR "agent-based simulation" OR "individual-based model" OR "multi-agent system" OR "multi-agent simulation") AND (LIMIT-TO(SUBJAREA, "ECON")), which resulted in a total of 1,770 search results, encompassing diverse document types such as articles, book chapters, conference papers, and books. With the explicit objective of conducting an in-depth

examination of prevailing research patterns, this investigation concentrated its attention on scholarly academic articles as the subject of analysis. The culmination of the data acquisition process yielded a dataset comprising a total of 1,294 individual documents. Subsequently, relevant citations and bibliographic particulars, alongside the abstract contents and keywords provided by the authors within the documented outcomes, were meticulously extracted and aggregated into a Comma-Separated Values (CSV) file. This comprehensive dataset was subsequently employed as the foundation for subsequent phases of detailed analysis.

B. Analysis method

Based on the dataset of studies applying agent-based modeling in economics and finance studies from Scopus, in this study, we employ network analysis techniques to explore the association among two or more elements, wherein each connection is denoted by a specific strength value. A higher link strength shows a stronger relationship between each element. The examination in this paper focuses on examining the associations between co-authorship among countries and the co-occurrences of author keywords.

Moreover, within the confines of this paper, a comprehensive examination employing time series analysis is executed to elucidate the temporal evolution of research within this specific domain. This endeavor aims to uncover the inherent dynamism and potential trajectories of research trends that may manifest in the forthcoming academic landscape.

III. RESULTS AND DISCUSSIONS

A. Descriptive statistic

In the capacity of a mechanism facilitating the assessment of scientific and technological endeavors, the bibliometric measurement framework furnishes a diverse array of both quantitative and qualitative benchmarks pertaining to scientific and technological accomplishments. The application of bibliometrics predominantly finds its utility within the realms of scrutinizing scholarly publications, evaluating scientific research endeavors, and gauging the progression of academic disciplines among other domains.

a. Trend of study outputs

The trend of economics and finance studies outputs applying agent-based modeling during 29 years from 1995 to 2023 is presented in Figure 3. It shows that there is a general increase in the number of academic articles, while the data for 2023 is slightly down because the year 2023 has not been finished by our statistics.

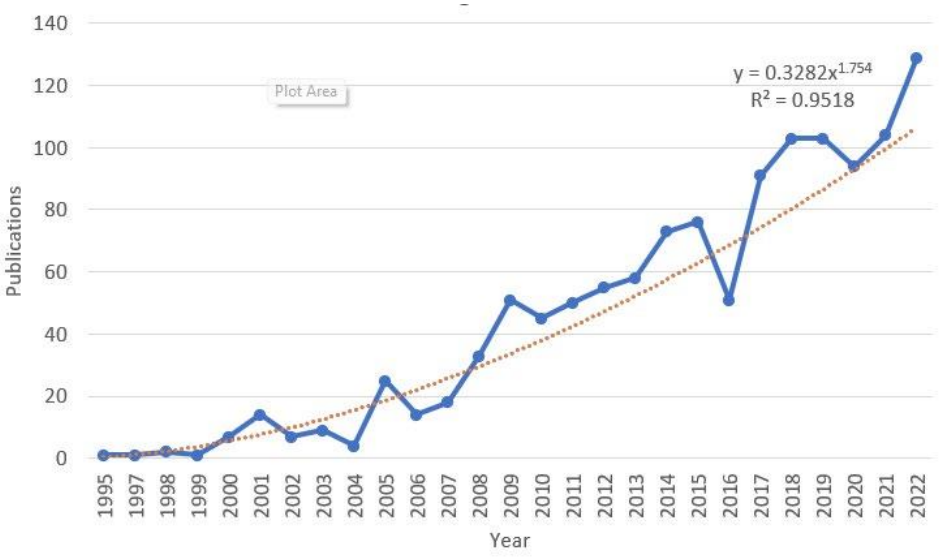

Figure 3. The annual number of academic articles on ABM from 1995 to 2022

The analysis of the number of academic articles shows that the number of academic articles from 1995 to 2007 is less than 30. During this period, ABM is not a hot research topic in the economics and finance field. From 2008 to 2022, the research on ABM grew. Generally, there was a substantial rise in annual publications, increasing from 1 document in 1995 to 129 in 2022.

Through the fitting curve of the number of academic articles, we get trend lines. The trend line may be expressed based on the power equation $y = 0.3282x^{1.754}$ with R^2 is 95.18%, whereby y is the number of academic articles and x is the year, which also proves that the research field of ABM in economics and finance studies has moved from the germination stage to the rapid development stage. Based on this equation, the predicted number of academic articles in 2030 is about 207,724 documents.

b. Publication sources

Table 1. The top 10 most productive journals in publishing academic articles related to ABMEF

No.	Journal name	Number of Published Articles	Total Citations	Most cited article	Citation number	Publisher
1	"Journal of Economic Dynamics and Control"	72	2590	"Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles"	353	Elsevier
2	"International Journal of Production Economics"	52	2575	"Virtual enterprise - Organisation, evolution and control"	225	Elsevier
3	"Ecological Economics"	44	1513	"Behaviour in commons dilemmas: Homo economicus and Homo psychologicus in an ecological-economic model"	187	Elsevier

No.	Journal name	Number of Published Articles	Total Citations	Most cited article	Citation number	Publisher
4	"Journal of Economic Behavior and Organization"	64	1305	"A new approach to business fluctuations: Heterogeneous interacting agents, scaling laws and financial fragility"	195	Elsevier
5	"Computational Economics"	86	1166	"Estimation of agent-based models: The case of an asymmetric herding model"	223	Springer
6	"Journal of Evolutionary Economics"	52	802	"Evolutionary models in economics: A survey of methods and building blocks"	103	Springer
7	"Journal of Economic Interaction and Coordination"	97	753	"The Naming Game in social networks: Community formation and consensus engineering"	78	Springer
8	"Resources, Conservation and Recycling"	24	616	"The stability and profitability of the informal WEEE collector in developing countries: A case study of China"	103	Elsevier
9	"Energy Economics"	12	446	"A critical survey of agent-based wholesale electricity market models"	267	Elsevier
10	"Nonlinear Analysis: Real World Applications"	11	349	"Adaptive flocking with a virtual leader of multiple agents governed by locally Lipschitz nonlinearity"	85	Elsevier

Articles related to ABMEF have been featured across 303 different journals, and the ten most prolific journals are outlined in Table 1. Among these, the Journal of Economic Interaction and Coordination boasts the highest output with 97 academic articles (12%). However, the Journal of Economic Dynamics and Control stands out for accumulating the highest citation count, reaching a total of 2590 citations. It is noteworthy that Computational Economics published the initial ABMEF article in 1995, contributing a total of 86 academic articles to the field. Additionally, the Journal of Economic Dynamics and Control, International Journal of Production Economics, Ecological Economics, Journal of Economic Behavior and Organization, and Computational Economics have collectively garnered over 1000 citations. The top 10 journals emanated from esteemed publishing houses, namely Elsevier and Springer. Among these prominent periodicals, a distribution is discerned wherein five journals are affiliated with institutions in the United Kingdom, two with Chinese institutions, one with a German institution, one with an American institution, and an additional one with a Dutch institution.

c. Research countries

Figure 4 illustrates the publication distribution based on the regions of the primary authors. The bar chart indicates that the United States has the highest publication count among all nations, with 256 publications constituting over 14% of the total. Subsequently, Italy follows with 224 publications, trailed by Germany with 177, China with 140, France with 136, and the United Kingdom with 132. Collectively, these countries contribute to more than 58.45% of the total publications.

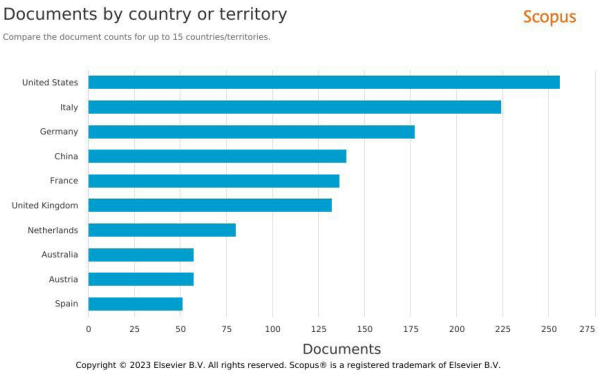

Figure 4. Number of academic articles by country

Figure 5 portrays the collaborative network established among nations in which the primary authors of the scholarly works are situated. As illustrated in Figure 6, inter-country collaboration is notably robust among the United States, China, Germany, the United Kingdom, Italy, and France.

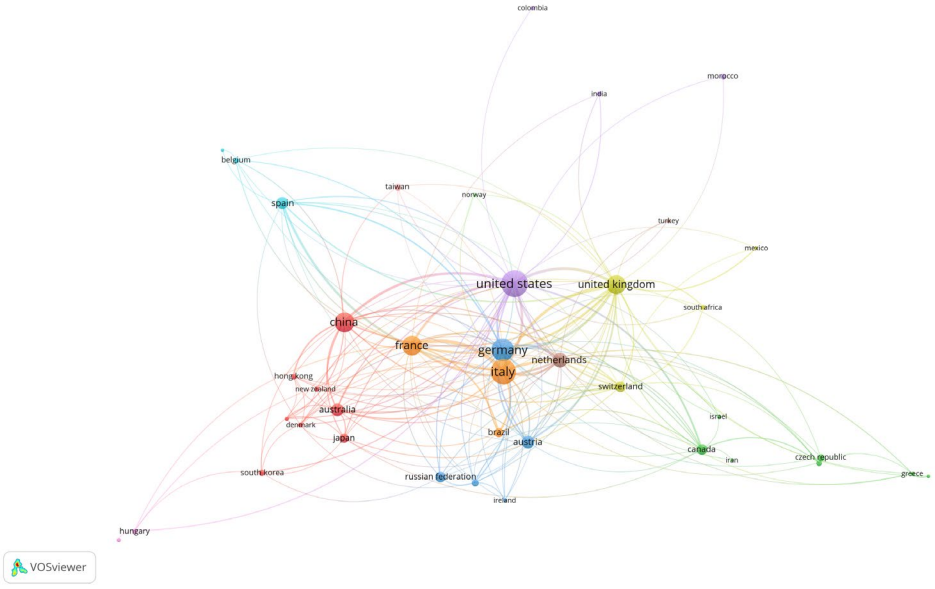

Figure 5. Network of co-author between countries

d. Prestigious scientific research institutions

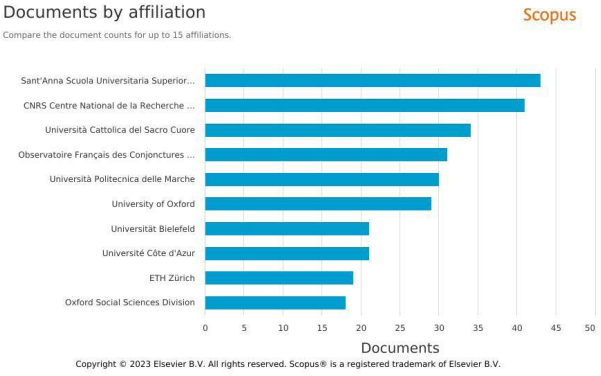

Figure 6. The top 10 institutions determined by their publications

Figure 6 shows the top 10 institutions based on publications. The top-ranked institution is Sant'Anna Scuola Universitaria Superiore Pisa, with publications of 43. The second is CNRS Centre National de la Recherche Scientifique, with publications of 41. The third is Università Cattolica del Sacro Cuore, with publications of 34. The 4th is Observatoire Français des Conjonctures Économiques Sciences Po (31). Every institution listed in the top ten rankings hails from the continent of Europe.

e. Author performances

To analyze author performance, we do not consider 51 articles that have more than 5 authors. The 13 authors with the highest publication output are listed in Table 2. The author of the first published research article on ABMEF is Andrea Roventini from Scuola Superiore Sant'Anna, Italy with 31 articles and total citation is 826. With 23 articles, Mauro Gallegati from Università Politecnica delle Marche, Italy is the second published author, however, his total citation is the highest of 916 citations. The third published author is Giovanni Dosi from Scuola Superiore Sant'Anna, Italy with 20 articles and 830 citations. The 5 first published authors are from Italy, this shows that ABMEF is very interested in research in Italy.

Table 2. The top author published

Name	Scopus author ID	Total research article	Total citation
Roventini, Andrea	24,067,448,600	31	826
Gallegati, Mauro	57,191,605,528	23	916
Dosi, Giovanni	6,603,808,130	20	830
Napoletano, Mauro	16,507,515,900	15	398
Delli Gatti, Domenico	7,007,102,859	11	389
Dawid, H.	7,003,308,973	10	340
Lux, Thomas	7,003,769,381	10	537
Wall, Friederike	37,108,706,900	10	42
Di Guilmi, Corrado	6,602,524,294	9	148
Chen, Shu-Heng	7,410,248,303	9	76
Grazzini, Jakob	36,170,809,500	9	160
Bakhtizin, A.R.	55,909,941,500	9	33
Makarov, Valerii L.	56,470,269,300	9	36

B. Analysis of co-cited articles

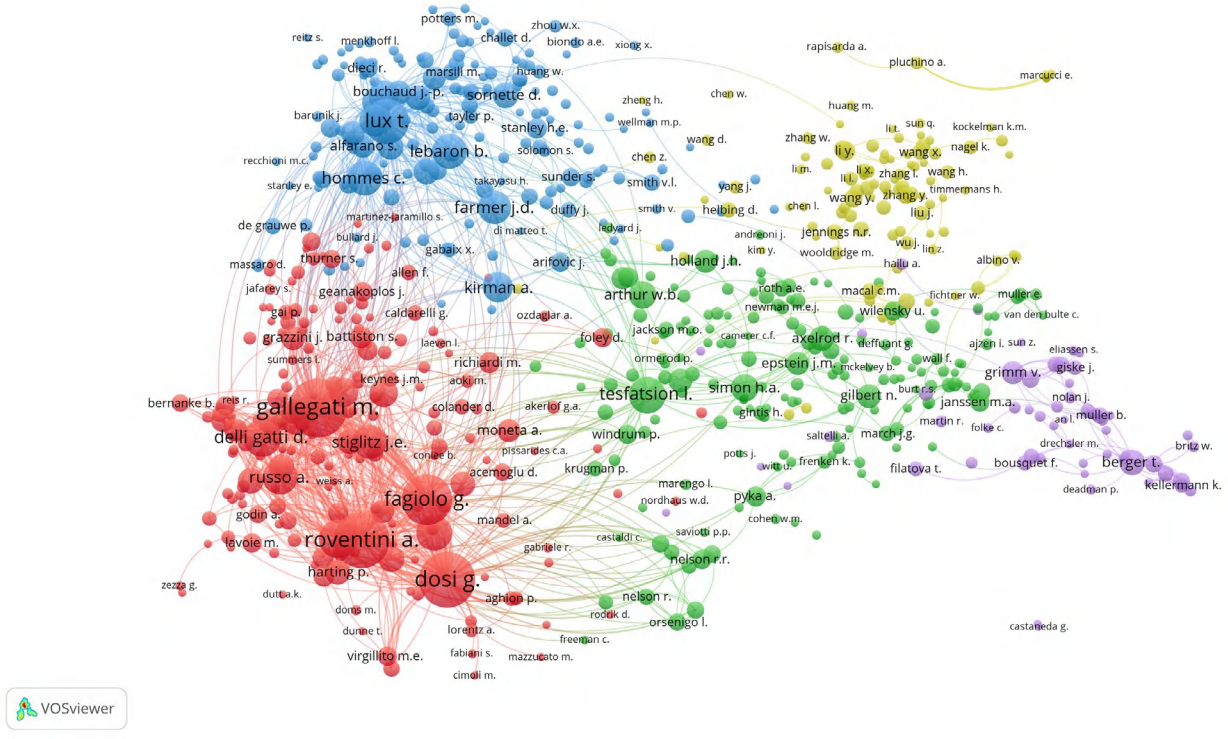

Figure 7. Co-citation network of ABMEF articles

When two articles are cited together by a certain number of other articles (denoted as n, where n = 1, 2, …), a co-citation association is established between these two articles. The strength of this co-citation connection is indicated by the value of n. Articles that share co-citations have thematic similarities, and the co-citation strength quantifies the contextual correlation between them. Through the analysis of co-citation relationships among a collection of articles, a co-citation network can be constructed. In this network, the proximity of nodes reflects the thematic closeness between articles. Figure 7 illustrates the co-citation network, displaying linkages between sample articles. The lines connecting nodes indicate co-citation relationships between corresponding pairs of articles. Node size correlates with citation frequency, reflecting higher citation rates with larger nodes. Notably, distinct clusters emerge within the co-citation network, with clusters 1 and 2 occupying central positions and representing the largest aggregations, as evident in both Figures 7 and 5.

C. Distribution of author keywords

A total of 3,371 author keywords sourced from the Scopus database was employed to visualize the research trends within the field of ABMEF. However, the presence of redundant keywords emerged. For instance, variations such as "agent-based model", "Agent-based simulation", and "multi-agent simulation" were employed interchangeably across publications. To address this, akin keywords were amalgamated into single entries, culminating in a refined list of 3,346 author keywords. A stipulated threshold of five occurrences was applied to this list to ensure a meaningful depth and breadth of research representation in the

field. Figure 7 elucidated the co-occurrence relationships among these author keywords. Notably, the term "agent-based model" held the highest frequency, occurring 781 times and thereby claiming a central position on the bibliometric map, showcased in Figure 8. Other prevalent keywords encompassed "simulation" (43 occurrences), "learning" (31 occurrences), and "innovation" (26 occurrences).

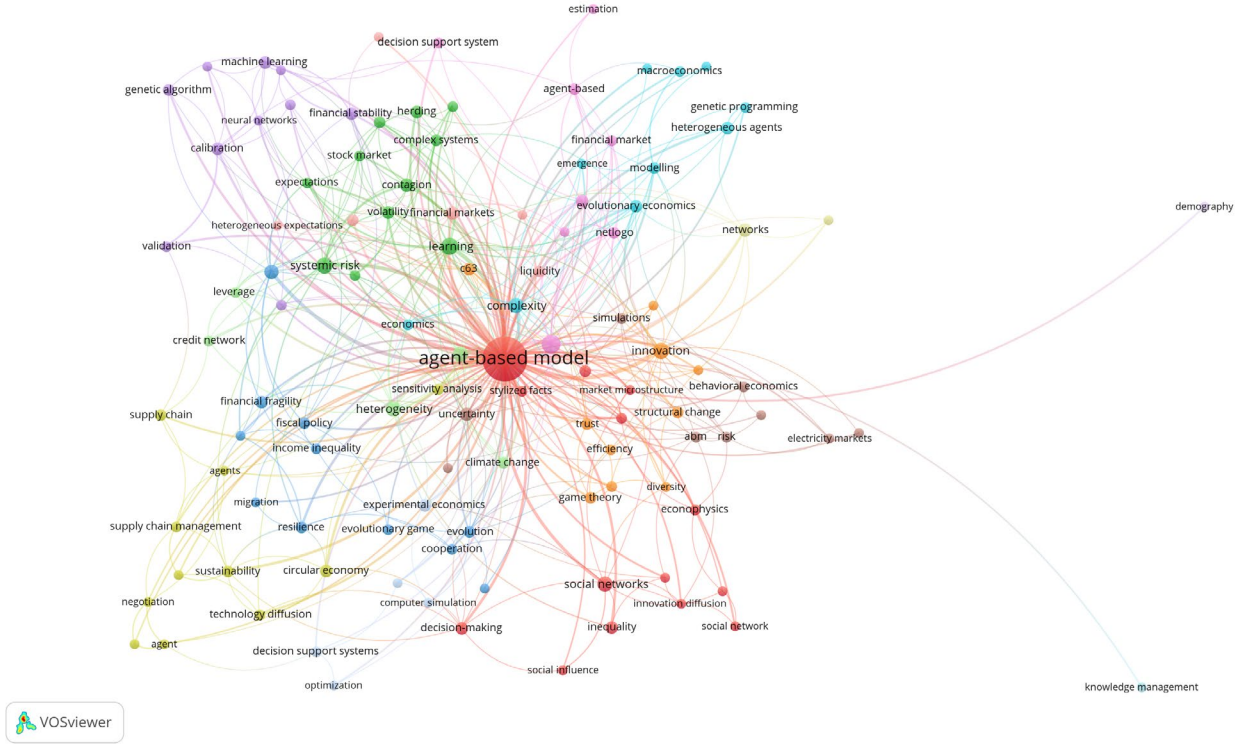

Figure 8. The author keyword co-occurrences

IV. CONCLUSION

In recent times, research within the ABMEF domain has gained significant attention. There has been a noteworthy surge in both publications and citations, yet a comprehensive overview of the research landscape remains absent. To address this gap, this paper employs bibliometric analysis to systematically review the literature pertaining to ABMEF. The study begins by conducting a descriptive statistical assessment of 1,294 academic articles spanning the period from 1995 to 2023. This examination encompasses aspects such as overall growth, publication sources, research origins, geographical distributions, and the involvement of high-profile scientific institutions. Notably, the analysis reveals that the publication count adheres to a potent trendline, characterized by the equation y = 0.3282x1.754, underscoring the rapid advancement in the ABMEF field. Based on the findings of our study, the following conclusions can be drawn.

1. Over 29 years (1995-2023), agent-based modeling in economics and finance research shows a consistent upward trajectory in academic articles, with

significant growth from 2008 to 2022 (1 to 129 articles). The transition from modest beginnings to rapid development is evident, with a projected 2030 article count of about 207,724.

2. All of the top ten research institutions are situated in Europe. However, The United States, with 256 publications (over 14% of the total), is the leader country the ABMEF publications. Notably, the first five published authors are all from Italy, indicating a strong interest in ABMEF research within the country. Within these top journals, which originate from reputable publishers like Elsevier and Springer, there's a notable distribution: five are linked to UK institutions, two to Chinese, one each to German, American, and Dutch institutions.

3. Drawing on the clustering analysis of the literature, we realize some highlighted fields of study with ABMEF, namely the intricate dynamics of innovation and technology adpoption processes; systemic risk of the economic and financial systems; asset pricing; dynamic mechanism of markets and economy; public policy and decision making; climate change, sustainability, and development economics; behavior economics and finance; social influence in complex networks; supply chain management and international trade.

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TOWARDS SMART BUILDING TECHNOLOGIES FOR SMART BUILDINGS IN BINH DUONG

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Abstract: The smart building technologies (SBTs) have received a broad audience due to the necessities and benefits of sustainable development. The SBTs for smart buildings have been applied in many different developed countries; however, in developing countries such as Viet Nam, construction professionals have paid little attention because of several constraints. This study presents a systematic review of 107 journal articles and relevant literature on benefits and barriers underpinning adoption processes of SBTs. Moreover, the paper provides insights into the current barriers and benefits of smart building technologies in Binh Duong province – Viet Nam while suggesting a tenant experience application solution that helps achieve better SBTs adoption.

Keywords: *smart building technologies, tenant experience application, internet of things*

I. INTRODUCTION

The construction and maintenance of buildings represent approximately 30 – 45% of final energy consumption and 25% of greenhouse gas emissions (Ghansah et al., 2021 ; ADEME). It is one of the most energy-intensive sectors of activity and is reputed to have the worst impact on the environment. For example, in the EU, US, Hong Kong and Africa, building energy consumed 40%, 20%, 90% and 56%, respectively (Fazli et al., 2021; Liu et al., 2019; Mejjaouli & Alzahrani, 2020; Pallante et al., 2020). In addition, in such regions, the building stocks are responsible for 36%, 40%, 33%, and 32% of greenhouse gas emissions, respectively. However, things are moving. In a context marked by the COVID-19 pandemic, there is a real change in attitude toward ecological and sustainable issues. 75% of French people would like to have housing that is more respectful of the environment (Qualitel-Ipsos barometer). Respecting the environment and preserving the well-being and quality of life in one's house are increasing virtual elements for buyers. Furthermore, with the 2020 ecological regulations, it is now the entire life cycle of the building that is taken into account, and not just the construction itself. Construction sites, transport, bio-sourced material, water management, recycling, recovery of waste, and many other criteria are now taken into consideration.

Pitcher Group pointed out that the impact of the building on the environment is 20% during construction and 80% during its lifetime, which is why it is important to take into account sustainable development throughout the life of the building.

In the case of Binh Duong, a survey was conducted to identify barriers to the adoption of smart building technologies in two large smart buildings in Binh Duong province, Vietnam. Out of 138 survey recipients, 40 responded, with a response rate of approximately 29%. The survey identified cost as the most severe barrier, with installment expenses and maintenance costs as the top two factors. Lack of technical skills was also identified as a significant barrier. Resistance to change from traditional practices was identified as a mild influence but could have negative long-term effects on building operations. The survey categorized participants into four groups: Owners, Tenants/Users, Architects, and Contractors/Engineers.

Finally, we discuss one potential solution for the adoption of smart building technologies. The building tenant experience application is a smart building technology solution that creates a digital connection between customers, occupants, and buildings. It allows for social interaction, access to amenities and services, neighborhood partnerships, and essential property information, promoting customer-centric sustainability and a sense of community loyalty.

II. METHODOLOGY

This study is primarily based on a literature review of the benefits and constraints to apply smart building technologies (SBTs). A thorough literature review of scientific research provides a solid base for processing knowledge of the topic. This study uses a systematic review method to analyze the existing literature comprehensively.

The Scopus search engine was used to perform the literature search of relevant papers. The first restriction for these papers is that they need to be published in academic journals (peer-reviewed sources), textbooks, or conference papers. For this reason, papers from other sources such as internet data, unpublished research articles, and academical thesis… were not adopted.

The second restriction related to the keywords that were used in the Scopus database. The group of keywords used for this paper are limited to three groups:

a) The building group, which includes but is not limited to some typical words such as: "Smart Grid", "Smart buildings", "Smart Systems", "Smart Buildings", "Intelligent Buildings", "Materials" ….

b) The technology group, which applies the same rule as the above group, has usual keywords such as: "HVAC", "Building technologies", "Internet of Things", "IoT", "Building Systems", "Network system", "Management system", "Home objects", "Building Objects", "Sensor", "Air Condition", "Applications", "Infrastructure", "Detection", "Elevator", "Hybrid Vehicles" ….

c) The efficiency group, which includes all relevant keywords that could demonstrate and express the efficient usage of energy and resources in the household(s), building(s), or citi(es), these keywords are: "Manage energy", "Optimal coordination", "Coordination", "Energy Management", "Energy Efficient", "Better energy-efficient", "Predictive control for building", "Performance analysis", "Reducing", "Saving", "Building performance", "Low energy", "Optimum" ….

The initial systematic search provided 1468 potential articles (searched in March 2023). The authors read through the Abstract,

Introduction, and Conclusion of all these articles and applied the inclusion criteria for the selection. The chosen articles needed to be

a) Written fully in English

b) Generated the topic related to "Science" and "Building Technology" and/or "Sustainability"

c) Published latest from 2003 (have a lifetime of less than 20 years when this search was conducted")

d) Referred to the benefits of applying building technologies, both directly or indirectly are accepted

These criteria limited the potential articles to 410, and the critical content review of these articles further reduced the potential articles to 107. These were the final number of articles that were used to conduct the systematic research. These articles qualified the first three restrictions, and their contents also satisfied and related to the definition of Smart Buildings that was referred to in the beginning of this paper. Moreover, these contents also demonstrated the benefits of applying technologies, which is the most important reason that explained why these 107 articles were chosen, and the rest 303 articles were eliminated. The eliminated articles did satisfy three restrictions, but they are out of the scope of the research, which focuses on the benefits of applying technologies for Smart Buildings. Figure 1 provides the process of this systematic review.

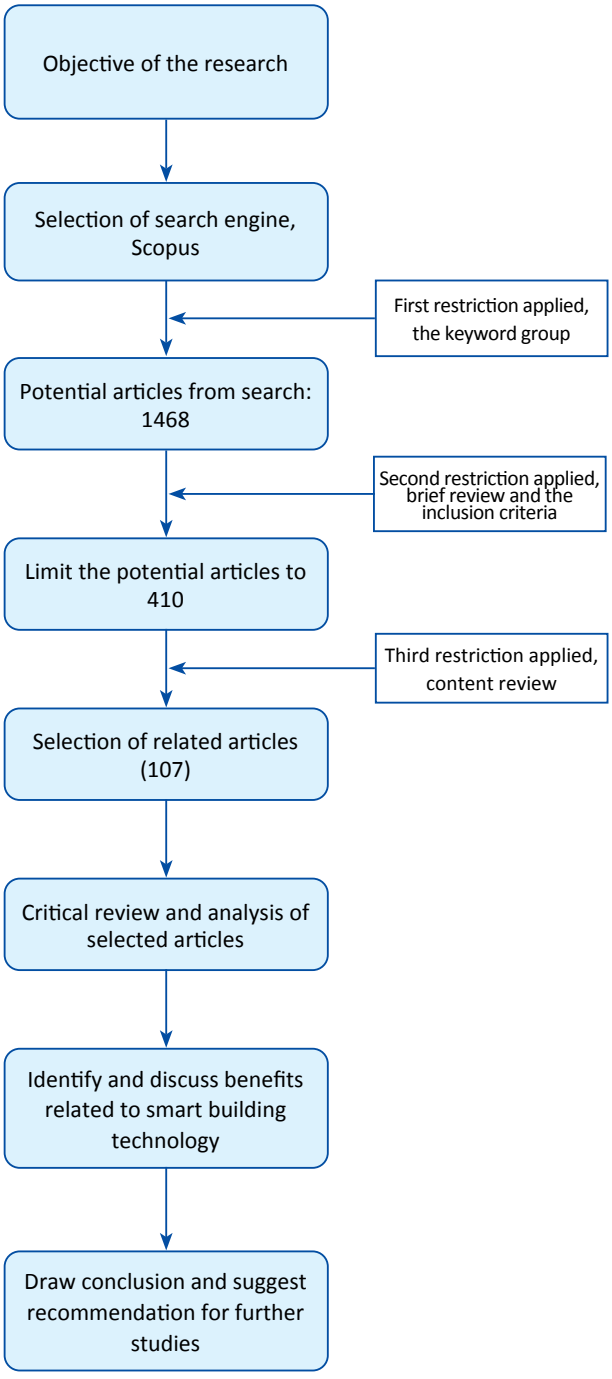

Figure 1. Overview research and flow

III. SMART BUILDINGS: DEFINITION AND BENEFITS

A. Concept of smart building

Understanding the characteristics of smart buildings is crucial. Over time, definitions of smart buildings have evolved from intelligent buildings and continue to be shaped by current experiences and knowledge. Powell (1990) defined an intelligent building as one that utilizes management computer systems to control technical operations such as heating and air conditioning, lighting, fire protection, telecommunications, security, and other similar functions. As time has progressed, the definition of intelligent buildings has expanded to include a range of features that accommodate the needs of modern buildings. This includes the interaction between occupants and tenants within the building, as well as the impact of these interactions on building performance. Clements-Croome (2011) suggested that an intelligent building is responsive to the requirements of occupants, organizations, and society. It means sustainability in terms of energy and water consumption, low pollution in terms of emissions and waste, and healthy in terms of well-being and functionality. Using the definitions addressed previously, it can be recognized that intelligent buildings will play a vital part in future designs but additionally integrates aspects of adaptable control, functions, materials, and humans.

In creating an appropriate definition for smart buildings, recent literature has addressed the subject to gauge an indication of new aspects and advantages in which smart buildings can provide. An academic study by Wang et al. (2012) stated that smart buildings become part of the next generation building industry. Both intelligence and sustainability issues by computer combine with intelligent technologies in order to achieve optimal overall comfort level and energy consumption.

In addition to the academic research in such areas, there have been numerous definitions and green policies of smart building by organizations and firms such as BBCA (Low-carbon building), CSR (Corporate Social Responsibility), NF Habitat HQE, RE 2020. For example, Icade has objectives that 100% of offices over 5,000 sq.m and 50% of homes to be E+C- certified with an E2C1 rating by 2022 and obtain HQE (High Environmental Quality) certification for 100% of new builds over 4,000 sq.m.

Batov (2015) distinguished a smart building from normal by three components, namely hardware, software and network. First of all, a smart building needs to be equipped with sensors and meters to recognize the inside and outside environment. Thus, such buildings can determine rooms' occupation, light intensity, indoor and outdoor temperature, carbon dioxide level, noise level, electricity and so on. Furthermore, a smart building can control systems like heating, air conditioning, lighting by devices and actuators. Secondly, besides providing raw information, a smart building should provide useful information, make decisions, and even predict the future. Two of the most widely used techniques are machine learning and the internet of things (IoT). Therefore, the software is a crucial part of any smart building. Finally, the network is the nervous system of a building. It allows the building and occupants to act as a whole. The network helps to connect all devices with the artificial intelligence component and humans. Hardware, software, and network together are the solution for smart buildings.

Buckman et al. (2014) showed the diagrammatic representation of the smart building definition. There were four methods that meet the drivers for building progression. However, adaptability is the heart of the definition of a smart building.

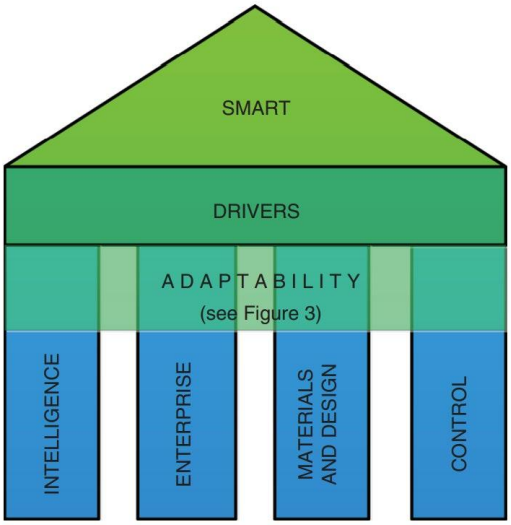

Figure 2. Features of a smart building

(Source: Buckman et al., 2014)

Adaptability

Adaptability lies at the core of smart buildings' features. It involves utilizing internal and external sources to prepare the building for future events. A prime example of adaptability is the ability to consider people's varying comfort levels based on the time of day and season, changes in occupants' usage patterns, rental data characteristics, and typical weather conditions. Building an adaptable structure is crucial for maintaining or enhancing energy efficiency and occupant satisfaction in smart buildings.

Control within smart building

Buildings reconcile both human control and automation in order to achieve the drivers for smart building progression. The aim of control is to support occupants with information that they can adapt as well as the building self-adapting to occupants' preferences and requirements. To be specific, real-time environmental information directs occupants to an area within their personal comfort preferences. For example, the library informs users on the arrival of the temperature, number of people, and other varying conditions in each area. Simultaneously, influencing adaptive comfort warns occupants what the living condition or temperature is going to be before they leave home. As shown in Figure 3, smart buildings recognized the importance of re-engaging the occupants with the building in order to allow them to have better control over their own buildings.

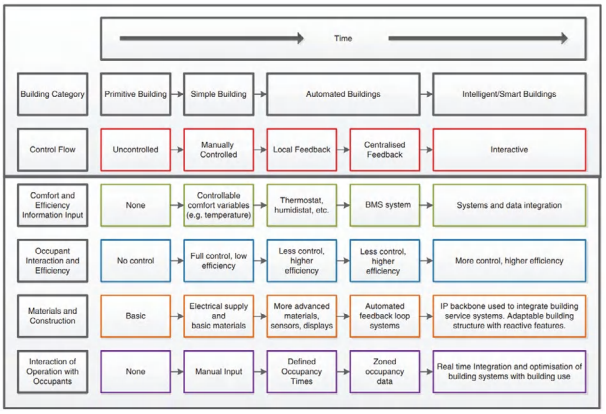

Figure 3. Building process

(Source: Buckman et al., 2014)

Enterprise within smart building

Smart buildings are created by integrating enterprise systems into real-time building operations, as defined by Powell (2010) and Singer (2010). Such buildings have major building systems integrated on a common network, which allows for the optimization of the building's functions. For example, a university may use a room booking system to allocate

rooms in specific zones of a building. When a room is booked, such as a meeting room, the system will invite the expected attendees into the enterprise system. This integration enables adjustments of operational requirements and controls for heating and cooling, maximizing productivity while maintaining comfortable conditions. By incorporating an enterprise system and occupant choices, building operation can be adapted proactively, reducing energy consumption and enhancing comfort levels.

Materials and construction within a smart building

The built form of a smart building, as well as its functions, are defined by its materials and construction. These buildings are designed to accommodate changes in use and climate, as well as the needs of its occupants. For example, a smart building can adjust to future climate changes by replacing features, and can close zones during periods of low occupancy based on occupancy data collected by the enterprise system.

To achieve adaptability, smart buildings integrate intelligence, enterprise, materials, design, and control into their core functions. These features are well-defined components of hardware, software, and network, and are aimed at fulfilling the drivers of building progression: longevity, energy efficiency, comfort, and occupant satisfaction.

In smart buildings, learning and prediction play important roles. Learning is achieved by analyzing past usage data and adapting to improve comfort and satisfaction levels. On the other hand, prediction relies on Artificial Intelligence systems to anticipate future changes and optimize building performance.

IV. SMART BUILDINGS, SMART CITIES IN VIETNAM AND BINH DUONG

In the last ten years, Vietnam has undergone a swift urbanization process, resulting in significant societal disruptions and posing numerous challenges. The emergence of these challenges has increased the demand for urban planning and governance to adapt and make necessary changes, aiming to transform cities into more livable and intelligent environments. As a result, urban development needs to be approached with a greater emphasis on intelligent solutions. The trend of smart city development is on the rise not only globally but also within Vietnam. Twenty-three cities and provinces in Vietnam have been designated as "smart cities", and approximately ten additional cities express their intent to adopt similar strategies, with encouragement and support from the central government (Leducq & Scarwell, 2018).

CYFEER and Cyhome SMS have offered valuable insights into the potential applications of the Internet of Things (IoT) in the context of building infrastructure in Vietnam (Minoli et al., 2017). CYFEER should explore the possibility of forming joint ventures as a strategic approach to bolstering the availability of technological and managerial expertise from foreign investors. This strategic decision becomes even more appealing given the increasing profitability of CYFEER's projects and the robust business infrastructure the company has been diligently building, thus presenting significant prospects for foreign investors. The utilization of IoT-based platforms is experiencing a rapid growth, providing adopters with the benefits of time savings, cost reduction, enhanced efficiency, and elevated living comfort and convenience.

The implementation of smart city initiatives represents a long-term solution for addressing the current challenges faced by Dalat city which aims to enhance the quality of life for its residents and stimulate economic development within the city. (Bach & Kim, 2020). Nonetheless, research indicates that establishing a smart city in Dalat is a challenging endeavor. Indeed, the establishment of a smart city in Dalat is a multifaceted and long-term undertaking that demands the engagement of various sectors of society, specialized expertise, and the unified commitment of both municipal authorities and residents. Firstly, the city necessitates a comprehensive shift in policies and information and communication technology (ICT) infrastructure, guided by a forward-looking vision to address a range of challenges. Secondly, there's a need to cultivate a skilled workforce capable of meeting the demands of smart city development. Thirdly, the city must actively promote extensive communication efforts and provide guidance to citizens and businesses on utilizing online public administrative services, fostering citizen participation through transparency.

Binh Duong Smart City is indeed taking form through a collaborative endeavor that includes the Smart City Office, Becamex, the government agency responsible for the project, educational institutions, entrepreneurs, and various government committees. Their collective efforts are dedicated to building a contemporary, environmentally sustainable city with the long-term goal of housing one million Vietnamese residents. Binh Duong Smart City is making remarkable progress by offering ubiquitous Wi-Fi connectivity, fostering an innovation ecosystem, and improving rural living standards through information technology training initiatives.

V. RESULTS AND DISCUSSION

A. Bibliometric analysis outcomes of the paper

Through a critical review and analysis of 107 articles, 10 benefit sectors were identified. The section below will explain in detail what these benefit sectors are. Based on the number of times these benefits sectors are mentioned in the articles, they will be ranked from 1 to 10, with 1 meaning the sector that makes the highest appearance and 10 meaning the lowest.

All the articles were published after 2005, with the highest number of articles published in 2016 (15 articles), followed closely by the year of 2012 (14 papers), and 2017 (12 articles). In the opposite direction, the top three lowest number of articles were respectively published in 2006 and 2007 (0 article), and 2005 (1 article).

Based on the year of publication, these articles are reliable and current because the majority of them were published in the last 10 years (95 / 107 articles, including 2012), as shown in Figure 4. With the group of 10 benefit sectors these articles mentioned about, the connection between the adoption of Smart Building Technologies and the benefits of Smart Building Technologies will be drawn for further discussion. According to the priority rank of these business sectors, the top five sectors with the highest appearance will be focused on detail more than the other five sectors.

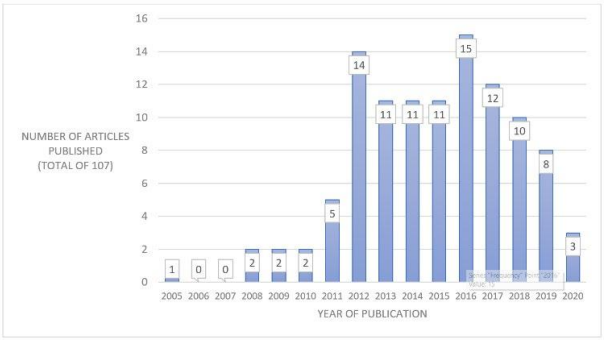

Figure 4. Papers in selected articles about the benefits of smart building technologies by year

B. The benefits of smart building technologies

Adopting smart building technology will bring benefits to professionals, clients, occupants in particular, and the country as a whole. Bandara et al. (2019) found the three sustainability goals, namely economic, social and environmental when adopting smart building technologies. Smart building technologies also help to limit greenhouse gas emissions through energy usage and carbon emission control (Sovacool & Del Rio, 2020). Moreover, traditional structure is another benefit of adopting smart building technologies (Frank Pennisi, 2016). According to (Balta-Ozkan et al., 2014b) safety, healthcare system improvement, and occupants' security are other benefits related to social aspect. In addition, SMTs identify the benefits as a strategy for cost reduction, collaboration and efficiency (John et al., 2005; Keles et al., 2015; Xu et al., 2017). In Table 1, the top 10 benefits are discussed, which is based on the frequency mentioned by researchers.

Table 1. The benefits of smart building technology

Code	Benefit sectors	References	Number of times articles mentioned	Ranks
B1	Energy saving management	Berawi et al. (2017); Darko & Chan (2017); Goyal et al. (2013); Jia et al. (2018); Kylili & Fokaides (2015); Li et al. (2020); Love & Arthur Bullen, 2009; Sovacool & Del Rio (2020); Yoo et al. (2012)	90	1
B2	Cost Saving	Balta-Ozkan et al. (2014a); Berawi et al. (2017); Bruno et al. (2009); Gabay et al. (2014); John et al, (2005); Keles et al. (2015); Koomey et al. (2013); Lawrence et al. (2016); Magno et al. (2014); Okoye & Okolie (2014); Sovacool & Del Rio (2020); Zhang et al. (2011)	56	2
B3	Technical Performance	Balta-Ozkan et al. (2014b); Berawi et al. (2017); Casini (2016); Deng et al. (2012); Goyal et al. (2013); Kwon et al. (2014); Maasoumy et al. (2011); Mosalam et al. (2018); Okoye & Okolie, (2014); Ortiz et al. (2010); Wei et al. (2015); Xu et al. (2012); R. Zhang & Hong (2017)	55	3

Code	Benefit sectors	References	Number of times articles mentioned	Ranks
B4	Operation Efficiency	Bandara et al. (2019b); Berglund et al. (2020); Bruno et al. (2009); Labeodan et al. (2015); Pacheco et al. (2012); Pérez-Lombard et al. (2008); R. Zhang & Hong (2017)	41	4
B5	Collaboration	Bandara et al. (2019b); Labeodan, Aduda, et al. (2015); Marinakis et al. (2013); Stoppel & Leite (2014); Wang et al. (2012)	27	5
B6	Global Warming	Berawi et al. (2017); Dubois et al. (2015); Liu et al., (2019); Love & Arthur Bullen (2009); Mosalam et al. (2018)	25	6
B7	Health	Akadiri et al. (2012); Bandara et al. (2019b); Darko & Chan (2017); Kolokotsa et al. (2011); Okoye & Okolie (2014)	13	7
B8	Safety	Bandara et al. (2019b); Minoli et al. (2017); Sovacool & Del Rio (2020); Yuliastri & Amani (2017)	10	8
B9	Flexibility	Akadiri et al. (2012); Bandara et al. (2019a); Marinakis et al. (2013); Sun et al. (2014)	9	9
B10	Value	Bandara et al. (2019a); Darko et al. (2017); Darko & Chan (2017)	3	10

Energy saving management

In recent years energy efficiency has become a topic for national and international policy discussion. Smart buildings improve energy efficiency and maximize energy saving over time through the adoption of IoT integrated with artificial intelligence.

Digital Transformation Monitor (2017) breakdowns the majority of in-build energy use into two main categories, namely lighting energy and HVAC energy.

Figure 5 shows that the use of annual electricity consumption in commercial buildings saves up to 60% of lighting and 5-15% of HVAC thanks to the communication with other equipment and detectors in an automatic way or in a real time. A study conducted by the American Council for an Energy Economy shows a cost saving of 24-32% when applying smart HVAC and smart lighting.

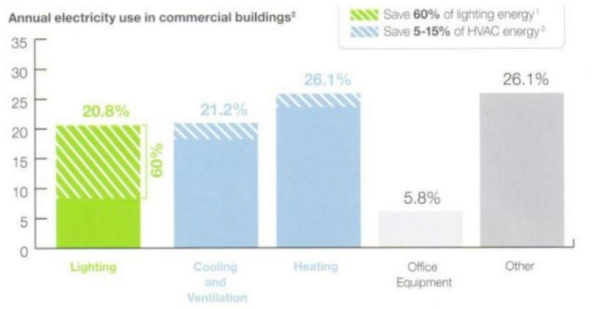

Figure 5. Breakdown of energy use in buildings and expected savings

(Source: Digital Transformation Monitor, 2017)

Cost-saving

Smart buildings could save not only construction costs but also operation and maintenance costs which can reach up to 80% of the life cycles of the building. Smart

buildings reduce the cost by automating and controlling energy used, lowering the costs of fixed appliances, and using modern technology to integrate elements and systems.

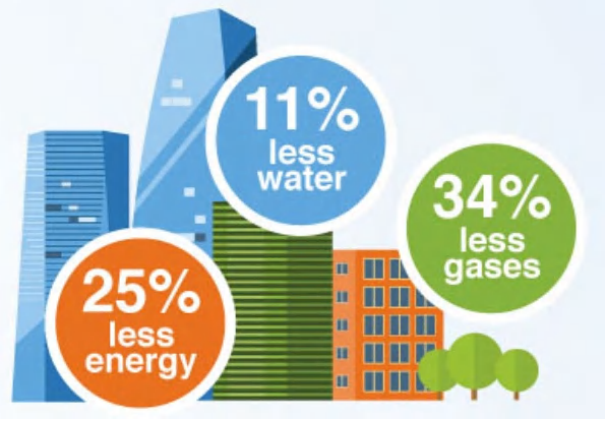

Figure 6. LEED Gold Buildings energy consumption

(Source: Frank Pennisi, Put your buildings to work: smart approaches to better business results)

Technical performance

Smart building technologies can improve the technical performance of buildings through optimizing energy consumption, monitoring indoor air quality, improving security, enabling proactive maintenance, and providing data analytics. These technologies can control HVAC systems, lighting, and other energy-consuming devices based on occupancy and weather conditions, resulting in significant energy savings (Jia et al., 2018). They can also monitor and adjust indoor air quality parameters to improve occupant comfort and health, and enhance building security by detecting intrusions and alerting security personnel. In addition, they can collect and analyze data from various sources to identify areas for improvement and optimize building operations and energy management.

Operation efficiency

Based on Missaoui et al., (2014), smart building uses the collective data to analyze the users' behaviors, then self-develop their system over time as it keeps adapting according to the users to optimize energy usage. This provides information for occupants to save cost on energy and improve the building comfort at the same time. The HVAC systems (including Heating, ventilation, and air conditioning) and lighting (Zhang and Hong., 2017) utilities are the common instruments using Smart Building Technologies to reduce energy waste and increase occupancy comfort, as well as to track assets gains/losses in the building.

Figure 7. Opportunity for impact

(Source: Frank Pennisi, 2016)

Figure 7 shows the report of Frank Pennisi (2016), which revealed that better air quality can improve the productivity of employees by up to 5%. System integration in smart buildings boots sustainability, safety and productivity while also enhancing the quality of life for employees and occupants (Frank Pennisi, 2016).

Global warming

Smart building technologies can mitigate climate change by improving energy efficiency, integrating renewable energy sources, using sustainable materials and design practices, integrating with smart grids, and conserving water (Liu et al., 2019). By optimizing energy consumption, reducing reliance on fossil fuels, and promoting sustainable practices, smart

building technologies can reduce greenhouse gas emissions and improve the environmental impact of buildings.

Health

The health of building occupants and the performance of the building have a strong positive correlation (Kolokotsa et al., 2011, To et al., 2018). Factors that impact their health include cybersecurity, indoor air quality, electromagnetic radiation, maintenance, and user interface. It is necessary to ensure the safety, security, and health of building occupants by addressing these factors in smart building technology design and implementation.

Safety and security

Smart buildings reduce the cost of managing threats associated with natural and man-made catastrophes and make buildings more comfortable. Implementations of safety and security management systems include detection and response to threats, controlling access to the facility, securing lives and assets, security framework and cyber security, and publishing safety and privacy policy. Occupants and tenants require complete safety and security in residential or commercial buildings. In addition, Indrawati et al. (2017) stated that 94% of respondents from the survey agree that safety and security are considered dimensions of a smart building.

Flexibility

Flexibility in building operations and management allows owners and managers to adapt to changing needs. They can be scaled up or down, customized, and accessed remotely (Sun et al., 2015). Interoperability and future-proofing ensure that buildings remain relevant and responsive. Smart building technologies can help owners and managers stay competitive in a rapidly changing market.

Increased property value

Smart building technologies can increase property value by improving building performance, functionality, and sustainability. Energy efficiency, occupant comfort, maintenance and upkeep, sustainability, and resilience are some of the ways in which smart building technologies can achieve this (Darko et al., 2017). Efficient and sustainable buildings are highly valued by potential buyers or tenants and can command premium prices or rents.

VI. CONCLUSION AND RECOMMENDATION

People spend more than 80% of time indoors, no matter how our living and working habits fluctuate. Moreover, sustainable, healthy, and human-centric are in vogue in the post-pandemic world. Smart building technologies enhance the methods used by professionals in the built environment and also entail a shift in the experts' attitudes toward the modern era of technological growth in the construction sector. Furthermore, smart building solutions automate building activities and prioritize flexibility and user-centricity, as it does in many other areas of our lives.

Building tenant experience application is considered one of the recent smart building technology solutions. The app will build a digital bridge between customers, occupants and buildings, bringing connections to the amenities, services and loyalty living in and around the assets. Customers will be able to develop a sense of neighborhood and living loyalty, interact with one another proactively, and take part in the shared goal

of customer-centric sustainability thanks to digital tenant experience solutions. Consumer connectivity, social interactions, accessibility to neighborhood partnerships, rapid access to essential property information, and much more are offered through the application. Also, the tenant experience application could promote climate action alongside our clients, such as through energy-saving advice and monetizing energy use via the app's smart metering feature.

By applying a unique algorithm to the proprietary insight derived from how Unissu users engage with Prop Tech companies to produce weight-adjusted rankings of matching vendors, Trusted Prop Tech Procurement (2022) navigated the market with over 300 vendors identifying as providers of Tenant Experience solutions and provided the top players in the world (Figure 8).

When planning to introduce a tenant experience application in their building, many landlords or managers question whether they should build their own tenant satisfaction solution software, or outsource it. Building an app can be a good option if landlords have the necessary resources and expertise in-house such as strong expertise in app development, security, user experience, and data management. In contrast, it can be a complex and time-consuming process and may not be the best option for others.

Based on a survey conducted by the authors in March 2023, some barriers to Smart Building Technologies Adoption were identified. The authors collected these data by sending a survey to the chosen participants who are working in two big Smart Buildings in Binh Duong province, Vietnam. Out of 138 members who received the survey form, 40 of them responded to the survey, which made the response rate of approximately 29%. 40 participants were categorized in 4 groups based on their responsibility regarding the building they are working for. These groups are: a) Owners (2 participants), b) Tenants / Users (26 participants), c) Architects (5 participants), and d) Contractors and Engineers (7 participants).

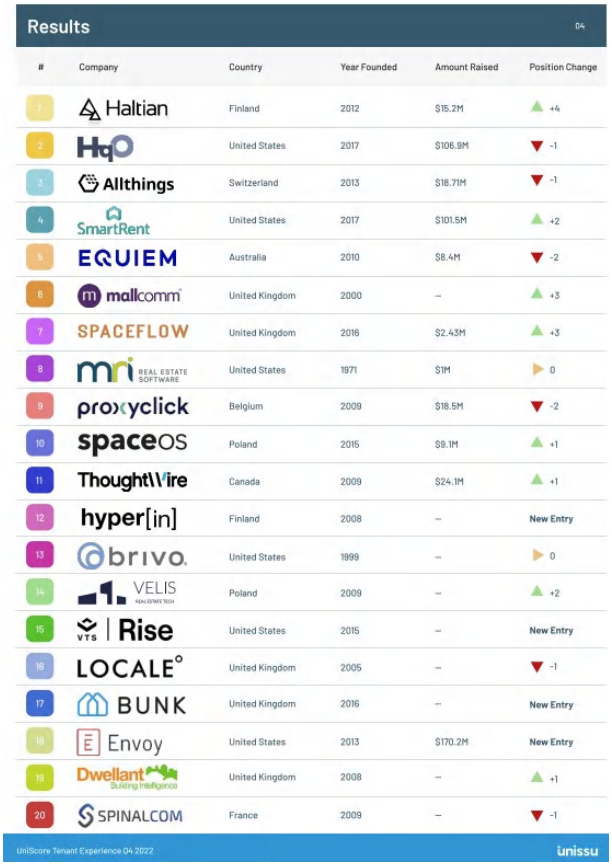

Figure 8. Tenant Experience Market in detail with Data Explorer

(Source: Trusted Prop Tech Procurement, 2022)

Using the 1-5 Likert scale (1 = not a barrier at All and 5 = an extreme barrier), the survey provides the result of Cost as the most serious factor that prevent the adoption of smart building technologies, with the two highest-score-factors are related to the Cost group, which respectively are Installment Expenses

(4.88 – Top 1) and Maintenance Cost (4.62 – Top 2). The other factor that has a score higher than 4 (which is considered a serious barrier) are Lack of Technical Skills (4.2 – Top 3).

In the group of mild influence, one factor that could be considered as significant is the Resistance to change from traditional practices – 3.88, top 4 (from both the owners and the users of the building). Since traditional practices may be outdated and inefficient, leading to wasted time, effort, and resources, the Resistance to change to the new different approach, in the long run, will cause more and more damage to the operation of the building.

To limit the effect of above barriers, one solution related to creating one managing app could be considered as it brings many benefits. It will naturally be a tailor-made solution for owners' demands. The features can vary from basic features to several integrations such as keyless access, parcel management, and facility management. On the other hand, if the building owners or landlords have many assets and require high-end features and eventually digitalize the whole tenant journey, especially if they have long-term digitalization and ESG aspirations such as getting certifications such as WELL or Smartscore for assets, then it is better to work with an experienced tenant experience software provides.

In order to build tenant software, specific needs must be taken into consideration. First of all, it is important to define the tenants and portfolio needs. Needs vary from one asset type to another. In addition to the size and location of the building, considering the cultural differences of tenants is also important when creating neutral, modular, and flexible solutions. Secondly, after identifying tenants and portfolio demands and needs, the next step is to hire an innovation leader who researches the existing solutions from the market in detail. After weighing both possibilities, the innovation leader would choose between developing their own tenant experience software in-house or contracting out to a vendor. If it is decided to develop software internally, a group of skilled product managers, engineers, and UX designers will need to be hired. After that, the team size, technology selection (the server or cloud where the program will operate), and recruiting order will be specified. It will be expensive and time-consuming to maintain the employees. Large firms that have portfolios in many cities and nations should consider this strategy. Building such a large innovation team does not make sense if landlords have a small number of properties.

Outsourcing the software may initially appear to be more expensive on paper, but it will end up being less expensive and have a quicker start-up. Building owners will be working with experts that have expertise in managing the app and a pre-existing solution. Let's take a look at Haltian as an example. Haltian is a global IoT solution provider from Finland and takes the first position on the Uniscore report Q1 2022. Haltian IoT solutions include solutions for smart buildings and digital workplaces, and Thingsee IoI device solutions. Haltian solutions focus on improving employee well-being and happiness which combine technology, culture, and physical space into one. Therefore, everyday tasks of the end-users become easier and simpler. Moreover, it helps employees find the right workplace, share information and voice their concerns as well as provides valuable data in space utilization, air quality, and employee satisfaction.

Last but not least, there are the technology layers that should not go unnoticed while building the tenant experience application. We must take into account human variables, such as user behavior and psychology, when we develop an app for human usage. This will assist in making the app as current and demand-driven as feasible. The software industry is undergoing rapid change. To stay current on user behaviors and needs, you must keep an eye on the overall technology scene as well as the real estate and PropTech sectors as you create the product. The environment we live in and the words we use are shaped by these tendencies. For instance, a well-known app introduced the terms "swipe right" and "swipe left", which denote "accept" and "reject" into common usage. There are innumerable instances and have a capable customer success staff. From user onboarding to ensuring that they receive the expected benefits from the technology, it is an essential component of the business where a single app altered our vocabulary, as we can see. Last but not least, we need to focus heavily on the human element.

Table 2 gives some other suggestions for a tenant experience application for smart buildings. It is important to create a centralized platform that enables tenants to easily interact with various building systems and services. For office solutions, smart building applications can improve safety and health by monitoring lobby traffic and building usage, maintaining air quality, providing flexible workspace reservations, and touchless experiences, keeping tenants informed, and enabling online food and drink booking.

For residential solutions, a smart building tenant application can promote community health and engagement by offering live-streamed yoga and fitness classes, providing regular updates on cleaning schedules, COVID-19 information, and social distancing requirements, and engaging the community through surveys, events, and local vendors. The building can also offer touchless access, online booking, and exclusive promotions to ensure safe and convenient experiences for tenants.

Table 2. Suggestion for tenant experience application for smart building (both office solution and residential solution)

Office solution / Return to work	Residential solution / Remote workforce
• Track and monitor lobby traffic and building usage to control and keep safety • Make the save and healthy working environment through air quality information, the latest cleaning services, the expected number of people in the building everyday... • Offer desk, ad hoc meeting rooms and other reservations for flexible working • Provide touchless experience during entrance, elevator and office doors • Keep tenants informed about updated regulation, social distancing and busy area • Offer online booking for food and café	• Deliver live-streamed yoga, fitness classes such as morning meditation, lunch time workout... to keep community connected and healthy • Update tenants on cleaning schedules, new information about COIV-19, social distance requirement, lobby traffic... to build trust with community • Make surveys, polls and analytics...to track community's attitudes and custom the programs • Engage community via events such as film, book clubs, outdoor activities... • Offer touchless access and online booking • Connect local vendors, exclusive promotions and enable safe and contactless delivery

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APPENDIX

Ngày sử dụng cuối cùng: 22 tháng 7, 2023

Ngày chỉnh sửa cuối cùng: 25 tháng 9, 2023

Bảng câu hỏi khảo sát

(Dành cho người phỏng vấn)

I. Thông tin cá nhân

Họ và tên	
Tuổi	
Giới tính	
Nghề nghiệp	
Công Trình Thông Minh có liên quan đến người được phỏng vấn	1) Toà nhà Hành chính tỉnh Bình Dương 2) Becamex Tower 3) Trường Đại học Việt Đức
Mối tương tác với công trình	1) Chủ sở hữu 2) Người sử dụng 3) Kiến trúc sư, người vận hành, kĩ thuật viên 4) Khách mời
Số điện thoại liên lạc	

II. Nội dung câu hỏi

Xin chào Anh/Chị!

Chúng tôi là nhóm nghiên cứu thuộc trường Đại học Quốc tế Miền đông (EIU). Hiện tại chúng tôi đang thực hiện một cuộc khảo vát về suy nghĩ của người sử dụng về những công trình thông minh trong tỉnh Bình Dương.

Nếu có thể, phiền Anh/Chị vui lòng cung cấp một số thông tin cho cuộc khảo sát này. Chúng tôi cam kết sẽ bảo mật tuyệt đối và mọi thông tin sẽ chỉ được dùng cho mục đích nghiên cứu.

Anh/Chị đã sử dụng qua những thiết bị thông minh nào ở công trình anh chị đang làm việc / học tập?

- Chưa sử dụng
- Đã sử dụng qua thiết bị: …..

(Phần cho người phỏng vấn)

*Nếu **chưa** sử dụng, cám ơn và xin ngừng phỏng vấn*
*Nếu **đã** sử dụng, lưu lại và thông kê vào một trong 3 nhóm*
1) Virtual Reality, 2) Internet of Things, 3) Sensors

Định nghĩa của công trình thông minh:

"Một công trình thông minh là công trình có sử dụng hệ thống máy tính để có thể tự quản lí hoặc một phần quản lí các hoạt động kĩ thuật như điều chỉnh nhiệt độ, cảm ứng bật – tắt các thiết bị đèn – điện, nâng cao bảo an, phòng ngừa cháy nổ, kết nối viễn thông, và các chức năng khác… mà không cần sự giám sát của người điều hành."

Anh/Chị vui lòng đánh dấu (X) vào ô thể hiện đúng nhất quan điểm của Anh/Chị theo những mức độ sau:

Rất không đồng ý	Không đồng ý	Trung lập	Đồng ý	Rất đồng ý
(1)	(2)	(3)	(4)	(5)

Theo Anh/Chị, công trình thông minh này cung cấp những giá trị:

STT	Các tiêu thức	Mức độ đánh giá				
Sử dụng tài nguyên – năng lượng		**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
1	Giảm tổng chi phí vận hành trong vòng đời của công trình					
2	Nâng cao hiệu quả sử dụng năng lượng (điện, nước, khí đốt …) của công trình					
3	Giảm tác động của công trình đến môi trường xung quanh trong quá trình vận hành					
4	Giảm việc sử dụng vật liệu xây dựng (hiệu quả về vật liệu)					
5	Giảm lượng rác thải khi xây dựng và phá vỡ					
Hiệu suất hoạt động		(1)	(2)	(3)	(4)	(5)
6	Tăng cường hiệu suất trong quá trình xây dựng và quản lí					
7	Nâng cao năng suất lao động tổng					
8	Thiết lập tiêu chuẩn cho thiết kế và xây dựng trong tương lai					
9	Thu hút nhân viên chất lượng và giảm tỉ lệ nghỉ việc của nhân viên					
Các giá trị khác		(1)	(2)	(3)	(4)	(5)
10	Cải thiện sức khoẻ của người sử dụng					
11	Tăng cường an ninh của công trình					
12	Tạo sự thoải mái về nhiệt độ trong toà nhà (Nhiệt độ bên trong tốt hơn)					
13	Cải thiện môi trường làm việc					
14	Tạo ấn tượng tốt về công trình xây dựng					
15	Tăng giá trị của công trình xây dựng					

UNVEILING THE INFLUENCE OF SUBJECTIVE NORMS ON FAIR TRADE PURCHASE INTENTION: THE MEDIATING ROLE OF SELF-EFFICACY IN THE VIETNAMESE CONTEXT

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Abstract: This study investigates the impact of fair-trade certification, subjective norms, perceived behavioral control, perceived price, and ethical identity on consumers' fair trade purchase intention in Vietnam, with a particular focus on the mediating role of self-efficacy. Following a comprehensive review of previous empirical studies, the authors conducted a research survey involving a sample size of 200 respondents. The findings of this research indicate that the factors examined in this study have a positive effect on self-efficacy and also exert indirect effects on fair trade product purchase intention. Notably, subjective norms emerge as the strongest driving factor influencing consumers' intention to purchase fair trade products. The insights derived from this study offer valuable implications for marketers and firms seeking to foster business development with a corporate social responsibility (CSR) focus.

Keywords: *Fair-trade product, Self-efficacy, Fair-trade certification*

I. INTRODUCTION

In today's society, consumers are increasingly concerned about the social and moral aspects of the products they purchase (Andorfer and Liebe, 2015). As a result, ethical forms of commerce, such as fair trade, have emerged within the global economy and have gained significant popularity in recent years (Bezencon and Blili, 2010). Fair trade is a market approach aimed at improving the livelihoods of small producers in developing countries (Randall, 2005). Since the late 1990s, Vietnam has become the world's second-largest coffee producer (Arnot and Cash, 2006). However, Vietnamese coffee farmers still face significant vulnerability to global market demands, which often require them to sell their products at lower prices. Within Vietnam, fair trade products, specifically coffee, remain highly vulnerable due to a lack of interest among domestic consumers. There is a limited understanding of the factors that influence customer responses to fair trade items, particularly among Vietnamese consumers. It is crucial to encourage domestic consumers to purchase fair trade products as they help establish direct connections between buyers and producers. These collaborations provide consumers with a sustainable option that enhances the livelihoods of farmers, craftspeople, and their families.

According to Bandura (1986), self-efficacy is the belief that one has control over their own motivation, attitude, and social context. It is a driving force behind learning and taking action

to complete tasks (Bandura, 1982). Self-efficacy is also associated with ethical decision-making behaviors, attitudes, and choices. Previous studies have demonstrated a connection between self-efficacy and prosocial actions (Alessandri et al., 2009). Additionally, Song and Kim (2018) found that self-efficacy predicts customers' socially responsible purchasing and disposal behaviors. Consumers with high levels of perceived efficacy tend to prefer fair trade products over those with lower levels of perceived efficacy (Vermeir and Verbeke, 2006). At the manufacturing level, certification provides consumers with information about the environmental and economic advantages associated with certified products (Milder et al., 2015). Consumers often evaluate details about the certifier and certification information to gain insights into the company's motivations. Therefore, fair trade certifications can influence consumers' perceived efficacy in purchasing fair trade products. According to Van Birgelen, Semeijn, and Keicher (2009), customers' sentiments towards ethical purchasing and the influence of friends or family members greatly influence the decision to purchase fair trade products. Self-efficacy serves as a personal reassuring factor that guides individuals to engage or avoid specific behaviors. Thus, the recommendations from friends and family members can enhance consumers' perceived efficacy in purchasing fair trade products, particularly in highly collectivist countries like Vietnam. Previous studies have identified significantly higher prices as one of the primary factors that discourage consumers from purchasing eco-friendly and fair-trade products (Fotopoulos and Krystallis, 2002). As Vietnam is a developing country, fair trade products generally have higher costs due to fair pay, improved working conditions, and environmental protection expenses. However, research has shown that price may not deter buyers from purchasing goods if they strongly believe in the product attributes, including fair trade products (Ma, Littrell, and Niehm, 2012). They make fair trade purchases because they believe their buying behavior can make a positive impact on others, viewing themselves as ethical consumers. Ethical self-identity is also associated with a tendency to purchase fair trade products (Ozcaglar-Toulouse, Shiu, and Shaw, 2006). Perceived behavioral control refers to an individual's belief in their ability to engage in a specific behavior (Ajzen, 1991). When consumers have confidence in their self-efficacy regarding ethical consumption, they feel more optimistic about their ability to purchase fair trade products (Ma et al., 2012).

H1: *Fair trade-certification (FC) has a positive impact on self-efficacy (SE).*

H2: *Subjective norms (SN) have a positive impact on SE.*

H3: *Perceived behavioral control (PC) has a positive impact on SE.*

H4: *Perceived price (PP) has a positive impact on SE.*

H5: *Ethical identity (EI) has a positive impact on SE.*

H6: *SE has a positive impact on fair trade purchase intention (PI).*

H7: *The relationship between FC and PI is mediated by SE.*

H8: *The relationship between SN and PI is mediated by SE.*

H9: *The relationship between PC and PI is mediated by SE.*

H10: *The relationship between PP and PI is mediated by SE.*

H11: *The relationship between EI and PI is mediated by SE.*

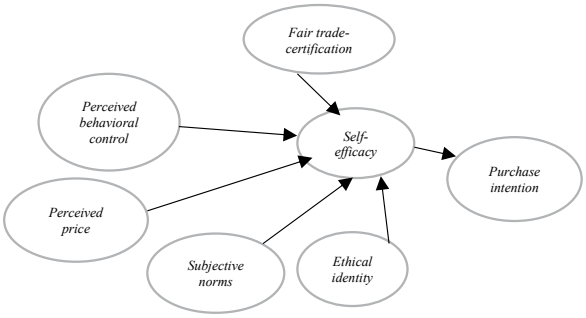

Figure 1. Conceptual framework

II. METHODOLOGY

A survey was conducted online with 200 respondents to test the hypotheses mentioned above. The gender distribution among the respondents was as follows: 62.5% identified as female, 37% identified as male, and the remaining 0.5% identified as other. The measurement of FC (α=0.837) was adapted from Konuk (2019), while the measurements of PC (α=0.708), EI (α=0.777), SN (α=0.806), and PI (α=0.810) were adapted from Beldad and Hegner (2018). Additionally, the measurement of PP (α=0.837) was adapted from Castaldo et al. (2009), and SE (α=0.710) was adapted from Ashraf, Joarder, and Ratan (2018). The results indicated that all the measurements demonstrated satisfactory reliability and discriminant validity, supporting their suitability for further analysis.

III. RESULTS

The results revealed a significant relationship between subjective norms (SN) and purchase intention (PI) with a coefficient of $\beta = 0.397$, $p < 0.001$. However, the relationships between fair trade-certification (FC), perceived behavioral control (PC), perceived price (PP), and ethical identity (EI) on purchase intention (PI) were found to be insignificant. On the other hand, a significant relationship was observed between FC, SN, PC, PP, EI, and self-efficacy (SE) ($\beta FC = 0.264$, $p < 0.001$; $\beta SN = 0.397$, $p < 0.001$; $\beta PC = 0.234$, $p < 0.001$; $\beta PP = 0.257$, $p < 0.001$; $\beta EI = 0.274$, $p < 0.001$). Furthermore, there was a significant indirect effect of FC, SN, PC, PP, and EI on PI through SE. As a result, all hypotheses were supported. Refer to Table 1 for a detailed presentation of the results.

Table 1. The indirect effect of fair trade-certification, subjective norms, perceived behavioral control, perceived price, ethical identity on purchase intention through self-efficacy

	Effect	LLCI	ULCI
FC->SE->PI	0.104	.0368	.1918
SN->SE->PI	0.108	.0218	.1939
PC->SE->PI	0.082	.0198	.1821
PP->SE->PI	0.087	.0290	.1615
EI->SE->PI	0.091	.0295	.1715

The findings of this study highlight the significant role of self-efficacy as a crucial factor in mediating the relationship between fair trade-certification, subjective norms, perceived behavioral control, perceived price, ethical identity, and fair trade purchase intention. Particularly, subjective norms emerge as the strongest predictor influencing consumers' intention to purchase fair trade products through self-efficacy. Subjective norms have a positive and significant impact on fair trade purchase intention ($\beta = 0.397$, $p < 0.001$), and this relationship is mediated by self-efficacy (indirect effect = 0.108, LLCI = 0.021, ULCI = 0.193). The pressure and influence of others, especially close relatives such as family, friends, and highly valued individuals, play a significant role in shaping the intention to purchase fair trade-certified products.

On the other hand, the relationships between fair trade certification, perceived

behavioral control, perceived price, ethical identity, and purchase intention were found to be insignificant ($p = 0.5202$, 0.8336, 0.2190, 0.1518, respectively). However, these factors still exerted an indirect effect on fair trade purchase intention through self-efficacy. These findings highlight the importance of these factors in attracting customers who are concerned about ethical issues and promoting fair trade consumption.

IV. CONCLUSION

Self-efficacy acts as a crucial mediator in the relationship between various factors and fair-trade purchase intention. The study emphasizes the strong direct impact of subjective norms on fair trade purchase intention, as they encourage consumers to choose ethical products in the domestic market while supporting farmers in challenging conditions. The implications of this research can be valuable for marketers and sustainable manufacturers in developing strategies that promote ethical purchasing behavior.

Targeted Marketing Strategies: The findings suggest that subjective norms have a significant influence on consumers' fair trade purchase intention. Marketers can leverage this insight by developing targeted marketing campaigns that highlight the positive social influence of purchasing fair trade products. By emphasizing the support and approval of family, friends, and influential individuals, marketers can create a sense of social responsibility and encourage consumers to choose ethical options.

Building Brand Reputation: The study highlights the importance of ethical identity and perceived behavioral control in influencing fair trade purchase intention, although their direct effects were found to be insignificant. Marketers can focus on building a strong brand reputation that aligns with ethical values and empowers consumers to make conscious choices. By emphasizing the brand's commitment to fair trade practices, sustainability, and responsible sourcing, marketers can attract customers who prioritize ethical consumption.

Enhancing Self-Efficacy: Self-efficacy was found to be a crucial mediator in the relationship between various factors and fair-trade purchase intention. Marketers can play a role in enhancing consumers' self-efficacy by providing information, education, and support regarding fair trade practices and their positive impact on local communities and the environment. By empowering consumers with knowledge and confidence, marketers can facilitate their decision-making process and encourage them to choose fair trade products.

Collaboration with Certifications: The study suggests that fair trade certification may indirectly influence fair trade purchase intention through self-efficacy. Marketers can collaborate with fair trade certification organizations to communicate the environmental and economic advantages associated with their certified products. By educating consumers about the certification process and its significance, marketers can build trust and credibility, thereby enhancing consumers' perceived self-efficacy and intention to purchase fair trade products.

Market Development in High Collectivism Countries: The influence of subjective norms was found to be particularly significant in high collectivism countries like Vietnam. Marketers can capitalize on this by incorporating social influence elements in their marketing

strategies, such as testimonials, social proof, and community endorsements. By showcasing the positive experiences and support of influential individuals and groups, marketers can leverage the collective mindset and encourage fair trade consumption. Overall, the study's findings provide marketers with valuable insights into the factors that influence fair trade purchase intention. By incorporating these insights into their marketing strategies, marketers can effectively target and engage ethically conscious consumers, build brand reputation, enhance self-efficacy, and contribute to the growth of fair-trade consumption.

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PART II.

ENGINEERING SYMPOSIUM

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DEEP NEURAL NETWORK FOR FUNCTIONAL MRI DATA ANALYSIS[*]

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Abstract: Functional network analysis is an essential task in functional Magnetic Resonance Imaging (fMRI) applications. The Independent Component Analysis (ICA) is the conventional data-driven approach for detecting brain functioning networks. The ICA approach has its foundation on the assumption that decoupled components remain statistically independent. However, such a mathematical assumption lacks a physiological explanation. The success of deep learning in medical applications has motivated researchers to apply it in brain functional network identification. In this paper, we investigate an analysis method based on deep neural networks for dictionary learning combined with Orthogonal Matching Pursuit (DNN-OMP) and evaluate the performance of the proposed method compared with ICA in fMRI brain functional network decomposition. Methods: Using the DNN-OMP algorithm, acquired fMRI signals in matrix form are decomposed into components that have sparse signal overlap. Results: It is shown that DNN-OMP is able to decompose and demonstrate the expected brain functional networks from the input fMRI signals. Conclusion: DNN-OMP preserves network spatial structures similar to those of ICA. Additionally, it demonstrates the spatial localization effect due to the spatial constraint exploited by the method. Spatial maps of the DNN-OMP model indicate that deep learning-based models are potential approaches for brain functional network analysis.

Keywords: *machine learning, deep learning, fully-connected layer, dictionary learning, orthogonal matching pursuit, fMRI functional networks.*

I. INTRODUCTION

A prevalent non-invasive radiological method for investigating human anatomy and function is Magnetic Resonance Imaging (MRI). fMRI supports the comprehension of brain activities through analysis of metabolic fluctuations associated with neuronal processes, which are based on the influences of a magnetic field on oxygenated and deoxygenated hemoglobin within the human brain (Jung et al., 2001). Resting-state fMRI identifies functional networks without performing any explicit activity by analyzing the synchronization of spontaneous blood oxygenation level-dependent (BOLD) signal oscillation between brain regions (Greicius et al., 2002). Brain functional networks are collections of interconnected brain areas that are active during cognitive or behavioral activities, such as paying attention, speaking,

[*] Best oral presentation award - Lecturer session

or controlling emotions. The breakdown of these networks can offer important insights into the neural circuits that underlie diverse brain functions and how they are affected by various neurological and psychiatric illnesses. For instance, fMRI has been used in the field of neurology to pinpoint the precise brain regions in charge of various types of motor and cognitive dysfunction, such as Alzheimer's and Parkinson disease, and multiple sclerosis. In order to analyze fMRI data and conduct blind decomposition of the mixed response, model-driven or data-driven techniques are used to discover the signal sources that reflect the neural activity.

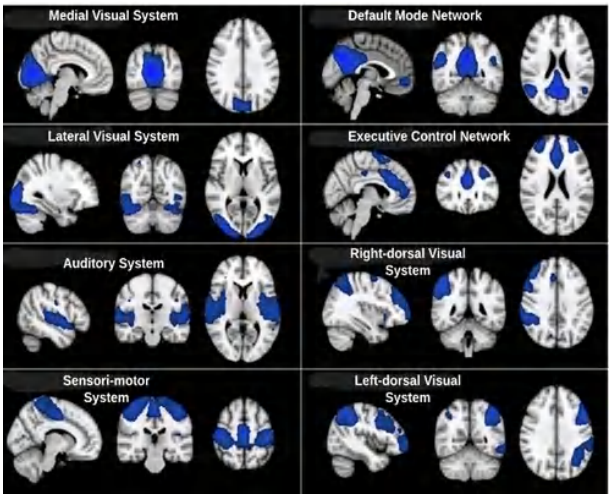

Figure 1. Functional networks in the human brain associated with fMRI (Adriaanse et al., 2014)

A data-driven method looks for patterns in data without any assumptions or models (Stroman, 2016). The ICA approach was designed to address the problem of Blind Source Separation (BSS) and is widely employed as an instrument for identifying functional networks (Mckeown et al., 1998). ICA relies on two critical assumptions: the sources being considered are statistically independent and the independent components have non-Gaussian distribution (Naik & Kumar, 2011). Another recent approach for functional network decomposition is the MCA-KSVD method (Nguyen et al., 2022), which employs sparse signal overlap among functional networks – a physically more plausible constraint than that of ICA.

The recent success of emerging state-of-the-art machine learning in medical applications such as liver segmentation (Bogoi & Udrea, 2022) and anomaly classification and prediction (Samudra et al., 2023) has motivated many researchers to apply it to the field of fMRI. The majority of studies on machine learning for resting-state fMRI are focused on unsupervised learning methodologies, an ideal technique for discovering patterns, groupings, and differences in unstructured fMRI data. In (Zhao et al., 2020), a spatial-temporal Convolutional Neural Network (ST-CNN) was proposed to learn the spatial and temporal patterns of targeted networks. However, the study followed a supervised dictionary learning framework, which relies on accurate data labeling. Meanwhile, a different technique was examined in (Li et al., 2021), where a Deep Sparse Recurrent Autoencoder was leveraged to study the spatial patterns and temporal fluctuations of brain networks at the same time. The paper focused on decomposing general active neural regions, while the quantitative accuracy of the estimated major functional networks such as Visual 1, Visual 2, Sensorimotor, and Auditory networks remain unknown. An unsupervised deep learning method, utilizing a deep Encoder-Decoder network in CNN, was used to identify large-scale functional networks (Li et al., 2020). This paper did not contrast the effect of the sparsity constraint versus the statistical independence assumption on the decomposed spatial maps.

Using acquired task-based and resting-state fMRI data, this paper proposes the DNN-OMP deep learning-based approach for identifying functional brain networks. As an alternative to ICA, this method uses a deep neural network for dictionary learning combined with the sparse-coding method, Orthogonal Matching Pursuit. We study the impact of how the neural network learns a dense basis combined with the sparsity constraints of OMP on finding a sparse representation of the data versus the independence assumptions on the quality of the spatial map of brain functional networks. Specifically, this method approximates spatial-temporal elements by deconstructing acquired fMRI data into functional network components that consist of an overlap of sparse signals (Nguyen et al., 2022). The spatial maps of brain networks such as visual, sensorimotor, default mode network executive control network, and auditory indicate that the number of concurrently active functional brain networks may be expected to be sparse across voxels. Sparse spatial overlap between network elements is a more practical assumption than the statistical independence condition of the ICA method.

We describe in-depth and thoroughly evaluate the DNN-OMP approach under a noiseless experimental condition. An appropriate parameter of sparsity and the quantity of decomposed components are further suggested. The sparsity criterion of our suggested approach is less stringent than that of ICA since the components are no longer required to be statistically independent.

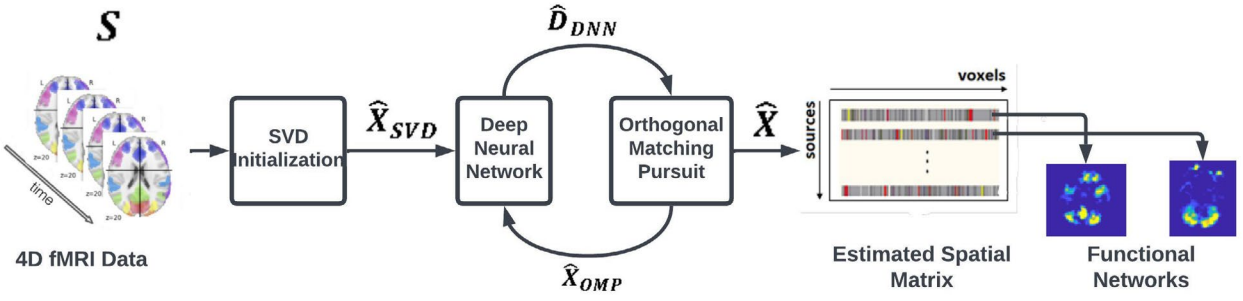

Figure 2. Schematic diagram of the proposed deep neural network for functional brain network decomposition

II. METHODOLOGY

A. Proposed DNN-OMP method

Assuming that the acquired fMRI data is demonstrated mathematically as a spatial-temporal function $s(r_n, t_m)_{n=1,m=1}^{N,M}$, discovering patterns of connectivity between brain networks is the main objective of conventional data-informed approaches through deconstructing the observed $N \times M$ data matrix, which contains noise, from $s(r,t)$ as

$$\boldsymbol{S} = \boldsymbol{S}_0 + \boldsymbol{E},$$
$$\boldsymbol{S}_0 = \boldsymbol{DX}, \quad (1)$$

where $\boldsymbol{S}_0$ is the noiseless data matrix, $\boldsymbol{D}$ is the mixing matrix (dictionary) with the k-th column $\boldsymbol{d}_k$ considered to be the temporal series (also known as *atoms*) of the k-th decomposed

spatial component; the k-th row $x^{(k)}$ of the matrix $\boldsymbol{X}$ is the spatial component of the k-th deconstructed functional component; $\boldsymbol{E}$ is the noise matrix. We also made an assumption that the fMRI data can be approximated sparsely over the dictionary $\boldsymbol{D}$, which means a linear combination of a number of $\boldsymbol{d_k}$, which is approximate to $\boldsymbol{S}$, can be found. To solve the BSS problem in (1), the following cost function is proposed in (Nguyen et al., 2022):

$$\widehat{\boldsymbol{D}}, \widehat{\boldsymbol{X}} = arg\ min_{D,X} \left|\left|\boldsymbol{S} - \boldsymbol{D}\boldsymbol{X}\right|\right|_F^2$$
$$\text{subject to} \quad \left|\left|\boldsymbol{x_i}\right|\right|_0 \leq L. \qquad (2)$$

The sparsity constraint in (2) means that no more than L components are active at the same time at each spatial voxel. Research results show that a functional neural response is sparse (Lee et al., 2011) corroborating this assumption. Inspired by the sparsity constraint and its physiological meaning and recent fruitful results of deep learning applications in fMRI data analysis, we propose utilizing multiple dense (fully connected) layers of neurons to learn the temporal matrix $\boldsymbol{D}$ combined with the greedy OMP algorithm to estimate the spatial matrix $\boldsymbol{X}$. The schematic diagram of our method is shown in Figure. 2.

A dense layer solves the problem of shallow dictionary learning by minimizing the following cost function:

$$arg\ min_{\boldsymbol{W}} \left|\left|\boldsymbol{Y} - \widehat{\boldsymbol{Y}}\right|\right|_2^2$$
$$\widehat{\boldsymbol{Y}} = \boldsymbol{W}^T\boldsymbol{X}, \qquad (3)$$

with $\boldsymbol{X}$ being the input data; $\boldsymbol{W}$ is the weight matrix of that layer or also known as the dictionary; $\boldsymbol{Y}$ is the referenced output data. Stacking multiple fully-connected layers to perform deep dictionary learning transforms (3) into a multi-linear problem where we have $\widehat{\boldsymbol{Y}} = \boldsymbol{W}_n^T \ldots \boldsymbol{W}_2^T \boldsymbol{W}_1^T \boldsymbol{X}$, with n being the number of layers of the neural network.

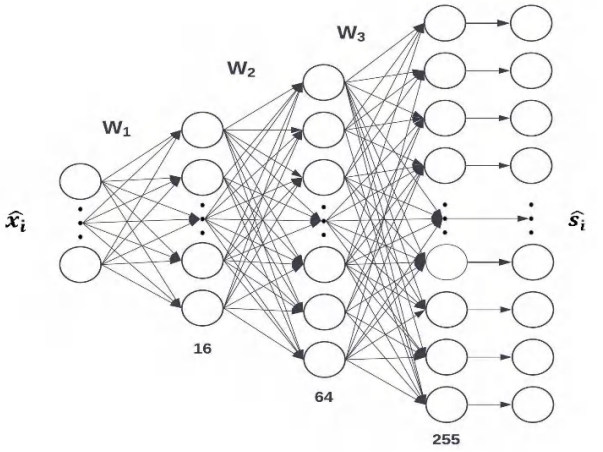

Figure 3. Fully-connected layers architecture of the deep neural network where $\widehat{x}_i$ is the spatial initial guess and $\widehat{s}_i$ is the predicted data

OMP is a popular iterative and greedy algorithm used to recover sparse signal representation from linear measurement data. It has gained significant attention due to its simplicity and effectiveness. The goal of the algorithm is to find the sparsest representation of the measured data by optimizing the following equation:

$$\min_{\boldsymbol{x_i}} \left|\left|\boldsymbol{s_i} - \boldsymbol{D}\boldsymbol{x_i}\right|\right|^2 \text{subject to } \left|\left|\boldsymbol{x_i}\right|\right| \leq L, \qquad (3)$$

where L is the sparsity coefficient and $\boldsymbol{D}$ is the mixing matrix (dictionary).

B. Algorithm

Consider the fMRI data $s(r,t)$, expressed in the matrix form, the iterative and greedy DNN-OMP method performs the spatial-temporal estimation as follows:

1) *Proposed Initialization:* Select the number of decomposed components K and the

sparsity parameter L. Pre-whiten fMRI data using the eigenvalue decomposition of the data covariance matrix $\boldsymbol{SS}^T$. Initialize the spatial matrix $\widehat{\boldsymbol{X}}_{\boldsymbol{SVD}}$ via the SVD method and select the K first columns of the right most singular matrix.

2) *Repeat until convergence:*

- *Dictionary update:* Provided with the estimated $\widehat{\boldsymbol{X}}$, update every weight matrix $\boldsymbol{W}_n^T$. The number of batch size and iterations is predefined. In each iteration of the DNN, every column $\boldsymbol{x}_i$ of the spatial map is passed through three consecutive fully-connected layers to reconstruct the estimated measured data as shown in Figure. 3. The final estimated dictionary is $\widehat{\boldsymbol{D}}_{\boldsymbol{DNN}} = \boldsymbol{W}_n^T \ldots \boldsymbol{W}_2^T \boldsymbol{W}_1^T$.
- *Sparse Coding*: Provided with the fixed approximation of the temporal matrix $\widehat{\boldsymbol{D}}_{\boldsymbol{DNN}}$, OMP computes a new matrix $\widehat{\boldsymbol{X}}_{\boldsymbol{OMP}}$.

The dictionary update and sparse coding stages of DNN-OMP are alternated until convergence. The estimated temporal $\widehat{\boldsymbol{D}}$ and spatial $\widehat{\boldsymbol{X}}$ matrices are then extracted.

III. RESULTS

A. Experimental data

Human participants supplied written, informed permission authorized by the Stanford Institutional Review Board were used to collect the experimental fMRI data. Spiral-in/out pulse sequence gradient echo that is similar to (Glover & Law, 2001) was used for $T_2^* - \text{weighted}$ functional imaging (TR = 2s, TE = 30ms, flip angle = 77°, spatial encoding matrix of size 64 × 64, FOV = 22cm, 31 slices, 4 mm slice thickness with no between-slice gaps, 255 time frames, 8 coils). Following a pseudo-random M-sequence paradigm, the individual was stimulated with random auditory tunes with stimulus timing patterns (Buračas & Boynton, 2002). Spatial ICA was executed by applying the GIFT (Group ICA of fMRI Toolbox) on MATLAB (Group ICA of fMRI Toolbox (GIFT) - TReNDS, 2020) with K = 20. The DNN-OMP method was applied on Google Colaboratory (Google, 2022) using Google GPU T4 and Keras API (Chollet, 2015) from TensorFlow (Google, 2015). As shown in Figure. 3, the deep neural network consists of a total of three consecutively dense layers with the number of neurons in each layer being 16, 64, and 255 respectively. The first and each remaining deep dictionary learning stages executed 2,500 and 100 iterations respectively. The DNN-OMP executed 100 iterations as a whole in this experiment. Other parameters used to implement the method are the sparsity constraint L = 2 and the batch-size = 1. The learning rate $\alpha = 5 \times 10^{-4}$ remained constant throughout the method execution.

B. Results and discussion

We evaluated both ICA and DNN-OMP methods on the original fMRI data, as shown in Figure. 4. Both returned similar four functional networks such as Default Mode Network, Visual 1, Visual 2, and Auditory. The DNN-OMP method has better signal localization, by eliminating the surrounding noise and weak spatial signals, which are preserved in the ICA components. The DNN-OMP remarkably suppressed spatial background noise compared to the ICA method. This can also be demonstrated by the Signal-to-Noise Ratio (SNR) value of each spatial component of the two methods compared

with the ground truth in Table 1. In this paper, the SNR is calculated as:

$$\mathrm{SNR}(\hat{x}) = 10log_{10}\frac{||x-\hat{x}||_2}{||x||_2}. \quad (4)$$

As observed from experimental results, the DNN-OMP and ICA algorithms reconstructed the spatial distribution map of the fMRI networks.

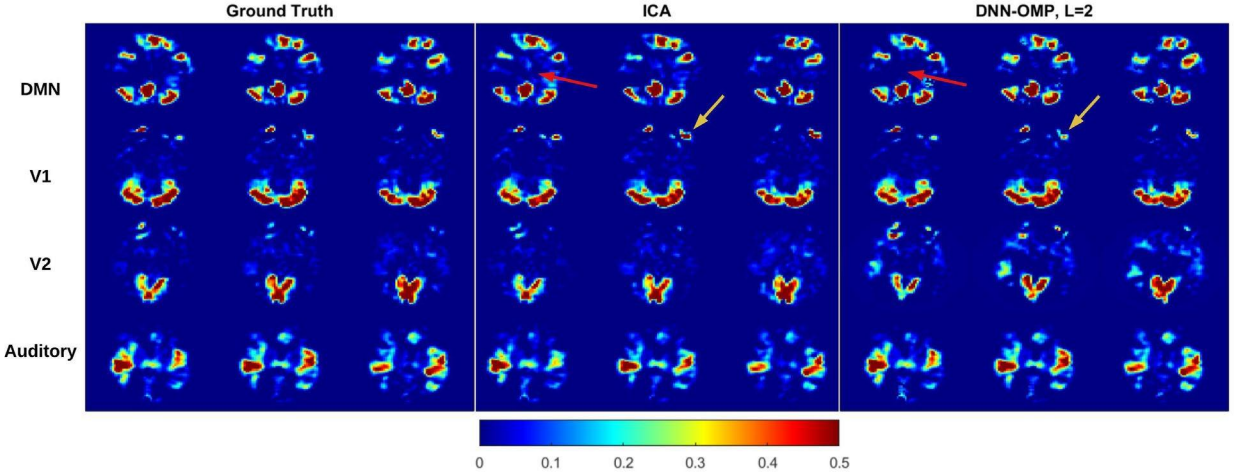

Figure 4. Normalized spatial maps of four decomposed brain functional networks using the ICA and DNN-OMP methods in a task-related fMRI experiment

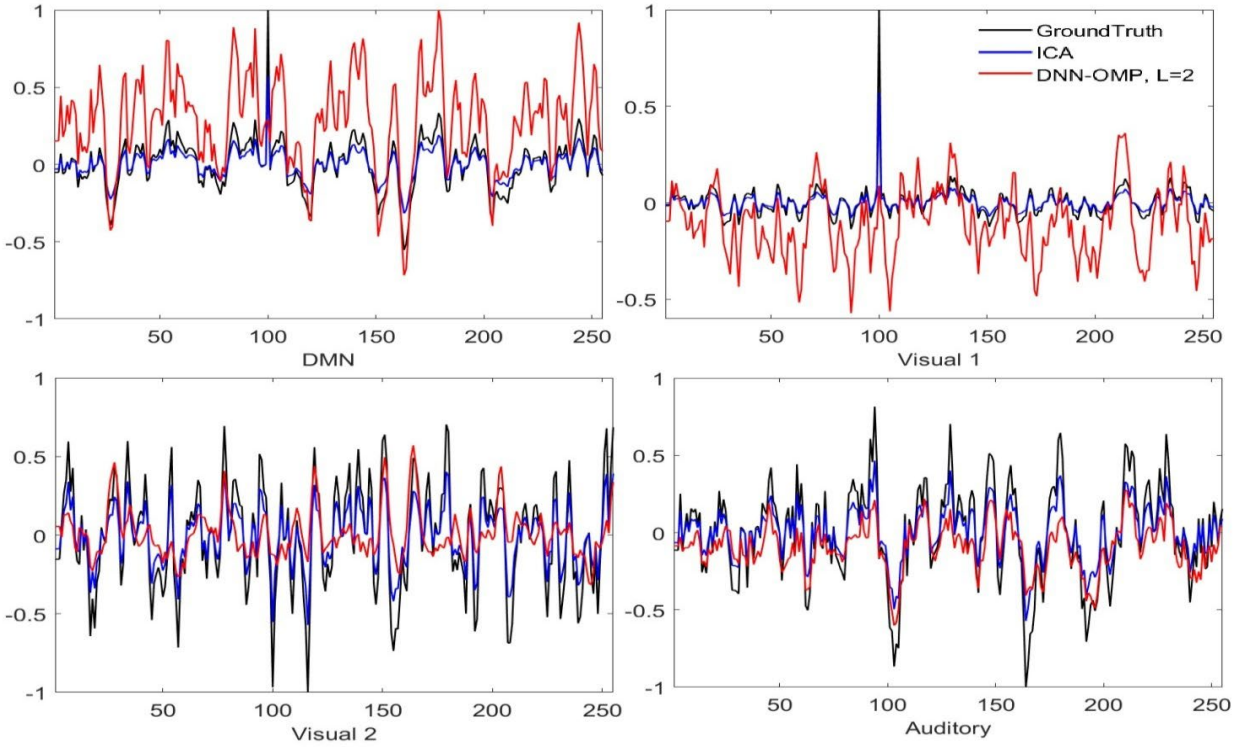

Figure 5. Temporal components reconstructed by ICA and DNN-OMP methods

Table 1. SNR values of estimated spatial networks reconstructed from ICA and DNN-OMP

SNR (dB)	Decomposition Method	
Functional Network	**ICA**	**DNN-OMP**
DMN	7.94	12.28
V1	9.92	12.10
Auditory	9.04	16.63

Experimental results show that networks decomposed by the DNN-OMP method have persistent spatial connectivity characteristics that resemble those of the ICA. Figure. 4 Shows the case of the moving eyes, where DNN-OMP successfully eliminated the false signals as indicated by yellow arrows. Also, we can also observe clearly that the DNN-OMP components have much fewer residual signals in the background (sparser) compared to those of ICA (see Figure. 4 as indicated by red arrows), showing a higher contrast than the ICA components. This is due to the sparsity constraint enforced by the OMP algorithm, which assists DNN-OMP in signal localization. The Temporal series of the third and fourth components (Visual 2 and Auditory networks) closely resembled the ground truth. In addition, we observed that the first two temporal series (DMN and Visual 1) of DNN-OMP are amplified, showing significantly stronger signals compared to those of ICA and ground truth.

IV. CONCLUSION

In this paper, we proposed an unsupervised learning method to decompose functional brain networks based on measured task-related BOLD fMRI data. The method employs fully-connected layers of neurons for deep dictionary learning combined with a pursuit algorithm for sparse representation solutions. The model is compared with the traditional data-driven ICA method. Experimental results show that the proposed method preserved spatial characteristics of the functional networks similar to those of ICA. This proves that deep learning models can potentially be advantageous in providing accurate images of decomposed spatial functional networks and competing with conventional fMRI analysis methods. The stringent mathematical independence assumption of the identified elements of the ICA method was replaced by the sparsity constraint, which was embedded in the DNN-OMP algorithm, enabling a sparse number of brain networks to be active at any given voxel. The DNN-OMP approach demonstrates its advantages in signal localization by suppressing spatial weak signals while enhancing strong activations.

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SEMANTIC SEGMENTATION WITH A U-SHAPE-LIKE MODEL[*]

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Abstract: The implementation of an encoder-decoder architecture network for the segmentation of images has become a popular training paradigm. These models basically extract the features and then create a pixel-accurate segmentation map. In this paper, we use ResNet-18 which is pre-trained with the ImageNet as the encoder of the network. In order to prevent the loss of image information after the MaxPool layers in the encoder, we add some residual blocks directly connected to the up-sampling blocks in the decoder section. This proposed model was trained on the LINEMOD dataset which is a part of our future work on 6D pose estimation of objects and received some optimistic results. The outcomes will be discussed and illustrated meticulously in the paper.

Keywords: *segmentation, sematic segmentation, encoder-decoder, u-shape model*

I. INTRODUCTION

Image segmentation is a fundamental task in computer vision which involves the task of separating the images into multiple segments or regions based on the underlying pattern and structures of the object present in the images. Segmentation plays vital roles in many applications, including medical image analysis (Ronneberger et al., 2015), autonomous vehicles (e.g., pedestrian detection, vehicle navigation), and video surveillance.

There are numerous algorithms were developed to implement in segmentation fields from earliest methods such as thresholding (Otsu, 1979), histogram-based bundling, and region growing (Nock & Nielsen, 2004) … to more advanced methods such as active contour (Butenuth & Heipke, 2012), sparsity-based method (Starck et al., 2005), (Minaee & Wang, 2019). In recent years, Deep learning (DL) models have shown remarkable performances over the former method – by achieving a high accuracy rate on the popular benchmarks. This is the reason why there is a shift in the discipline of object segmentation.

In the implementation of deep learning–based, there are many methods that have been successfully applied. For example, (Girshick, 2015) and (Ren et al., 2017) proposed a fully convolutional-based model which are stacking multiple layers like convolutional layers, pooling layers, and nonlinear layers together as a multiresolution pyramid. Moreover, some of the authors utilized the idea of the regional convolution network (R-CNN) and its extensions (Fast R-CNN, Faster R-CNN, Masked – RCNN) have proven effective in object detection and segmentation applications. (He et al., 2017) proposed a Mask R-CNN model which is efficient for simultaneously generating

[*] Best oral presentation award – Student session

the instance segmentation map and drawing the bounding boxes around the objects. An encoder-decoder architecture forms another widely adopted family of deep model for image segmentation. A model consists of two parts, an encoder using convolutional layers for extracting the features of the objects in the images and a decoder including deconvolution layers such as up-sampling layers, transpose layers for re-constructing the images and generating the predicted segmentation maps. U-net (Ronneberger et al., 2015), LinkNet (Chaurasia & Culurciello, 2017), V-Net (Milletari et al., 2016) and V-Net (Milletari et al., 2016) are well-known models of such architecture.

In this paper, inspired by the encoder–decoder architecture, we have built a model that utilizes ResNet-18 (He et al., 2015) with pre-trained on ImageNet as the backbone. Then, we apply up-sampling layers, and residual connections to recover the original image while keeping the spatial information. Although, the many datasets such that the PASCAL context (Mottaghi et al., 2014), and PASCAL Visual Object Classes (VOC) (Everingham et al., 2010) which is mainly built for object segmentation training and testing. We choose LineMod Dataset (Hinterstoisser et al., 2012) due to the extension of the project in the future for 6D pose estimation.

II. METHOD

A. Architecture

Our model architecture is described in Figure 1. The model consists of an extracting features path (on the left side) and a decoder path (on the right side). Each up-sampling layer of the decoder has skip connects to directly take the context and spatial information from the residual block.

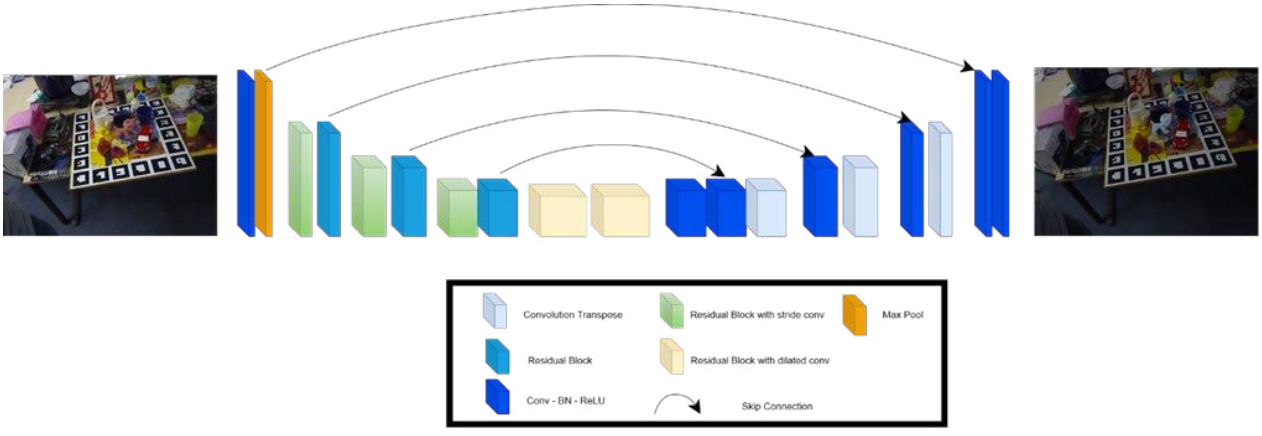

Figure 1. Model architecture for semantic segmentation

The encoder is taken from the architecture of ResNet–18 (Zheng et al., 2020). First, this model contains a convolutional layer, followed by batch normalization and a rectified linear unit (ReLU), and a 2x2 max pool layer for downsampling. After that, it consists of multiple residual blocks where each block consists of repeated applications of two 3x3 convolutions. At each block, the number of feature channels is doubled. At the end of the contracting path, we remove the 7x7 average pooling layer and fully connected layer.

Every step in the expansive path consists of convolutions with a stride of 1, followed by the bath normalization and leaky rectifier linear unit (LeakyReLU), then concatenating the skip connection taken from the respective residual block (residual block with the same output features channels). After the addition of the skip connection, we use convolution transpose to up-sample the block with a scale factor of 2. The concatenation of residual blocks with the corresponding convolution layer is vital to preserve the spatial information from the images after the multiple downsampling layers with a stride of 2.

B. Metrics

The Intersection over Union (IoU) or Jaccard Index stands out as a widely employed metric in semantic segmentation. Its definition involves calculating the intersection area between the predicted segmentation map (B) and the ground truth (A), divided by the union area of the two maps, Mathematically, IoU presented as:

$$IoU = J(A, B) = \frac{|A \cap B|}{|A \cup B|}$$

where A and B represent the ground truth and predicted segmentation maps, respectively. The resulting IoU value falls within the range of 0 to 1.

C. Dataset

LineMod Dataset has over 1200 images for each instance. However, this dataset was primarily built for evaluating the performance of the model in 6D pose estimation. Therefore, if we train our model in this dataset, we do not have enough images for the validation dataset.

To prevent overfitting, because of the lack of dataset. We separate LineMod Dataset with a ratio of one-fourth for the validation dataset, and three fourth for training. Then, we add 5000 synthetic images of the object, which has 4000 images rendered on the COCO dataset, and another 1000 images are taken from the train LineMod dataset (rendered images of objects in different rotations). Finally, we combine over 200 images and 800 images from the Occlusion LineMod Dataset (Mercier et al., 2018) to the train set and validation set respectively. We also apply data augmentation including color shifting, image flipping, resizing, random cropping, and blurring to enrich the training dataset.

D. Training

We use Binary Cross Entropy with Logit loss (BCEWithLogitLoss). The corresponding loss functions are defined as

$$\ell_{(x,y)} = L = \ell_1, \ldots, \ell_{\mathcal{N}}^T,$$

$$\ell_n = -w_n[y_n.log\sigma(x_n) + (1 - y_n).log(1 - \sigma(x_n))]$$

Where N is the batch size. If the reduction is not ‘none”, then:

$$\ell_{(x,y)} = \begin{cases} mean(L), & if\ reduction = 'mean' \\ sum(L), & if\ reduction = 'sum' \end{cases}$$

The decoder of the model is initialized with pre-trained ImageNet. Moreover, we use the Adam optimizer with an initial learning rate of 0.0001. The model is trained for 100 epochs on V100 GPU, with a batch size of 16.

III. RESULTS

We trained and tested out the model on two objects of the dataset namely cat and ape. Figures

2 and 3 respectively show the loss and accuracy of model training to segment cat and ape.

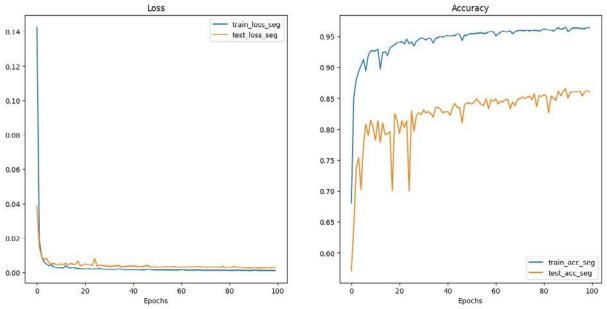

Figure 2. Train and validation learning curves with our model on ape

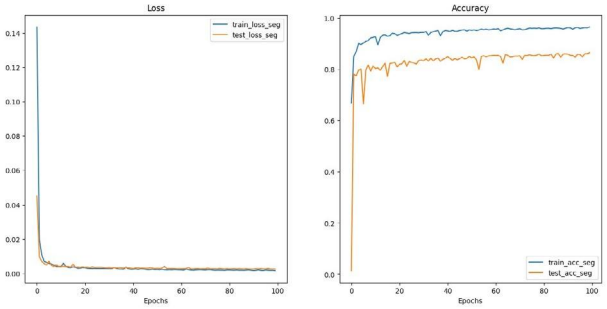

Figure 3. Train and validation learning curves with our model on cat

Due to the combination of the training set including synthetic images and real images, there is a gap between the accuracy of the training and validation steps. Our model archives over 92 % of accuracy on the training dataset, and over 85% of accuracy on the validation dataset. More specifically, Table 1 demonstrates the achievement of our model.

Table 1. Evaluation on the dataset with our model

Model	IoU (0.5)
Our Model (On Ape)	**0.858**
Our Model (On Cat)	**0.865**

Figure 4. Visualization of segmentation results for ape and cat

The final outputs are visualized in Figure 4. It is worthing to point out that model shows the promising results. Our model performs better in the scene where objects are not occluded. When the objects are fully present in the scene, the segmentation maps show better results in comparison with occluded objects. It can be explained that the larger the appearances the more features of objects our model can extract and recover after the encoder–decoder path.

However, it is clear that the details at the boundaries of the objects are not segmented well, especially when objects are concealed. Figure 5 depicts this problem.

Figure 5. Resutls on the bounderies of objects

IV. CONCLUSION

In this work, we have built a segmentation framework, as an extension of our other project.

Our model gives acceptable performances on the segmentation. Because the training dataset mostly consists of synthetic images, besides there are only real images on a test set, which is the reason why there is a noticeable gap between the IoU on the training set and the test set. Therefore, there is some room for this model to be improved. We might train our model on different datasets such as COCO for segmentation, PASCAL… which are primarily developed for training and testing segmentation. Finally, we believe that our model can be a baseline for our development in the future which is the combination of segmentation and objects pose estimations.

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SURFACE ROUGHNESS IMPROVEMENT BY INVESTIGATION OF CUTTING PARAMETERS ON CNC LATHE USING THE TAGUCHI METHOD[*]

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Abstract: Effects of cutting parameters in the turning process are essential to the surface roughness of the finished products. The cutting parameters that were investigated in this research are cutting speed, feed rate, and depth of cut. The experiments were conducted on the quality cutting of steel S45C and used the CNC lathe DMG MORI CLX 350. Using the Taguchi method, the experiment was a three factors four levels design and included sixteen samples. The surface roughness was measured to find the optimal value. Through this research, the optimal cutting parameters that were found in the experiment are used to improve the quality of the turning process.

Keywords: *Optimization, Taguchi method, cutting parameters, cutting speed, feed rate, depth of cut*

I. INTRODUCTION

The turning process is a basic method of machining. It has been used and optimized to get better results for many years. There were many research on the optimization of the cutting parameters for the machining cost and the tool wear in the turning process (Chung et al., 2022; Sheng, 2015). Camposeco-Negrete et al. investigated the cutting parameters to minimize energy consumption (Camposeco-Negrete et al., 2016). However, the quality of the finished surface is an important requirement in the turning process (Sumardiyanto et al., 2018) that is needed to minimize. It can be affected by many factors including tool deflection (Nghiep et al., 2018).

In this research, the cutting parameters and their effect on the surface roughness are investigated. They are cutting speed, feed rate, and depth of cut. The effect of the cutting parameters on surface roughness has been investigated by many researchers (Akgün & Demir, 2021; Chung et al., 2022; Demir et al., 2019; Kaladhar, 2021; Lazarević et al., 2012). The cutting speed is the most important factor in creating surface roughness according to many researchers (Akgün & Demir, 2021; Obiko et al., 2021). However, Lazarević et al. (2012) found that feed rate is the most significant parameter that affects the surface roughness in the turning operation of polyethylene. Others showed the same results on cutting titanium (Gariani et al., 2021), and stainless steel 304 (Prasada Rao et al., 2018). Saedon et al. (2021) also found out that feed rate was the most influential factor on surface roughness on turning titanium alloy. Touggui et al. (2020) did research on dry-

[*] Best poster presentation award

turning stainless steel using a cermet tool and proved feed rate affected the surface roughness with a contribution ratio of 79.61%. In addition to that, Sijo MT & BijuN (2011) showed the equal effectiveness of the cutting speed and feed rate on the surface finish. Hanafi et al. (2011) investigated the CNC turning process of Poly-Ether-Ether-Ketone plastics and showed that the depth of cut is the most important factor in affecting the surface roughness.

All the research above has been using the Taguchi method to design experiments; however, the results they have achieved are different from each other. The reason for this is that the material, the machine, and the cutting conditions that have been used are different. In practical conditions, a small change in the environment or cutting conditions affects the surface finish quality. Therefore, it is necessary to investigate the effect of the cutting parameters on the surface finish in the specific material and machine that have been used in specific manufacturing centers.

II. METHODOLOGY

A. Material and equipment

The CNC turning machine used in this research is DMG MORI CLX 350 (Figure 1). The important specifications of the machine are the spindle speed of 5000 rpm, and the maximum turning diameter of 320 mm. The longitudinal travel is 580 mm, and the cross travel (X) is 242,5 mm. The maximum rapid traverse is 30 m/min.

The cutting tool used in this research is the Sandvik's insert VNMG 160408-PM4325. The holder is DVJNL 2020K 16. The cutting parameters that the manufacturer recommends for this type of tool are the cutting speed of 310 m/min, the feed rate of 0.3 mm/r, and the depth of cut of 2 mm.

The samples were measured for their hardness on Rockwell hardness testing machine (Figure 2). Specimens are typically crafted from S45C with a hardness of 88.7HRB, a commonly employed material in the fabrication of machining products. This choice is attributed to the favorable properties of S45C, including its ease of machinability, weldability, and capacity to undergo heat treatment. The chemical composition % of S45C is shown in Table 1.

At the start, the workpiece's diameter was gauged using a high-precision digital micrometer, essential for determining the depth of the upcoming cut. The workpiece was then securely positioned in a chuck.

Before conducting the experimental trials, the test specimens were segmented into ten sections, each measuring 10 mm in length. A gap of 5 mm was maintained between adjacent sections (Figure 3). The design of the cylinder sample is depicted with dimensions as illustrated in (Figure 4). There are 20 samples (Figure 7) with a diameter of 63 mm. Before fixation, meticulous attention was given to aligning and ensuring the workpiece's horizontal surface (Figure 8). In this context, L_1 signifies the distance of 30 mm between the clamping location and the starting point (Figure 5, Figure 6). The roughness response was evaluated by conducting tests on individual examples, where a consistent starting and ending point were established. The surface roughness of the samples is measured by Mitutoyo Surftest SJ-210 Series 178 – On-site Surface Roughness Tester (Figure 9).

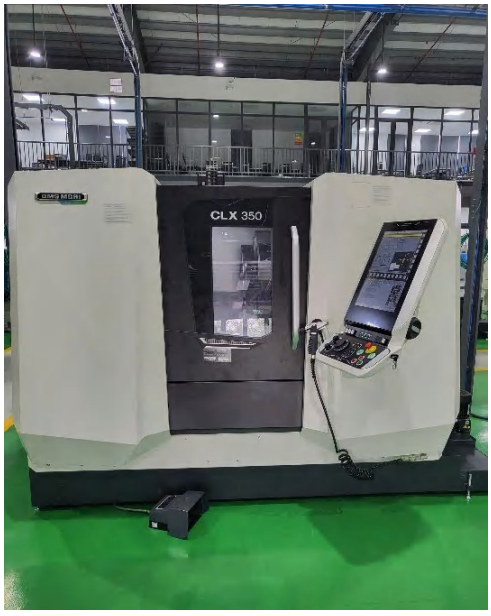

Figure 1. CNC turning machine

Figure 2. Measuring the workpiece hardness

Table 1. Chemical composition % of S45C

C	Si	Mn	P	S	Ni	Cr	Cu
0.42~0.48	0.15~0.35	0.60~0.90	≤0.03	≤0.035	≤0.2	≤0.2	≤0.3

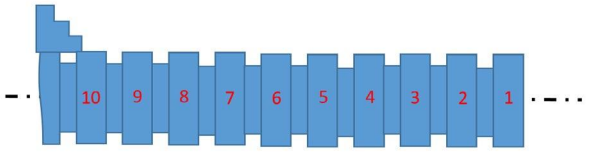

Figure 3. Diagrammatic view of the samples

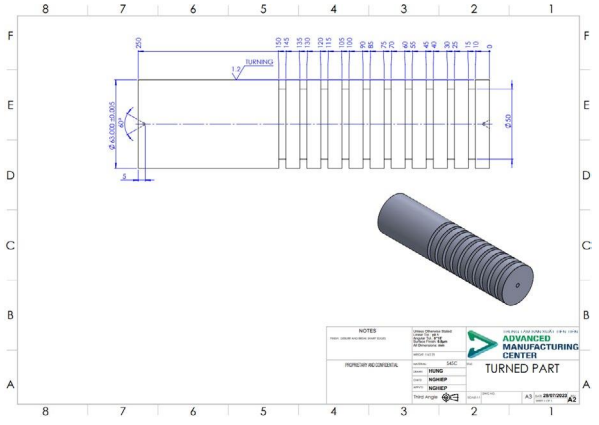

Figure 4. Dimensions of the samples

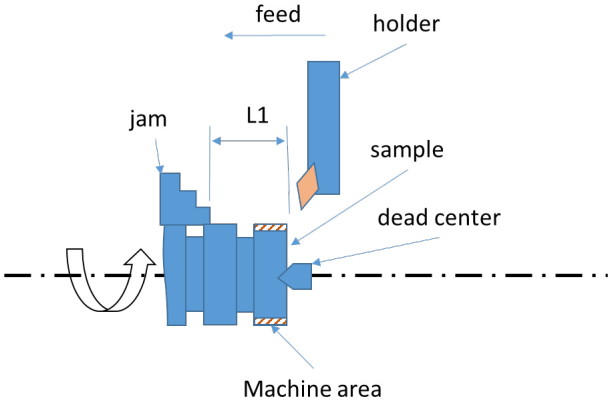

Figure 5. Clamping position of the first sample

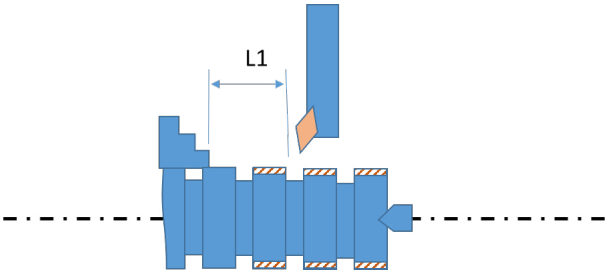

Figure 6. Clamping position of the other sample

Figure 7. The samples used in the experiments

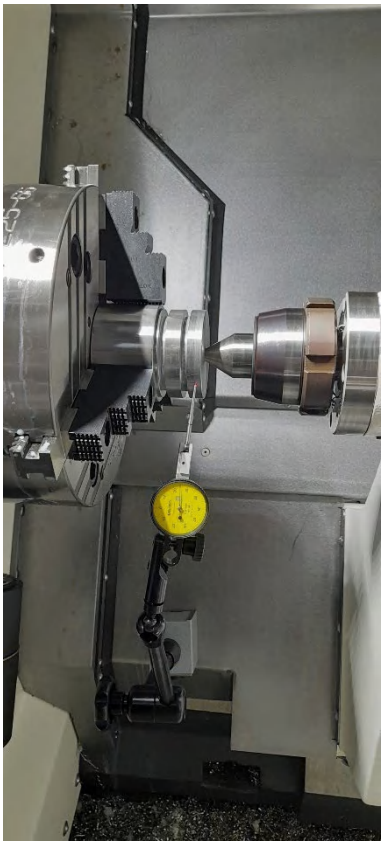

Figure 8. Set up the specimen

Figure 9. Measuring surface roughness

B. Experimental design

With three factors and four levels each, there are 4^3, 64 samples in total. To save time and samples, the Taguchi method was used. The experimental runs were carried out in accordance with L16 Orthogonal Array design of the experiment (Table 3). There were 20 samples prepared; 16 samples were used for turning and measuring, and the rest were used to do the confirmation test. In the method, the signal-to-noise (S/N) ratio is used to measure the deviation of the surface roughness. The response can be placed into three categories: lower-the-better, higher-the-better, and nominal-the-best. For the surface roughness, lower-the-better is preferred for the optimum cutting parameters. The formula calculating S/N is shown in Eq. (1).

$$S/N = -10\log(\frac{1}{n}\Sigma y^2) \quad (1)$$

Three control factors with 4 levels each are listed in Table 2. They include cutting speed V_C (m/min), feed rate f (mmm/r), and depth of cut a_p (mm). The values were selected according to the recommendation of Sanvik's, the tool producer.

In most cases, CNC machines are controlled by various adjustable variables like spindle speed, feed rate, and depth of cut, among others. Typically, the optimization of CNC turning processes relies on trial-and-error methods, drawing from shop floor expertise to determine specific process parameters. However, this approach does not assure quality or cost-effectiveness. Hence, a comprehensive optimization strategy is essential to eliminate the need for time-consuming trial runs on the machine and reduce waste.

Table 2. Cutting factors and levels

Factors		Levels			
		1	2	3	4
A	V_C (m/min)	280	320	360	400
B	f(mm/r)	0.15	0.26	0.37	0.5
C	a_p(mm)	0.1	0.25	0.4	0.55

III. RESULTS

The surface roughness of the samples is shown in Table 3. The S/N ratios are shown in the same table. The surface roughness was measured at three positions. The surface roughness is changed dramatically when factor B is changed from level 1 to level 2, from level 2 to level 3, and from level 3 to level 4. With this result, factor B is the most important factor that affects the surface roughness in these experiments.

Moreover, in this research, the significant contribution of each factor to the surface roughness using Pareto ANOVA analysis. The square of difference for each factor (S_iS_i) is calculated for 4 levels based on the following equation.

$$S_i = (R_{i1} - R_{i2})^2 + (R_{i1} - R_{i3})^2 + (R_{i1} - R_{i4})^2 + (R_{i2} - R_{i3})^2 + (R_{i2} - R_{i4})^2 + (R_{i3} - R_{i4})^2 \quad (2)$$

The results of contribution are shown in Table 5. It shows that the surface finish is most influenced by the feed rate at 99.94% contribution. For a better representation, data are plotted in Figure 10, Figure 11, and Figure 12.

Table 3. Avergae surface roughness

Run #	Control factors and levels			Surface roughness (Ra) μm			Mean	S/N
	A	B	C	Y1	Y2	Y3		
1	1	1	1	0.567	0.574	0.572	0.57	4.87
2	1	2	2	1.794	1.780	1.777	1.78	-5.03
3	1	3	3	4.423	4.375	4.370	4.39	-12.85
4	1	4	4	8.041	8.150	8.051	8.08	-18.15
5	2	1	2	0.672	0.636	0.673	0.66	3.60
6	2	2	1	1.893	1.869	1.863	1.88	-5.46
7	2	3	4	4.281	4.363	4.292	4.31	-12.69
8	2	4	3	8.055	8.128	8.078	8.09	-18.16

Run #	Control factors and levels			Surface roughness (Ra) µm			Mean	S/N
	A	B	C	Y1	Y2	Y3		
9	3	1	3	0.663	0.659	0.658	0.66	3.61
10	3	2	4	1.805	1.832	1.823	1.82	-5.20
11	3	3	1	4.374	4.473	4.456	4.43	-12.94
12	3	4	2	7.866	7.848	7.863	7.86	-17.91
13	4	1	4	0.656	0.668	0.700	0.67	3.41
14	4	2	3	1.833	1.845	1.831	1.84	-5.28
15	4	3	2	4.415	4.355	4.374	4.38	-12.83
16	4	4	1	8.123	8.189	8.098	8.14	-18.21

Table 4. Response table for s/n ratios of error

Level	Factor		
	A	B	C
1	-7.79	3.87	-7.93
2	-8.18	-5.24	-8.04
3	-8.11	-12.83	-8.17
4	-8.23	-18.11	-8.16
Difference	0.44	21.98	0.23
Rank	2	1	3

Table 5. Square of difference response for surface roughness

Level	A	B	C
1	-7.79	3.87	-7.93
2	-8.18	-5.24	-8.04
3	-8.11	-12.83	-8.17
4	-8.23	-18.11	-8.16
Square of differences	0.46	1095.94	0.15
Sum of squares of differences	1096.55		
Contribution ratio %	0.04%	99.94%	0.01%

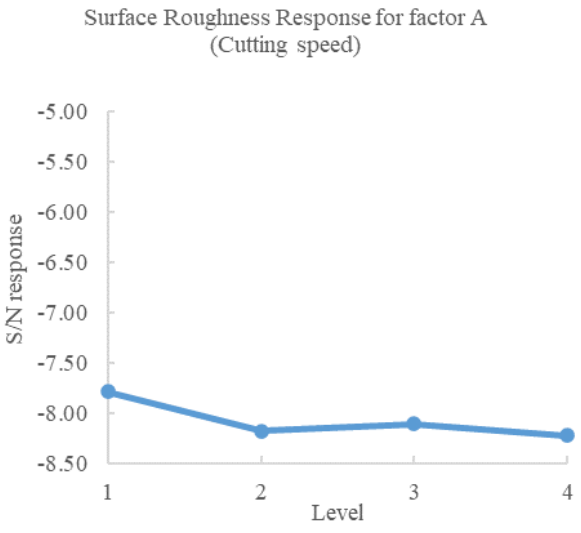

Figure 10. Signal/Noise Response of Factor A (Cutting Speed)

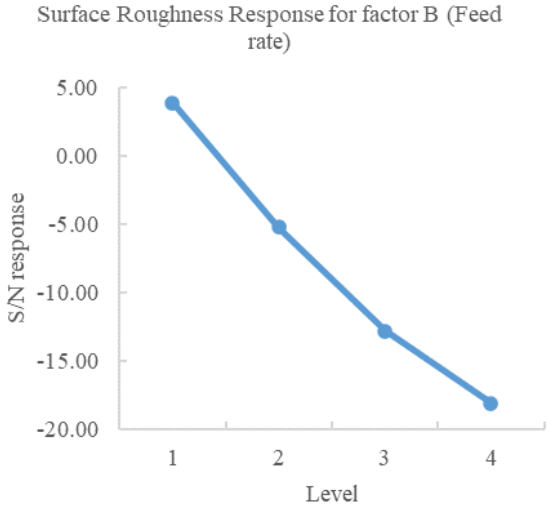

Figure 11. Signal/Noise Response of Factor B (Feed rate)

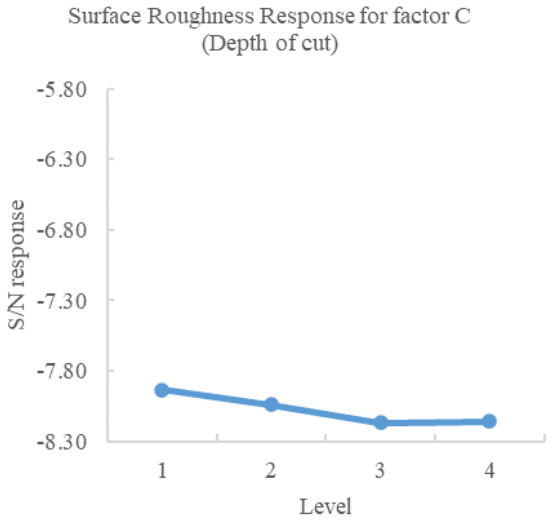

Figure 12. Signal/Noise Response of Factor C (Depth of cut)

Based on the graphs, the optimal result has been found in this experiment is $A_1B_1C_1$. It means the optimum level for control factor A is level 1, B is level 1 and C is level 1. For that, the optimal cutting parameters are the cutting speed of 280 m/min, the feed rate of 0.15mm/r, and the depth of cut of 0.1mm. However, with this result, the machine time is quite high. Because the contribution ratio of factor B is 99.94%, the surface roughness is mainly affected by this factor. The best value of factor B is level 1. Therefore, the authors proposed to use $A_4B_1C_4$ in order to reduce the machining time and achieve the acceptable surface roughness below 0.8 μm.

IV. CONCLUSION

Through this research, three conclusions were reveal as following:

1) Surface roughness responses are analyzed using a technique involving three factors and a four-level approach. This article has explored the utilization of the Taguchi methodology to enhance the cutting parameters during turning processes.

2) Among the factors affecting the surface roughness of S45C carbon steel material in lathe operations with the VNMG 160408-PM4325 finishing insert, the feed rate exhibits the most significant influence. Subsequently, the cutting speed and depth of cut also play roles in determining the surface roughness level.

3) For achieving a surface roughness level around 0.675 µm (Ra), the specified parameter values are employed: a cutting speed of 400 m/min, a feed rate of 0.15 mm/min, and a depth of cut at 0.55 mm. However, in cases where the machining depth is less than 0.5 mm, utilizing the configuration A1B1C1 can optimize tool longevity and surface roughness, especially in scenarios demanding low cutting speeds and high precision. The enhancement in machining time and surface roughness, transitioning from the initial cutting parameters to the optimal ones, reflects an impressive increase of approximately 300%.

The experiments have found out the optimal cutting parameters to achieve the best surface roughness. However, the coolant fluid and other parameters such as tool geometry, vibration and temperature have not been investigated. Therefore, in the future more and more experiments need to be conducted to find acceptable cutting conditions to optimize multi-objective problems, including surface roughness, tool wear, productivity, energy consumption, and machining time.

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EASTERN INTERNATIONAL UNIVERSITY
SCIENTIFIC CONFERENCE 2023 (EIUSC 2023)
PROCEEDINGS

SMART INDUSTRIAL ELECTRICAL CABINETS DESIGN FOR SMART WAREHOUSE SYSTEM[*]

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Abstract: In the past, the design of electrical cabinets was typically bulky and had a box-like structure made of steel or other sturdy materials. Traditional cabinets tend to be larger in size compared to modern ones. And, wiring in traditional cabinets is often done manually, with individual wires being routed and connected using terminal blocks. Any faults or changes in the system may involve time-consuming troubleshooting and rewiring. In this paper, we apply new technologies to design more modern capacitors for smart warehouses. Modern industrial electrical cabinets are designed with a focus on compactness and efficiency. Modern cabinets are generally smaller and more space-efficient than traditional ones. Modern cabinets are also designed with improved reliability and ease of maintenance.

Keywords: *Industrial electrical cabinets, Smart Warehouse, Industrial 4.0*

I. INTRODUCTION

An electrical enclosure is a purpose-built cabinet designed to house electrical and electronic devices, providing the required protection. In the article SOXS Control Electronics Design, SOXS (Capasso et al., 2018) is a unique spectroscopic facility that will operate at the ESO New Technology Telescope (NTT) in La Silla from 2020 forward. The following cabinets design for the electronics controls all the movements, alarms, cabinet temperatures, and electric interlocks of the instrument are very important to the system (Capasso et al., 2018). In 2020 in San Luis Obispo, CA, USA, the authors of the research paper Work-in-Progress—A Proposal to Design of Virtual Reality Tool for Learning Mechatronics as a Smart Industry Trainer Education use VR technology to design and simulate industrial electrical cabinets (Tovar et al., 2020). In the 52nd CIRP Conference on Manufacturing Systems, it was mentioned that using robots to assemble and construct high precision capacitors (Kildal et al., 2019). Following the trend of technology, the design of smarter electrical cabinets is being applied. In the study Design of Energy Monitoring System based on IOT also mentioned the design of electrical cabinets according to IoT (Luan & Leng, 2016). The authors at Clemson University with the article Review of Internet of Things (IoT) in Electric Power and Energy Systems have come up with IoT solutions for energy optimization, whereby the control of systems including electrical cabinets must also meet IoT

[*] Excellent presentation award

for the system to work optimally (Bedi et al., 2018). From the above studies, capacitors are an important component in an industrial system. In the smart warehouse project, the design of electrical cabinets to meet the smart and convenient direction has been implemented in this paper.

II. METHODOLOGY

A. Modeling for electrical cabinets

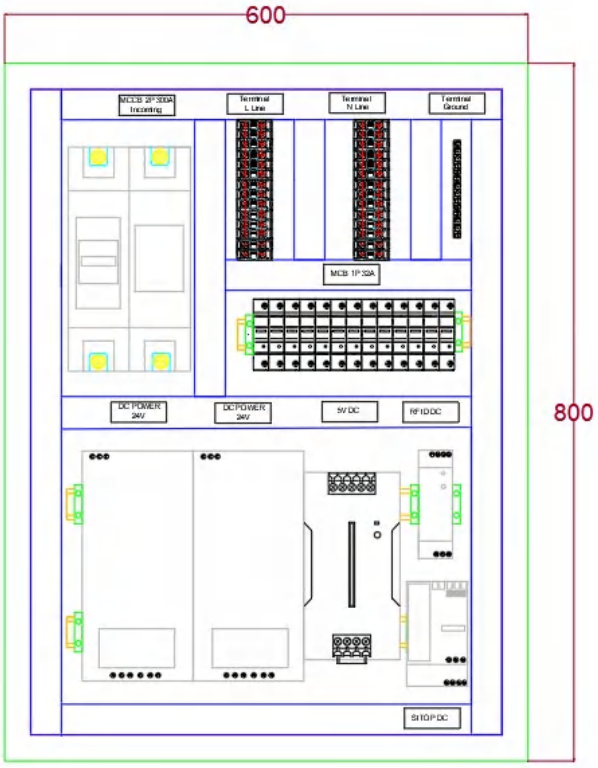

Figure 1. 2D models on CAD software

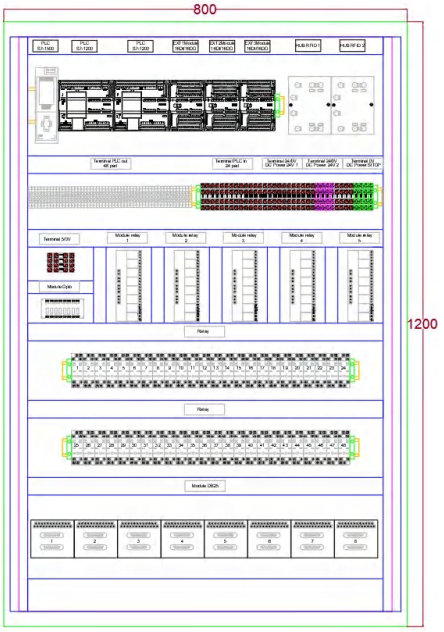

Figure 2. 2D models on CAD software

The electrical cabinet designed for the smart warehouse system is divided into two sections: the dynamic cabinet section with dimensions of H600 × W800 × D300 and the control cabinet section with dimensions of H800 × W1200 × D300. These technical specifications are illustrated in Figure 1 and Figure 2.

The Smart Industrial Electrical Cabinets for the smart warehouse are divided into two parts: the dynamic section and the control section, as shown in Table 1.

Table 1. Table of equipment's

Electrodynamic cabinet	Upstream CB
	MCB RCBO
	MCCB 1P
	Power supply 24VDC 50A
	Power supply 5VDC 60A
	Power supply 24VDC IFM for RFID
	Power supply 24VDC SITOP for PLC
Control cabinet	PLC 1500
	PLC 1200
	Module IO for PLC 1200
	Module RFID
	Module OPTO
	Module Relay 8 channel
	Relays coil

III. RESULTS

A. Actual results

From the basics of level 2 electrical cabinets mentioned above as well as through technical standards on industrial electrical cabinets, we have assembled and completed electrical cabinets in accordance with and close to industry standards. as professional as possible. Since then, the actual results as shown in Figures 3, 4, 5, 6 and 7 have been obtained.

Figure 3. Electrodynamic cabinet

Figure 4. Control cabinet

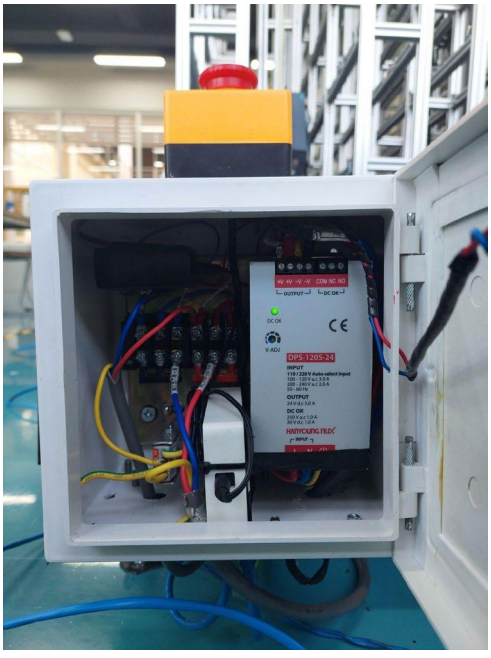

Figure 5. Local box for AGV in station

Figure 6. Local box for AGV in station

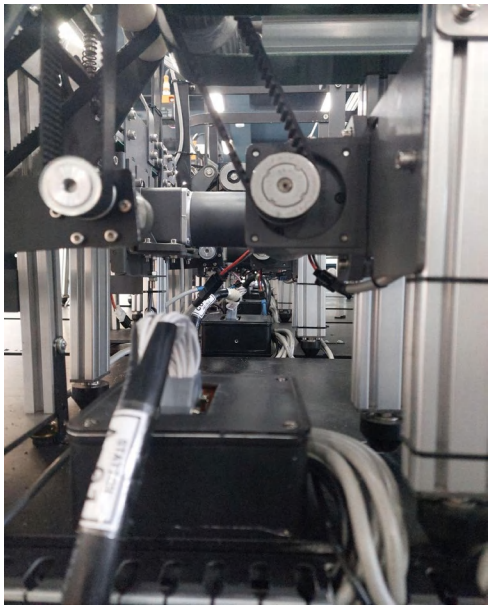

Figure 7. Local box for conveyor in station

B. Figures and tables

Level 2 smart industrial electrical cabinets have garnered popularity due to their balanced approach. They deliver substantial enhancements over basic monitoring (level 1), and they are more accessible in terms of implementation complexity and cost compared to higher levels. The remote monitoring and control capabilities of level 2 cabinets offer notable advantages, such as real-time insights, reduced downtime, and improved maintenance strategies. Moreover, their integration with Programmable Logic Controller (PLC) systems, signal systems, and Supervisory Control and Data Acquisition (SCADA) systems greatly amplifies their efficiency and applicability. From these, we have made a comparison between the levels of electrical cabinets in Figure 8 and Figure 9.

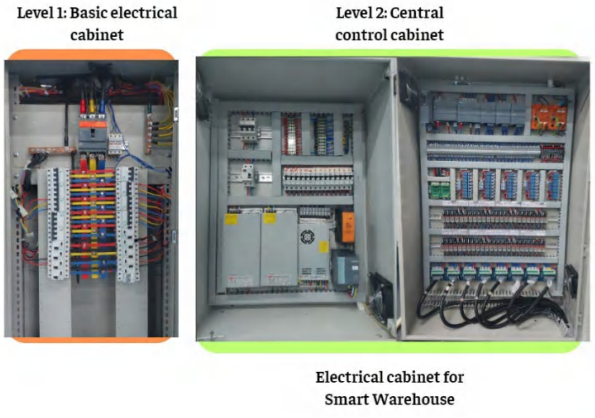

Figure 8. Local box for conveyor in station

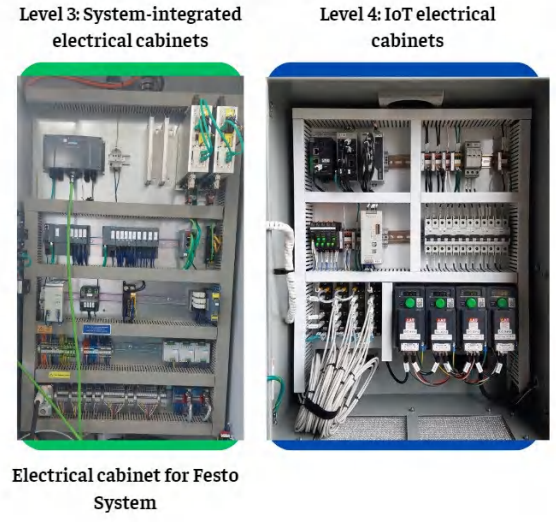

Figure 9. Comparison between electrical cabinet levels

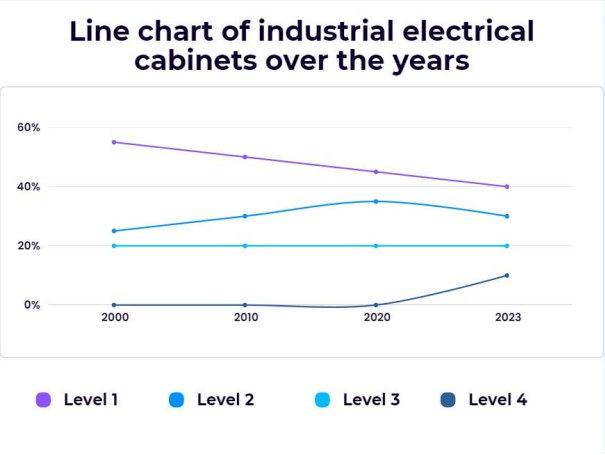

Figure 10. Line chart of electrical cabinets

As can be observed, this chart in Figure 11 illustrates the percentage distribution of various types of industrial electrical cabinets chosen for utilization within the industry from the year 2000 to 2023. Specifically, the chart depicts the prevalence rates comparison among different cabinet types ranging from Level 1, Level 2, Level 3, to Level 4.

Level 1 electrical cabinets dominated usage at 60% due to their simplicity, implementation ease, and cost-effectiveness. However, their lack of advanced integrated smart features, essential in today's advancing era, leads to lower efficiency. Consequently, their usage has consistently declined due to this limitation, with no expected upturn according to the projected chart.

Moving on to Level 2 electrical cabinets, these cabinets have overcome the simplicity drawback that Level 1 cabinets couldn't address. Level 2 cabinets feature an integrated control system, which can include devices like PLCs, HMIs, and more. This enhances control capabilities and reduces operational issues, significantly boosting the efficiency of the cabinets. As a result, the usage percentage of these cabinets has steadily increased in the industry from 2000 to 2020, with a slight decrease only in the year 2023.

Level 3 electrical cabinets maintain consistent usage at 20% annually from 2000 to 2023. This stability is due to their advanced nature, although they present challenges in manufacturing, programming, and higher costs.

Level 4 electrical cabinets are the most advanced and modern of the four levels, though they come with higher installation costs. However, due to a lack of necessary knowledge and resources in earlier years, their usage rate remained at 0% from 2000 to 2020, with a slight uptick in recent times.

In summary, based on these comparisons, level 2 electrical cabinets emerge as the most reasonable choice for us to select and use in this smart warehouse project. This decision is driven by their ability to meet time-related requirements during construction, installation, and assembly costs that align with the available budget. Furthermore, they offer functions that are sufficient, without excess waste or lack leading to operational inefficiencies.

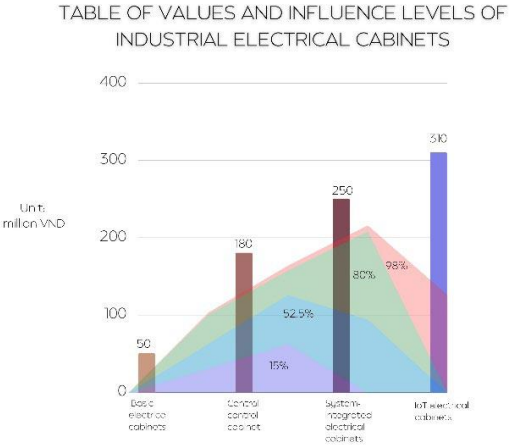

Figure 11. Cost comparison between electrical cabinet levels

Based on the real-world model we have made for the smart warehouse, we have calculated the actual value of each level of industrial electrical cabinets in Industry 4.0, as shown in Figure 11.

Basic Electrical Cabinet (Level 1: 50,000,000 VND): The Level 1 electrical cabinet plays the role of the foundation in the smart warehouse system. While it offers crucial capabilities, it lacks the features and complex integration necessary for a truly smart warehouse. Despite providing fundamental infrastructure, it lacks enhancements in operational efficiency and advanced functionalities. It achieves 15% efficiency.

Central Control Cabinet (Level 2: 180,000,000 VND): Moving up to Level 2, the central control cabinet expands upon the basic infrastructure. This cabinet provides centralized management and monitoring capabilities, allowing operators to oversee multiple electrical components from a single location. This increased level of control enhances productivity, reduces downtime, and improves issue resolution. With centralized control and monitoring, this level enhances efficiency and facilitates easier maintenance. Achieves 52.5% efficiency.

Integrated System Electrical Cabinet (Level 3: 250,000,000 VND): At Level 3, the cabinets become smarter and more integrated. These cabinets provide seamless communication and coordination between warehouse systems such as lighting, HVAC, and security. The enhanced connectivity improves automation capabilities and data-driven decision-making, resulting in higher operational efficiency and cost savings. Integrated system capabilities boost productivity and decision-making skills, leading to significant cost savings. Achieves 80% efficiency.

IoT Electrical Cabinet (Level 4: 310,000,000 VND): The IoT Electrical Cabinet reaches the highest complexity. A Level 4 cabinet employs Internet of Things (IoT) technology to collect, analyze, and adjust real-time data. Warehouse managers can make informed decisions based on actionable insights facilitated by this high level of connectivity. IoT cabinets also pave the way for predictive maintenance, reducing downtime and optimizing resource allocation. The pinnacle of smart warehouse technology, this level offers unparalleled detail and automation, maximizing productivity. Achieves 98% efficiency.

Cost and Efficiency Analysis: To determine the cost efficiency of each cabinet level, analyze the advantages it brings in relation to its price. Efficiency can be assessed through characteristics such as improved operational efficiency, reduced maintenance costs, and increased overall output.

Given the needs and budget of the EIU smart warehouse, the Level 2 central control cabinet is the best choice. Its low cost, combined with significant efficiency benefits and future upgradability, makes it the optimal selection. Furthermore, the Level 2 cabinet can serve as a stepping stone, enabling easy upgrades in the future to Level 3 and Level 4 cabinets. This strategic approach ensures that the EIU smart warehouse remains adaptable and technologically sophisticated, allowing it to harness the benefits of Industry 4.0 and beyond.

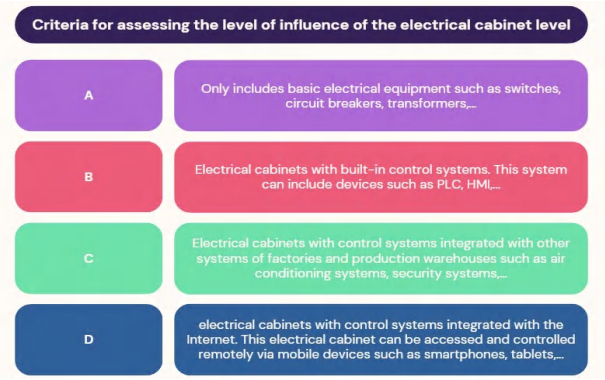

Figure 12. Criteria for assessing industrial electrical cabinets

Based on the electrical cabinet evaluation standard of the Ministry of Industry and Trade of The Socialist Republic Of Vietnam, we have identified four criteria for evaluating the components of electrical cabinets at the level of Industry 4.0. As shown in Figure 12, we list the criteria A, B, C, and D. Specifically, these criteria will evaluate the percentage of the level achieved by each level of electrical cabinet and provide the actual impact level compared to Industry 4.0

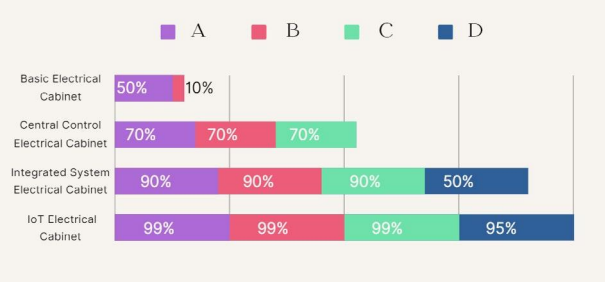

Figure 13. Standards for evaluating industrial electrical cabinets

Illustrated in Figure 13, the level of compliance for the basic electrical cabinet reveals a notable shortfall, with a peak of merely 50% aligning with Criterion A, and a meager 10% with Criterion B. Regrettably, neither Criterion C nor D meets the mark, both registering a 0% index.

Moving on, the central control electrical cabinet delivers a more balanced and optimized set of indicators compared to the Type 1 electrical cabinet, spanning three criteria - A, B, and C, at a commendable 70% compliance rate. However, Criterion D remains unattained, much like the Type 1 electrical cabinet, demonstrating a non-existent 0% compliance rate.

Thirdly, the Integrated System electrical cabinet outshines its predecessors by presenting considerably optimized data. Beyond fulfilling the criteria that elude the Type 1 and 2 electrical cabinets, which is Criterion D, boasting a 50% fulfillment rate, it surpasses even the Type 3 electrical cabinet in the criteria of A, B, and C, achieving an impressive 90% fulfillment rate for each.

Last but not least, the IoT electrical cabinet stands as the pinnacle of contemporary electrical cabinet design, boasting the most elevated parameters. Remarkably, it scores an extraordinary 99% across each criterion - A, B, C - and demonstrates unparalleled excellence in Criterion D with an exceptionally high index of 95%.

IV. CONCLUSION

Level Name	(A+B+C+D)/4
Basic Electrical Cabinet	15%
Central Control Electrical Cabinet	52.5%
Integrated System Electrical Cabinet	80%
IoT Electrical Cabinet IoT Electrical Cabinet	98%

Figure 14. Conclusion table of the impact of the level of industrial control cabinets on Industry 4.0

Through thorough analysis of the percentage indices displayed on the chart, the evaluation of each cabinet's criteria can be meticulously conducted. This detailed scrutiny yields precise quantitative data regarding the optimization level for individual cabinets, a process facilitated by the formula (A+B+C+D)/4. This procedural framework allows for the creation of a tabular presentation, exhibiting average percentage scores representing optimal levels in line with the four established criteria established by the Ministry of Industry and Trade, as highlighted earlier.

Notably, Level 1 electrical cabinets have the most modest rating at just 15%, followed by Level 2 cabinets at 52.5%, then Level 3 at 80%. The pinnacle is achieved with Level 4 cabinets, attaining an exceptional score of 98%. Armed with these meticulous assessments, we can judiciously determine the appropriate cabinet level and consider the potential for advancement to higher tiers. This trajectory holds the promise of unlocking optimal operational efficiency and yielding amplified advantages, as depicted in Figure 14.

ACKNOWLEDGEMENT

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A HAND GESTURE-BASED DC MOTOR CONTROL SYSTEM FOR SMART FACTORY APPLICATIONS

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Abstract: Modern human-machine interactions are one of the most important factors in smart factories in Industry 4.0. Conventional interaction methods based on electronic devices, such as buttons, joysticks, and personal computer (PC) mice, were not suitable for controlling tasks in highly interactive environments, especially in virtual/augmented reality-based applications. Controlling methods that use hand gestures and/or voices are more flexible than conventional ones because they employ directly controlling signals from the brain. Implementations of hand gestures in industrial applications are relatively challenging due to large computational costs and low reliabilities when using classical computer vision techniques for detecting and classifying hand gestures and voice commands. Nowadays, deep convolutional neural networks (CNNs) have been successfully employed for enhancing both reliability and computational speeds in image-based hand gestures and voice processing, but they are mostly used for entertainment applications. Because of those reasons, in this study, we proposed hand gesture-based controlling methods for controlling industrial devices in smart factories. In particular, one mono camera was used for capturing hand motions and voice in real-time. The hand image was transmitted to a CNN-based hand detector for acquiring hand features in real-time. The tracked hand points in real-time were used for recognizing the hand gestures. The target hand gestures included closing, opening, downing the thump, and raising the thump gestures. These classified gestures were used to control the DC motor to stop, run, forward, and backward rotate. To evaluate the system's accuracy, we repetitively control the DC motor to different states 100 times. We counted the number of successful controlling times as the accuracy of the system. As a result, based on the computed accuracy and the surveyed data from the users, the developed controlling methods are flexible and can be implemented into the factory environment for controlling industrial devices with acceptable accuracy and in real-time.

Keywords: *hand gesture detection, human-machine interaction, computer vision-based control, smart factories*

I. INTRODUCTION

Controlling interfaces is one of the most important factors of smart factories in Industrial 4.0 (Jiang, 2018). These types of interfaces define the ways humans interact with the machines to control them according to the target positions/motions. Human-machine interfacing methods (HMIs) could be classified into mechanics-based, computer vision-based, electronic device-based, and biosignal-based. In mechanical HMIs, a human can control a machine based on mechanical interaction between physical devices and target actuators (Ravani, Gabibulayev, & Lasky, 2011). One of the most typical of this controlling interface is to use of a steering wheel for steering motion direction of a vehicle. In computer vision-based controlling interfaces, controlling commands were extracted from the images of the human body using image processing and/or computer vision techniques in 2-D or 3-D spaces (Chakraborty, Sarma, Bhuyan, & MacDorman, 2018). The extracted commands were then transmitted to electronic devices for controlling mechanical actuators. In electronic device-based controlling interfaces, some electronic devices such as buttons, joysticks, Inertial Measurement Unit (IMU) sensors, etc., were employed for generating electronic signals by interacting with the human limbs (J. Wang & Chortos, 2022). The generated electronic signals were then employed for controlling the target actuators. In biosignal-based controlling interfaces, biosignals (e.g., brain signals) were collected with special sensors (Rechy-Ramirez & Hu, 2015). These signals were then processed and converted to the controlling commands for controlling the target actuators.

Each controlling method has its advantages and disadvantages (J. Wang & Chortos, 2022). Although the mechanics-based controlling methods were the most stable and accurate, they cannot control mobile actuators (Bünte, Odenthal, Aksun-Güvenç, & Güvenç, 2002). The electronic device-based methods, the generated signals from buttons, joysticks, or IMUs could be transmitted wirelessly to drivers for controlling mobile actuators (Cardoso, Bochkezanian, Forner-Cordero, Melendez-Calderon, & Bo, 2022). However, in these types of control, humans must convert their hand gestures to the behaviors of electronic devices to control the target actuators. In computer vision-based controlling methods, motions of the upper and lower limbs could be directly employed for controlling the target actuators. However, these methods needed large computation costs and could not be computed in real-time (Franslin & Ng, 2022). In biosignal-based controlling methods, controlling commands were mostly extracted from the brain signals acquired by the Electroencephalography (EEG) sensors (Bi, Fan, & Liu, 2013). However, the signal processing was complex, and the processed results contained a lot of noise. Consequently, these methods were unstable and not suitable for complex controlling commands. Additionally, large and expensive EEG sensors should be worn while controlling the actuators. Limb gesture-based control methods with the help of computer-vision techniques for limb detection and recognition have the balance between computation complexity and natural levels of the controlling behaviors (X. Wang, Shen, Yu, Guo, & Wei, 2022).

Recently, the computation speed of computer vision-based processing techniques has been significantly enhanced with the support of convolutional deep neural network (C-DNN) methods and execution frameworks (e.g., TensorFlow, PyTorch, Mediapipe) (Vodrahalli & Bhowmik, 2017). Consequently, computer vision-based controlling methods are

one the most suitable controlling techniques in the future. In the literature, computer vision-based controlling techniques have been popularly employed for controlling different types of objects. For instance, hand gestures could be recognized to control robots (Oudah, Al-Naji, & Chahl, 2020). Several conventional image processing techniques have been employed for tracking and recognizing hand gestures, but they mostly focus on detecting the whole hand structures (Ying Wu & Huang, 2001). They have not detected the points on each finger separately. Consequently, the number of recognized hand gestures was limited. With the development of C-DNN methods and frameworks, more complex hand-detection models could be able to execute in real-time framerates (Goel, Tung, Lu, & Thiruvathukal, 2020). Especially, the Mediapipe framework developed by Google Corporation has been released (Kulkarni, Deshmukh, Fernandes, Patil, & Jabade, 2023). With large training datasets and modern & advanced deep neural network structures, this framework can support the detection and tracking of facial points, body skeletons, and finger points in both 2-D and 3-D spaces in real time based only on mono images (Lugaresi et al., 2019). This framework provides us with interactive means of human-machine interaction. Despite several advantages of the Mediapipe framework, it has mostly been applied in entertainment applications and has not been popularly employed in industrial applications.

Because of all the above drawbacks and reasons, in this study, we would like to develop a hand gesture-based DC motor control method based on mono cameras. In particular, mono images acquired by a mono camera were transmitted to a C-DNN for detecting and tracking hand feature points. The computed hand feature points were in the relative 3-D coordinate systems. These feature points were used for recognizing hand gestures. The target hand gestures included palm closed, palm opened, thump rising, and thump lowering. These gestures were used to control a DC motor to run, stop, forward, and upward. To evaluate the reliability of the method, we implemented a prototype of a DC motor control system. The developed methods were applied in this system to control the target DC motor multiple times. The percentage of successful trials per the total number of trials was the reliability of the system.

In the following, we will describe briefly the system's overall procedure and the detailed processing steps of the developed methods in Section II. The results and discussion will be presented in Sections III, IV. Conclusions will finally be stated in Section V.

II. METHODOLOGY

A. Overall processing procedure

The overall processing procedure of the hand gesture-based DC motor controlling system is illustrated in Figure 1. In particular, a mono camera was employed for capturing hand images. The hand images were then transmitted to the hand detector and hand recognizer for detecting hand positions and hand features in 2-D image spaces. The Mediapipe framework was used for hand detection & recognition. The detected hand features were then converted to motor commands for controlling a DC motor. A graphical user interface was also designed for effectively interacting between the human and the DC motor. In the interface, we could also implement a data management system for analyzing and diagnosing the motor's working conditions.

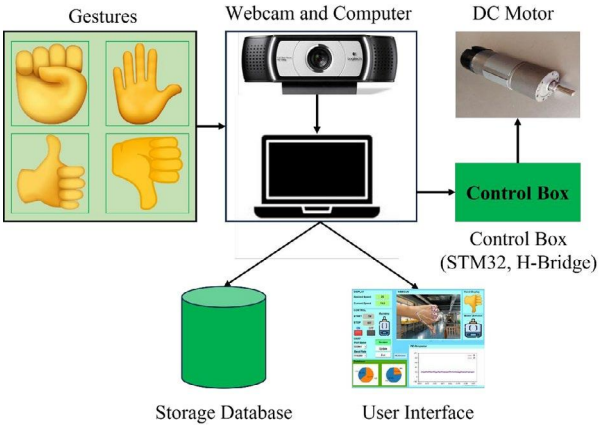

Figure 1. The overall blocking diagram of the hand gesture-based DC motor control system

B. Hand detection and recognition

The Mediapipe framework was developed by Google Corporation. This framework supports several models for detecting and tracking full-body motion, facial features, and hand features in real-time. In this study, we employed the hand detector and recognizer in the Mediapipe framework for detecting hand feature points. The details of the Mediapipe framework are presented in the reference [ref].

The hand detector received 2-D color images acquired by a mono camera. The output of the hand detector is the bounding box of the hand palm's position in the image coordinate system. The hand's bounding box was then employed for detecting hand feature points. Fig. 2 shows an illustration of the hand feature points in the image coordinate system. The total number of hand feature points was 20. Especially, the computed positions of the feature points were in the 3-D relative coordinate system. For instance, as shown in Figure 2, the thump tip point has the coordinates of (0.42, 0.43) for the x and y relative coordinates. The third dimension, so-called z, was estimated by the DNN of the hand detector. Consequently, with only mono images, we could estimate 3-D coordinates of hand feature points without using stereo-vision or structure-from-motion geometries. In this study, we just employed some main points among the twenty points for recognizing the target gestures.

For recognizing the opened and closed gestures, based on the nature of human hand movements of the healthy subject, we selected angles for detecting the closed and opened positions of a hand's palm. As shown in Figure 3, the angles A, B, C, D, E, F, G, H, and I were selected. Their values were computed as Eq. 1.

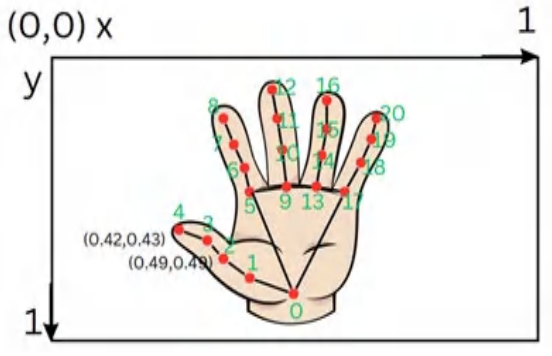

Figure 2. Twenty feature points are given from the face feature detector

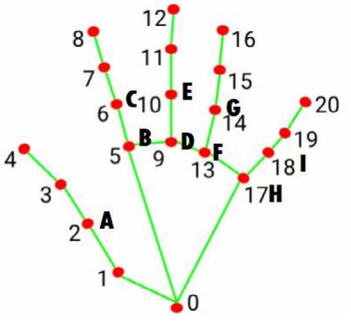

Figure 3. Angle names that are used for gesture recognition

$$\theta_{\Gamma} = \arccos\left(\frac{P_{ij} \cdot P_{kj}}{|P_{ij}||P_{kj}|}\right) \quad (1)$$

In which, P_{ij} is the vector from point i to point j of the hand feature points. P_{kj} is the vector from point k to point j of the hand feature points. Point j is the center vertex point of the angle Γ. Points i and k are the first and third vertex points of the angle Γ. Based on the experimental tests, when opening the hand, the values of the selected angles were in the ranges listed in Table 1. Moreover, when closing the hand, the selected angle values were also in specific ranges, as listed in Table 1. In Table 1, we can see that the hand-opening ranges and hand-closing ranges are separated from each other. We could use this separation to recognize the opening and closing gestures of the hand.

Table 1. The specific angle ranges of the selected angles in the opened and closed hand gestures

Angle Names	Hand Opening Ranges	Hand Closing Ranges
A	160 → 180	90 → 130
B	160 → 180	30 → 145
C	160 → 180	40 → 170
D	160 → 180	30 → 140
E	160 → 180	40 → 170
F	160 → 180	25 → 130
G	160 → 180	45 → 155
H	160 → 180	20 → 130
I	160 → 180	50 → 160

For recognizing the thump lowering and rising gestures, the angle between the center-to-thump vector and the vertical vector was used. In particular, as shown in Figure 4, the angles between the center-to-thump vector and the vertical vector were in the range of 0° to 90° degrees in the thum-rising gesture. These angles were in the range of 90° to 180° in the thump-lowering gestures. Thanks to these separate ranges, we could easily classify between the two gestures.

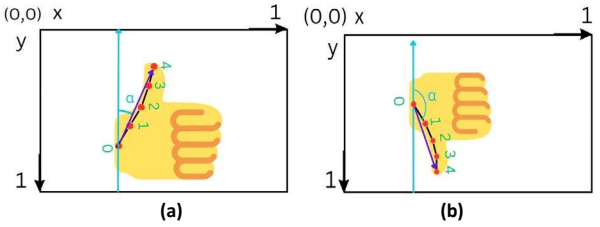

Figure 4. The angles between the vertical vector and the center-to-thump vector for recognizing the (a) thump rising and (b) thump lowering gestures

C. GUI and motor control

To support the user while using his/her hand gestures to control the DC motor, we designed a GUI whose illustration is presented in Figure 5. In particular, the GUI included text boxes for inputting the target controlling parameters. These parameters were the desired motor speed, connecting port, and connection speed. During the execution, the current motor speed, the recognized gestures, and motor directions were feedbacked to the user. Moreover, the database of motor running histories was also collected and analyzed for diagnosing the motor condition. The flow chart of the hand gesture-based DC motor control is illustrated in Figure 6. In this figure when detected the hand-opening gesture, the motor would run forward with the preset motor speed. When the hand-closing gesture, the motor would be stopped. When the thump-rising and lowering gestures, the motor would run forward and backward, respectively, with the preset motor speed. The motor speed control was conducted based on the Proportional-Integral-Derivative (PID) control.

Figure 5. The graphical user interface of the hand gesture-based DC motor control system

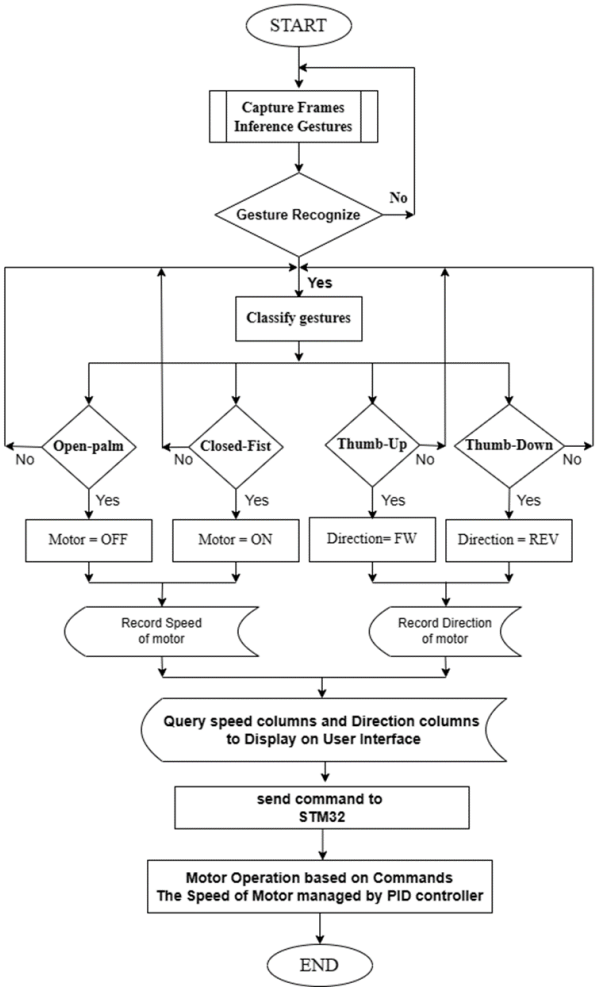

Figure 6. The flow chart of the hand gesture-based DC motor control

D. Implemented technologies

In this study, we employed the Logitech C922 Pro 960 camera as the mono camera of the target system. The image frames were 30 fps with the frame size (Width ×× Height) of 1920 ××1080. The interface was implemented based on the Qt framework for Python (PySide6). The connection from the GUI to the motor was supported by the embedded STM32 kit. Database management was supported by the MySQL server framework. The motor control driver was developed by our group member.

E. System validation

To evaluate the method and system reliability, we designed a model prototype of the hand gesture-based DC motor control system. Moreover, we repetitively tried to control the motor 100 times for each gesture. The percentage of successful control per the total control was computed as the system reliability.

III. RESULTS

We successfully implemented the model prototype of the target system, as shown in Figure 7. This prototype included a DC motor controlled by a motor driver controller. The connection between the control driver and PC was conducted by the embedded STM32 kit via the UART connection. The results of hand gesture recognition coupled with the GUI feedback are shown in Figure 8. After successfully detecting the hand-opening (Figure 8a), hand-closing (Figure 8b), thump-rising (Figure 8c), and thump-lowering (Figure 8d) gestures, the GUI also feedbacked to the user the appropriate images representing specific gestures, as shown in the top right corner of the Figs. 8a, b, c, d. After conducting 100 times the hand gesture recognition, the success rates of

the hand-opening, hand-closing, thump-rising, and thump-lowering gestures were 100%, 97%, 100%, and 100%, respectively. The framerates of the system iterations were 15.5 frames per second. The video demo of this system can be found via the link: https://www.youtube.com/watch?v=LWCWK4y_T64.

IV. DISCUSSION

Computer vision-based controlling methods were shown their advantages of not using complex devices and more naturally when directly capturing limb's motions for controlling actuators. With the advantages of C-DNN these days, the computation speeds have significantly increased. In this study, we employed an advanced and modern C-DNN framework (e.g., Mediapipe framework) for fast-detecting hand feature points based only on a mono camera. Hand gesture-based controlling methods will become one of the most popular controlling interfaces. This controlling strategy helps simplify the input devices in the controlling system by using only a mono camera, which is available in most computer and mobile systems. We also designed an interactive interface that can give feedback during the motor control. The whole controlling system is valuable for being integrated into smart factories for wirelessly controlling actuators based directly on hand gestures.

However, in this study, we also have drawbacks that need to be solved in further studies. Regarding the system function, the current version of the system just supported DC motor control with four running states, and the motor speeds could not be linearly controlled by hand motions. In the future, we will develop more methods for controlling motor speeds based on hand motions. Moreover, in this study, we have not compared the hand gesture-based controlling methods with the other controlling methods (e.g., joysticks, buttons, and steering wheels). This task will be conducted in our further studies.

In perspective, the developed system will be integrated into smart factories for controlling robotic arms, navigation robots, and other

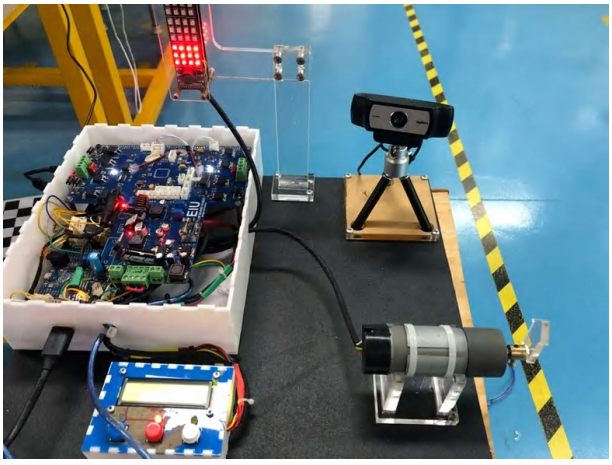

Figure 7. The model prototype of the hand gesture-based DC motor control system

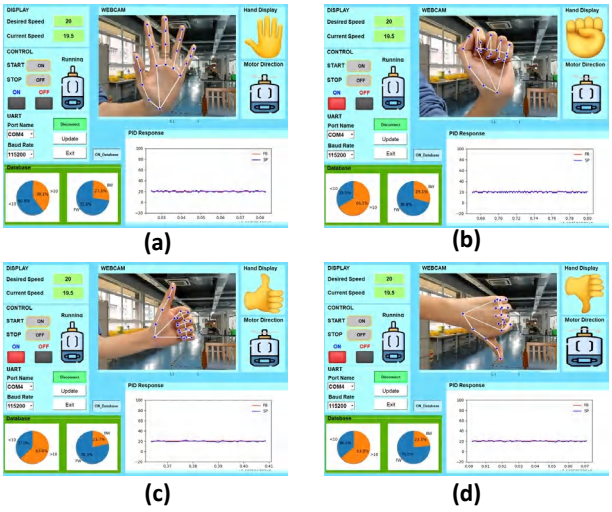

Figure 8. The results of hand gesture recognitions and feedbacks from the GUI: (a) the hand-opening gesture, (b) the hand-closing gesture, (c) the thump-rising gesture, and (d) thump-lowering gesture

related tasks. Moreover, a full validation procedure will be conducted to test and verify the precision of the hand motion detection and motor control. In particular, we will conduct environmental variability testing, user diversity testing, distance testing, and speed & precision testing. In the environmental variability testing, we will vary the light conditions of the working environments, such as bright, dim, and dark. In the user diversity testing, we will test the system execution on various subjects with different hand sizes, genders, and skin tones. In distance testing, we will also test the system working with different distances from the camera to the subject's hand. Finally, in the speed and precision testing, we will test the system success rates and accuracy with various hand speeds. Throughout these testing procedures, we will compute the system's precision, accuracy, and reliability as our system's plausible ranges so that the user can select the system for working in specific factory environments.

V. CONCLUSION

With the help of C-DNN and computer vision techniques, gesture-based controlling methods have been one of the best convenient controlling methods in comparison with mechanics, electronics, and biosignal-based ones. In this study, we employed only one mono camera for detecting & tracking 3-D hand feature points in real time. Based on the tracked hand features we could successfully recognize four hand gestures with relatively high success rates. The four recognized gestures were used for controlling a DC motor with four different running states. This controlling strategy helps control robots, machines, and other devices in factories more naturally by directly based on hand gestures.

ACKNOWLEDGMENT

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AN ADAPTIVE VENTILATION SYSTEM CONTROL FOR PARKING LOTS IN SMART CITIES

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Abstract: Modern smart cities usually face the situation of significant vehicle incrementation. Consequently, parking lots in these cities mostly have very high-density vehicles, so the fire risk in these parking lots is relatively high. Effectively controlling temperatures and humidity can help reduce the fire risk. Moreover, stable conditions of temperature and humidity can also keep electrical vehicles and devices in the parking lots from being damaged. Consequently, in this study, we proposed a prototype design of an adaptive ventilation system supporting the stabilization of temperature and humidity in smart parking lots. In particular, the prototype included the ventilation system, the ventilation control system, and the supervising system. In the ventilation system, infrared sensors were used for detecting coming and leaving vehicles. The number of vehicles inside the parking lot was computed based on the detections. Based on the current number of vehicles inside the parking lot, the power of the ventilation system, which was represented as the speed of a direct current (DC) motor, was controlled so that the temperature and humidity values could reach the target ones. In the ventilation control system, the current temperature and humidity values and the current number of vehicles were collected and visualized in real-time via a universal serial connection. Moreover, the control panel was also designed in this control system. The panel has both automatic and manual controlling modes. In the automatic model, the target power of the ventilation system was automatically computed based on the current number of vehicles inside the parking lot. In the manual mode, this target value was inputted manually. In the supervising system, which was tele-connected with the control system via wireless LAN or Internet connection, all types of system data were collected and stored in a database management system. The current status of the parking lot system was also visualized in the connected mobile station. The status of the data was stored during the working time for diagnosing the operation's effectiveness. In perspective, the proposed design will be implemented in a real ventilation control system for parking lots in smart cities.

Keywords: *smart parking lot, smart cities, ventilation control system, LabVIEW, DC motor control*

I. INTRODUCTION

Modern smart cities usually face significant increments in the number of vehicles (Haque, Bhushan, & Dhiman, 2022). In particular, the number of vehicles, such as cars and motorbikes, per the number of people inside a smart city has rapidly increased (Hasija, Shen, & Teo, 2020). This is because the living quality of the public is continuously enhanced. Each person tends to have more than one personal means of transportation (Venter, 2011). Moreover, living in apartments is becoming one of the main living styles in modern lives (Bloom, 1985). These factors make the density of vehicles inside these cities rise extensively. This high density of vehicles requires a lot of spaces for parking, but the areas in crowded cities have been narrowed these days (Johansson et al., 2012). Consequently, these parking lots have several levels, and the number of parked vehicles is large (Khalid et al., 2021). The temperatures and humidities in these parking lots also increase gradually due to the large density of vehicles. This situation makes the fire risks more and more serious in those places (Brzezinska & Bryant, 2022). Other than that, most vehicles these days are usually composed of numerous powerful electric and electronic devices (Chan & Chau, 1997). High temperature and humidity levels can therefore cause damage to these devices. Keeping good conditions of temperatures and humidity is, therefore, an urgent requirement in those parking lots (Perković, Šolić, Zargariasl, Čoko, & Rodrigues, 2020). However, energy saving is one of the most important requirements in smart cities (Khajenasiri, Estebsari, Verhelst, & Gielen, 2017), so always keeping very low temperature and humidity levels is not economical. Because of the above reasons, the development of an adaptive ventilation system for controlling temperatures and humidities according to the number of vehicles inside a parking lot is necessary.

In literature, most mart parking lots were just designed to optimize the efficiency of vehicle management. For instance, radio frequency technologies were employed for checking incoming and outgoing vehicles both manually and automatically (Ilie-Zudor, Kemény, van Blommestein, Monostori, & van der Meulen, 2011). Computer-vision technologies were also implemented for automatically detecting number plates for checking in/outcoming vehicles (Almeida, Alves, Parpinelli, & Barddal, 2022). These techniques were also employed for supervising the number of vehicles inside a parking lot (Ilie-Zudor et al., 2011). However, the temperatures and humidity levels have not been considered in these smart parking lot systems. This is because most of these systems were designed for outdoor environments. For indoor environments, numerous issues, such as air conditioning, should also be considered sufficiently.

Most air conditioning systems just control the temperatures so that they can reach the target values preset manually by the user (André, De Vecchi, & Lamberts, 2020). These target values have not been set automatically based on the current conditions of the whole system. Moreover, the humidity levels of the target environments have not been much regarded. Actually, besides the temperatures, humidity levels are also one of the most important factors highly affecting the living duration of electric and electronic devices. Keeping good conditions of both temperatures and humidities can, therefore, help enhance the reliability of these electric and electronic devices (Foucher,

Boullié, Meslet, & Das, 2002). Moreover, good air conditioning systems should also be coupled with energy-saving factors for optimizing energy consumption and ensuring sustainable developments on our planet (Yang, Yan, & Lam, 2014). This enhancement could also be more emphasized if these systems could take advantage of the Internet of Things (IoTs) and smart data managing systems for supervising and diagnosing the system's execution conditions (Fischer, 2008).

Because of the above reasons, in this study, we tried to develop an adaptive ventilation system coupled with smart data acquisition and management systems for smart parking lot systems in modern cities. In particular, we developed a prototype of this adaptive ventilation system. The sample model of the system included a Direct Current (DC) motor coupled with a fan system for controlling the ventilation speeds. An Infrared (IR) sensor was employed for counting the incoming and outcoming vehicles. The current number of vehicles inside the parking lot was used for controlling the speed of the fan system. A microcontroller system (e.g., an STM32 kit (Sipola, Alatalo, Kokkonen, & Rantonen, 2022)) was used for counting the number of vehicles from the IR signals and sending the analog signal to a DC driver to control the speed of the fan's motor. Moreover, the current number of vehicles and fan speeds were also acquired and transmitted to a server system for data management and supervision via the Universal Asynchronous Receiver/Transmitter (UART) connection. Additionally, we also employed a mobile computer system for tele-acquiring the system's current working condition. The main and mobile servers were implemented based on the LabVIEW framework. As a result, we could successfully control the fan's speeds adaptively with the current number of vehicles inside the parking lot model. All system conditions were acquired and stored in a sever system for supervising the diagnosing of the system's working condition. In perspective, we will employ the concept of the prototype system in a real adaptive ventilation system of the smart parking lots. This concept could also be applied to the control of air conditioning and/or ventilation powers to adapt to the number of people in offices or the number of products inside a warehouse.

In the following, we will first present the detailed implementations of the adaptive ventilation system in Section II. In Section III, the execution results of the target system will be reported. Conclusions and further implementation will be presented in Section IV.

II. METHODOLOGY

A. Overall processing procedure

The overall implementation procedure of the target system is illustrated in Figure 1. In particular, in the ventilation system, we counted the current number of vehicles in a parking lot system through IR sensors. The signals of the IR sensors were acquired by an embedded STM32 controlling system. This system was also used for outputting Pulse Width Modulation (PWM) signals (Yu, Mohammed, & Panahi, 1997) for controlling the fan speed of the ventilation actuator. The fan speeds were proportional to the current number of vehicles in the parking lots. In the ventilation control system, we implemented two controlling modes: manual and automatic. In the manual mode, users could control the fan speeds by sending the command through a server system via the

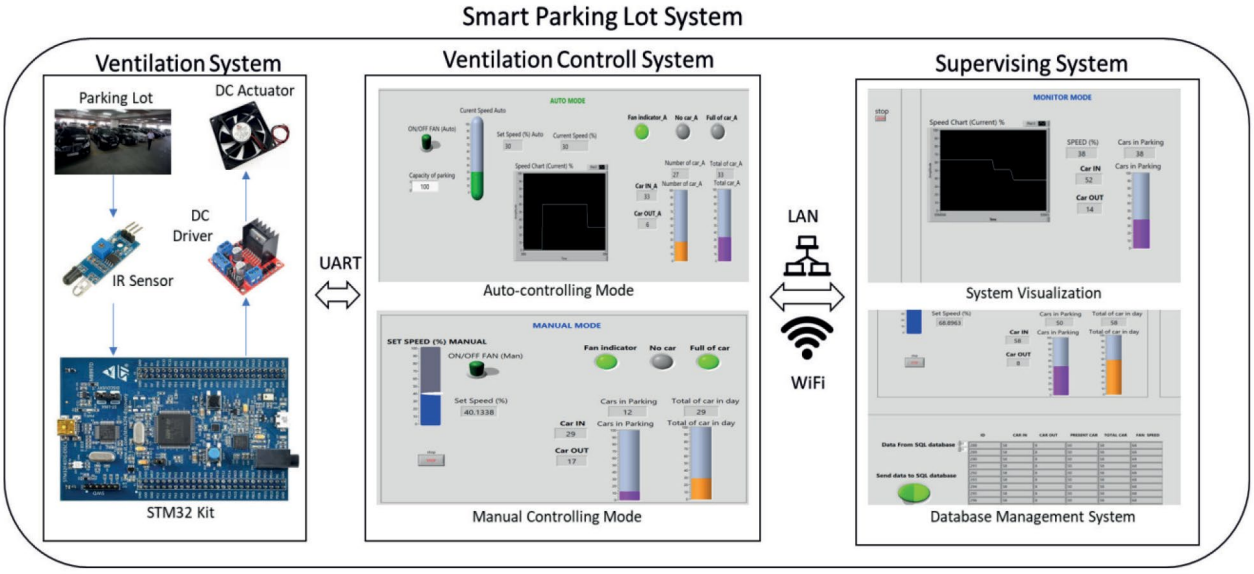

Figure 1. The overall blocking diagram of the adaptive ventilation system for smart parking lot

UART connection to the STM32 kit. In the automatic mode, the target fan speeds could be computed by arguing with the current number of vehicles in the parking lot. The number of incoming/outgoing cars was also acquired and saved in the server system for analyzing and diagnosing the system's reliability. In the supervising system, this system was connected to the server system via the Internet protocol. This connection allows the supervising system can acquire the status of the parking lot system globally. The state of the system during its execution including the current fan speeds, the current income vehicles, and the current outcome vehicles. All information was stored in a cloud data management system.

B. Ventilation system

In our prototype, the ventilation system was modeled as an embedded controller-based DC fan system, as shown in Figure 2. In particular, the system included two IR sensors. The two sensors were responsible for capturing incoming and outgoing vehicles. Each sensor included a transmitter and a receiver. When there is not an obstacle in front of the sensor, the receiver cannot receive the emitted infrared light from the emitter. Consequently, the input acquired by the STM32 kit would be in an inactive state. Inversely, when having an obstacle in front of the sensor, the receiver of the sensor can receive the responding light from the emitter after hitting the obstacle. Consequently, the acquired input will be in the active state. This effect will be employed for detecting incoming or outcoming objects. In our ventilation system, the first IR sensor was responsible for detecting incoming vehicles. The second IR sensor was for detecting outcoming vehicles. The current number of vehicles inside the parking lots will be the differential values between the incoming and outgoing vehicles. The current number of vehicles was used for computing the fan speeds of the ventilation system. In particular, the maximum power of the fan system was chosen so that it could handle the maximum number of vehicles inside the parking lot. Based on the current number of vehicles, the current power of the fan speed could be computed as in Eq. 1.

$$P_{fan} = \frac{N_{current}}{N_{max}} \times P_{fan\ max} \quad (1)$$

In which, P_{fan} is the current fan power, $N_{current}$ is the current number of vehicles in the parking lot, N_{max} is the maximum number of vehicles the parking lot can handle, $P_{fan\ max}$ is the maximum power of the ventilation fan.

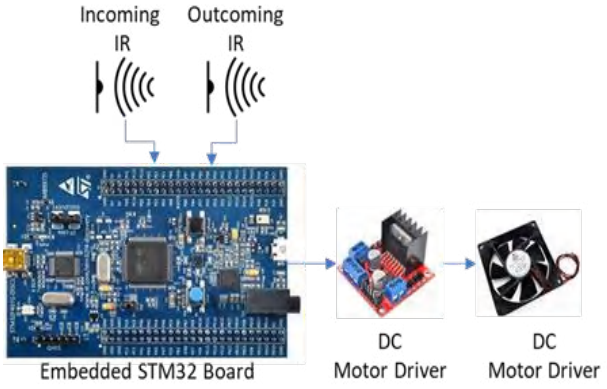

Figure 2. The block diagram of the ventilation system

In our study, the employed IR sensors were LM393. The employed fan motor in our prototype was a DC motor with a diameter of 6 cm, and a max input voltage of 12 VDC. The DC motor driver was L298N. The data acquisition from the IR sensors, fan power computations, and fan speed control were executed on the embedded STM32 kit.

C. Ventilation control system

The ventilation control system was implemented in the LabVIEW framework. The LabVIEW program was connected to the ventilation system controlled by the UART connection protocol. The control system included two operation modes: manual and automatic.

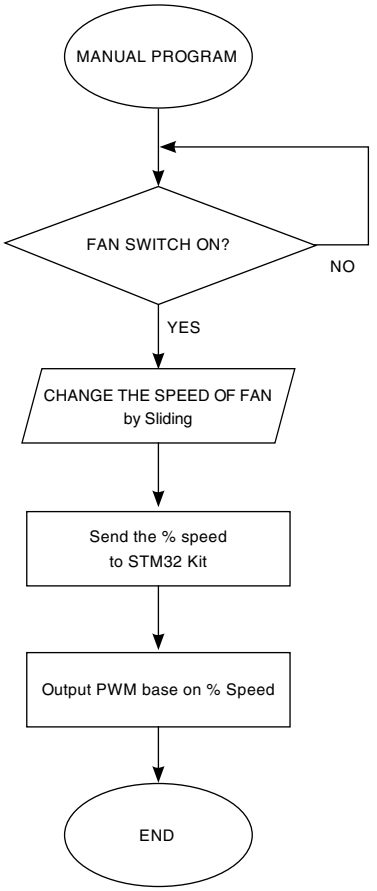

Figure 3. The flowchart of the manual controlling mode

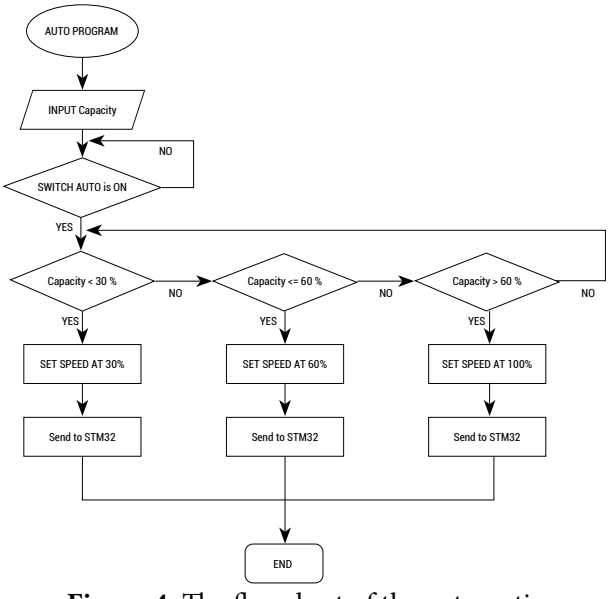

Figure 4. The flowchart of the automatic controlling mode

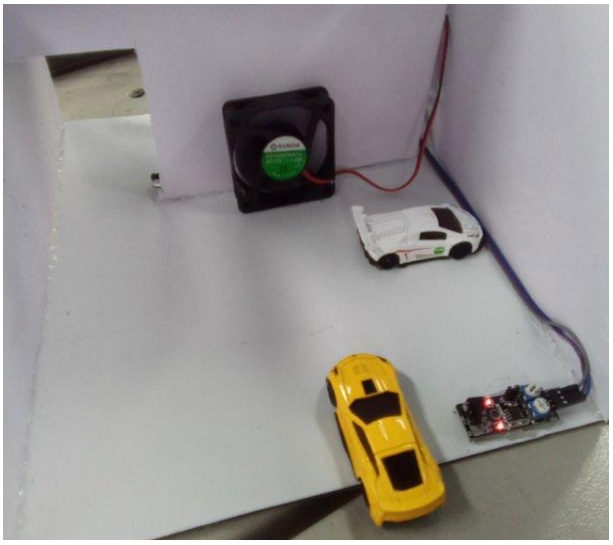

Figure 5. The prototype model of the adaptive ventilation system

In the manual operation mode, as illustrated in the flow chart in Figure 3, the system was composed of a switch and a slider. The system first checked the status of the switch for turning on or off the fan system. When being in the on state, the fan speed could be controlled by the sliding bar in the system's interface. The controlling signal from the sliding bar was transmitted to the ventilation system to control the fan speed whenever its value was changed.

In the automatic operation mode, as illustrated in the flow chart in Figure 4, the automatic or manual modes were controlled by a switch in the control system. For saving the controlling bandwidth during the system operation, only three levels of vehicle capacity were detected for controlling the power of the fan speed. In particular, if the number of vehicles is smaller than 30% of the maximum number of vehicles, the fan speed is operated at 30% of its max capacity. The rule was also applied when the current number of vehicles was larger than 60% and 90% of the maximum number of vehicles in the parking lot. The controlling signals were transmitted to the ventilation system whenever there was a transition among the three capacity levels.

D. Supervising system

The supervising system was operated as a mobile server connected with the control server via the Ethernet connecting protocol. Based on the advantages of the Ethernet connection, the supervising system could be connected with the control system through a local area network (LAN) or a wide area network (WAN). This connection was based on the advantages of the LabVIEW framework, which can help the mobile supervising server connect easily with the main control system for data acquisition, system analyzing & diagnosing. A data management system was also integrated into the supervising system for storing the histories of the system operations. The managed data included vehicles' IDs, the number of incoming and outcoming vehicles, the current number of vehicles, the total number of vehicles in a duration of time, and the fan speeds. These types of information were very useful for analyzing and diagnosing the system's efficiency for optimizing the system execution.

Figure 6. The current system's states are visualized in a local LCD displayer

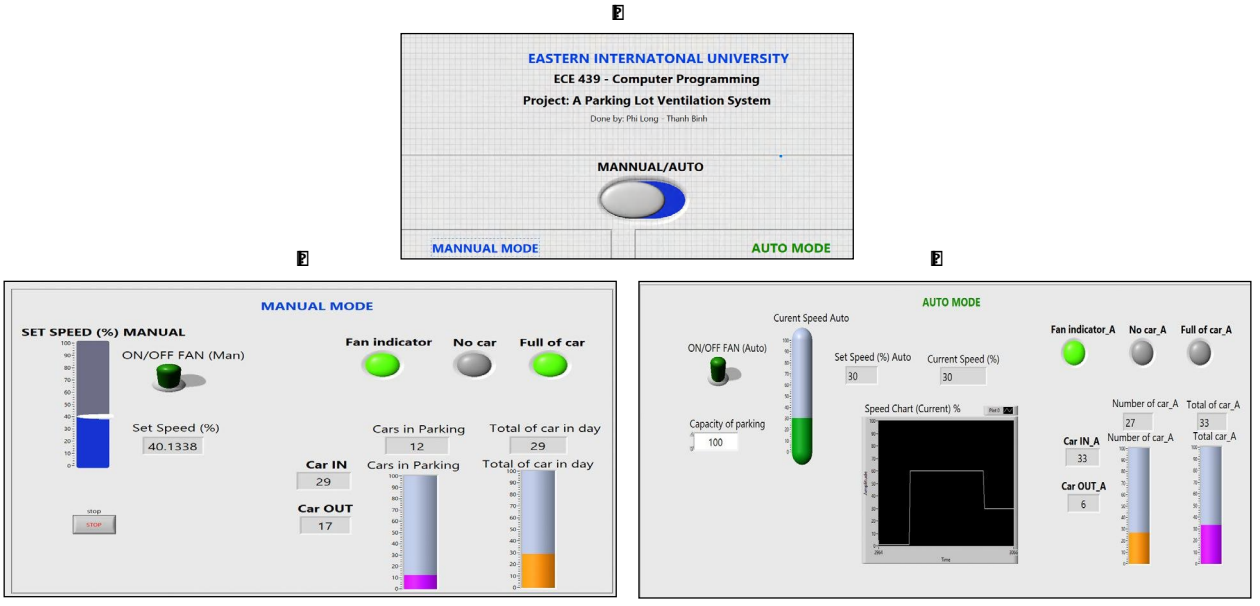

Figure 7. The graphical user's interface of the local server system: (a) the auto/manual controlling switch, (b) the manual controlling interface, and (c) the auto controlling interface

III. RESULTS AND DISCUSSION

The prototype of the adaptive ventilation system is presented in Figure 5. The ventilation system could support a Liquid Crystal Display (LCD) for fast visualizing the information of the current system, as shown in Figure 6. The current system states include the current number of vehicles and the fan speeds. Moreover, the local server system implemented in the LabVIEW framework had the interface shown in Figure 7. In particular, the user first selected the operational mode of the ventilation system control by choosing the state of the switch (Figure 7a). In the manual model, the user could control the on/off state of the fan system using a switch controller. The current fan power level was acquired and visualized in the manual interface (Figure 7b). Moreover, the number of incoming cars and outcoming cars was also acquired from the ventilation system and visualized in the interface. Additionally, the indications of special cases including on/off fan states, no car state, and full of car states were also visualized in the system control interface. In the auto mode (Figure 7c), we also had an urgent switch for turning on and off the fan immediately. Besides the information visualized in the manual mode, the chart visualizing the current speed of the motor was also integrated for analyzing the motor speeds in real-time. In the supervising system, as shown in Figure 8, we could collect the current speeds of the fan system remotely via the Ethernet connection. The current number of cars in and cars out were also able to be acquired.

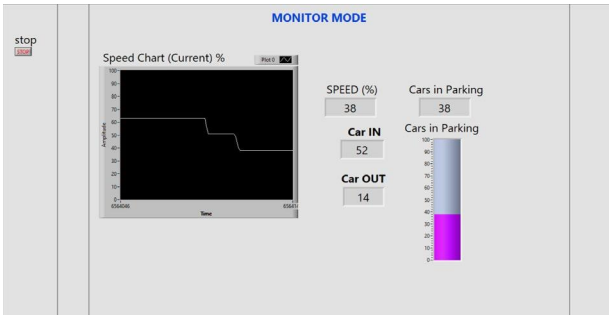

Figure 8. The current system's states are visualized in a local LCD displayer

In this study, although we could develop successfully the adapted ventilation system for smart parking lots supporting energy saving in smart cities. This prototype also contains drawbacks that need to be solved in further studies. First, this prototype was only the scaled version of the real ventilation for the parking lot. Moreover, in this study, we could only control the DC motor with three levels of speed. In further studies, we will enhance the resolution of motor speed control to 1% of the maximum motor speed. We will also apply the concept in this study to design the real ventilation system for smart parking lots. Second, the incoming and outgoing vehicles were counted on the signals acquired by the two IR sensors. This concept might not be very accurate in real systems. In future studies, we will implement computer vision techniques for quickly detecting the number of vehicles in and out of the parking lots and detecting the identification of each vehicle.

IV. CONCLUSION

Ventilation systems are important to smart parking lots that usually have a high density of inside vehicles. Effectively designing and controlling the power of ventilation systems based on the number of vehicles can help optimize power consumption in smart cities. In this study, we successfully designed the adaptive ventilation system control support to resolve this necessity. The system could support supervising and diagnosing the system states based on both local and global data management systems. This concept will be implemented in the real ventilation system to optimize the power consumption of smart parking lots in smart cities.

ACKNOWLEDGMENT

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EASTERN INTERNATIONAL UNIVERSITY
SCIENTIFIC CONFERENCE 2023 (EIUSC 2023)
PROCEEDINGS

BUILDING A SYSTEM TO MONITOR AND MANAGE THE WEIGHT GROWTH OF PIG FARMS

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Abstract: The paper presents a system for monitoring and managing the weight growth of pig farms. The PLC S7-1200 central controller connects to the SCADA interface designed on WinForm to control and monitor the actuators moving pigs in and out of the LoadCell weighing area and conducting weight checks. Each pig is attached to one RFID tag to read, write and monitor weight at the desired interval of time and the data will be fed into a database from the Arduino Uno to the SCADA interface. Solve the problem of monitoring and weight management of pig farms today by building a dynamic tracking and weighing system. The system is highly applicable, convenient for users, easy to search for data when needed and outputs reports. The model has two-layer security with an RFID card and a user-selected password.

Keywords: *RFID, Agriculture, Weight, Visual Studio, SCADA*

I. INTRODUCTION

Currently, large pig farms are focusing on improving the quality of breeding stock, constructing technically correct pens with requirements for temperature, humidity, ventilation, hygiene, and automatic feeding according to the needs of each developmental stage. Evaluating growth rates based on weight affects feed conversion ratios (FCR). Monitoring the weight of each pig to detect any health issues will impact the FCR of the entire herd (E. Vranken et al., 2017). Collecting and managing weight data for a large farm takes a considerable amount of time and effort, so it is necessary to establish a monitoring system to manage the weight growth of pigs.

Studies of pig farms are common and varied in different functions (M Santosh Pandey et al., 2019; A. Wongsriworaphon et al., 2015; W. X. Zhu et al., 2017; H. Skjervold et al., 2015; Geunho Lee et al., 2019; Hyungi Kim et al., 2014). In the study (M Santosh Pandey et al., 2019), the author developed a monitoring system using IC Tags to evaluate the stopping time, movement, and pig's stress level. In article (A. Wongsriworaphon et al., 2015), the author studied the weighing of pigs through algorithms and image processing techniques. In (W. X. Zhu et al., 2017), the author proposed a monitoring and management system for farms through IoT. An automatic wireless network for detecting and disinfecting in a disease-infected environment is studied in the article

(H. Skjervold et al., 2015). In addition, research on temperature and humidity stability in pig farms. These studies aim to provide solutions for building an intelligent farm, ensuring accuracy in pig weight, managing each animal on the farm, and collecting data to provide protocols for the pig farming industry (Geunho Lee et al., 2019; Hyungi Kim et al., 2014). However, these studies are independent and it is difficult to expand the features and scale of the farm or use the company's SCADA software to increase costs.

The main content of the research paper is the development of hardware and software systems on a computer using Winform C# to create a SCADA interface for monitoring and managing the growth level of pig farms. The structure of the article includes Part 1 - Introduction. Part 2 - System design and construction. Part 3 - Model completion and system operation evaluation. Finally, there are conclusions and references.

II. DESIGN AND CONSTRUCTION OF THE SYSTEM

A monitoring system managing pig weight growth requires components such as sensors, computers, controllers, software, and communication systems. This system will help humans perform tasks such as automatically measuring the weight of each pig, storing this information over time to create a shared database, establishing growth analysis reports for each pig and the entire herd, and sending this information to farm managers. These tasks will be done thanks to the modules as shown in Figure 1.

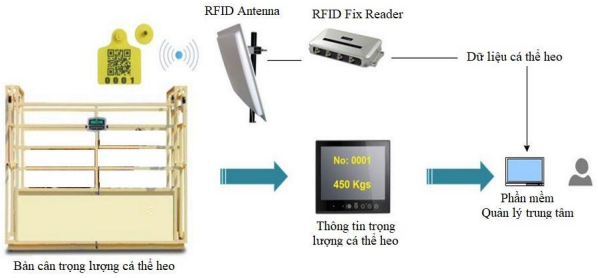


Figure 1. Pig weight monitoring model with scale-integrated RFID device

A. System block diagram

Figure 2 presents a block diagram of the system with functional blocks designed based on the model in Figure 1. The system maintains the function of monitoring the weight of individual pigs on the SCADA interface. The RFID module is responsible for identifying each pig and sending data to the SCADA interface on the computer through the Arduino module. Then, this data is processed by the management software (SCADA interface) and monitors the growth and weight gain of the pig herd. This data will be sent to the PLC controller to control the intelligent and automated systems on the farm, such as the feeding system, irrigation system, and other systems.

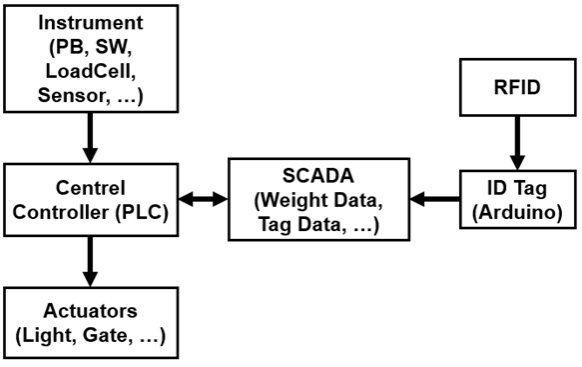
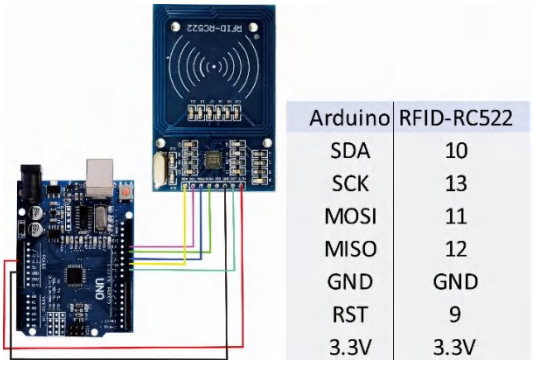


Figure 2. System block diagram

a. Module ID Tag

This module is designed to include an Arduino module combined with an RFID RC522 module that functions to authenticate and identify individual pigs based on radio frequency technology. Both devices operate on the same frequency, and the frequency commonly used in RFID is 13.56 MHz. The RFID reader emits an electromagnetic wave at a specific frequency, and the RFID tag device within the operating range senses this wave and collects energy from it to transmit its code to the RFID device. At that moment, the RFID reader identifies which tag is active within the electromagnetic wave range (Roy Want et al., 2006).



Arduino	RFID-RC522
SDA	10
SCK	13
MOSI	11
MISO	12
GND	GND
RST	9
3.3V	3.3V

Figure 3. Arduino with RFID

b. Module Dynamic Weight

This module is built from a Siemens PLC that reads Loadcell values through a LoadCell JY-S60 amplifier circuit. The Siemens 1214C DC/DC/DC PLC combines a processor, an integrated power supply, 14 digital inputs, and ten digital outputs, with two analog inputs of 0-10 VDC in a compact and powerful structure. The memory size of the 1214C for program and data is 50kB. This PLC has a network card with an RJ-45 connector for PROFINET communication. The PLC 1214C became an effective solution for the control (L.A. Bryan et al., 1997).

Figure 4. LoadCell 5Kg

The author uses a Loadcell sensor with a load capacity of 5 kg (Figure 4) to measure the mass of an object. The Rated Output is 1.0 +-0.15 mV/V, with an operating voltage of 5VDC. The sensor is made of Aluminum and can operate in temperatures ranging from -20 to 65°C.

The JY-S60 loadcell amplifier circuit (Figure 5) is a circuit that amplifies the input signal from the force sensor (loadcell) and the gain signal output. This circuit is capable of amplifying the signal from the load cell and provides signal output including 0-5V, 0-10V, and 4-20mA. It operates at a voltage of 24VDC and has input signal options with sensor sensitivities of 2.0mV/V, 1.0mV/V, and 1.5mV/V. The operating temperature range is -20 to 80°C.

Figure 5. LoadCell Weight Transmitter Amplifier JY-S60

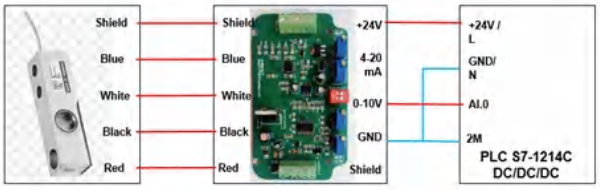


Figure 6. Diagram LoadCell – Amplifier circuit - PLC

In the Dynamic Weight module, the author offers a method of using a discrete-time variation low-pass filter as it is developed independently of the system model, thus making the measurement results avoid vibrations and interferences occurring in the system, although requiring extensive adjustment of the cutting frequency through testing (Yamazaki, T et al., 2007). (S Einarsson et al., 1978). The filter is designed by cascading first-order IIR filters that look like formula (1):

$$y_i(n) + a_k(n)y_i(n-1) = b_k(n)[y_{i-1}(n) + y_i(n-1)] \quad (1)$$

i = [1,..., k] with k being the number of filters in the layer.

i = [1,..., N] time steps until the load starts to leave the scale.

The output of the force sensor (loadcell) is referred to as the input of the layer, and the estimated weight is the output at $y_k(N)$. The coefficients are calculated as functions of the time-varying cutting frequency and the phase sampling rate.

The time-varying cutting frequency decreases exponentially to shorten the transient response. It starts at the initial value f_0 and decreases to the limit f_∞ at a rate of α, calculated using formula (2):

$$F_c(n) = f_\infty + (f_0 - f_\infty)\lambda\frac{n-1}{\alpha(N-1)} \quad (2)$$

c. SCADA Interface

In this paper, the author builds a SCADA interface using Visual Studio C# software, which functions as a manager, receiving data, sending data, and storing data. WinForm runs on the Windows platform, saving on license costs and not requiring high computer configuration compared to SCADA systems from other PLC manufacturers. This solution can connect with Arduino to record ID Tag data for individual pigs, while the PLC is also connected to a SQL database. Kepware OPC (KEPServerEX) is used to link the SQL Server and PLC, allowing data to be input into the database and potentially expanded to the Cloud.

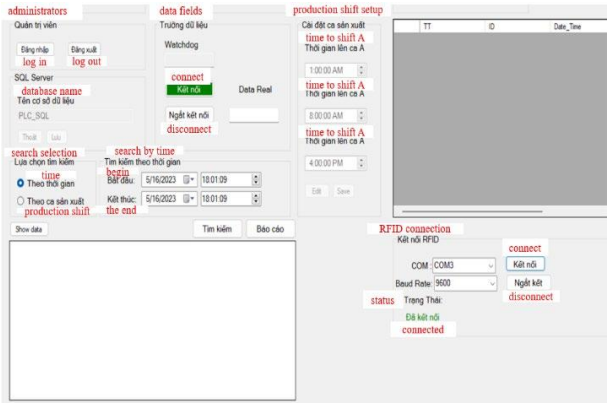


Figure 7. System monitoring Scada interface

Configuring and installing KEPServerEX is easy to do on medium-sized computers. In this model, the author uses a computer with a configuration of 4GB of RAM and a Core i3 processor to create the SCADA interface. KEPServerEX acts as an intermediary that implements data connections from the PLC to Visual Studio and vice versa. KEPServerEX will be installed in the computer running SCADA through the computer's physical connections to the PLC, and KEPServerEX will retrieve data from the PLC and then send the data through

Visual Studio C# and vice versa. Figure 7 is the SCADA interface that monitors the system. Data from each weighing of each pig collected via PLC will be stored through SQL Server database software, thereby exporting reports and storing production data in different formats. Figure 8 is the database used in the system to store data on pig weight scales (tag code, time, weight).

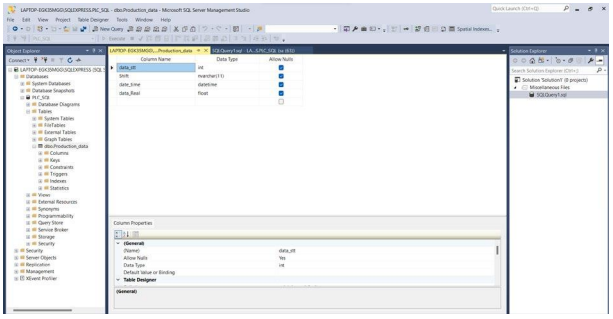


Figure 8. SQL database system

B. Algorithm flowchart

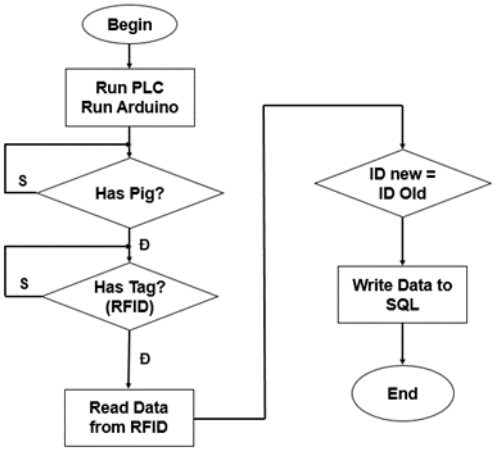


Figure 9. Diagram of reader ID tag algorithm

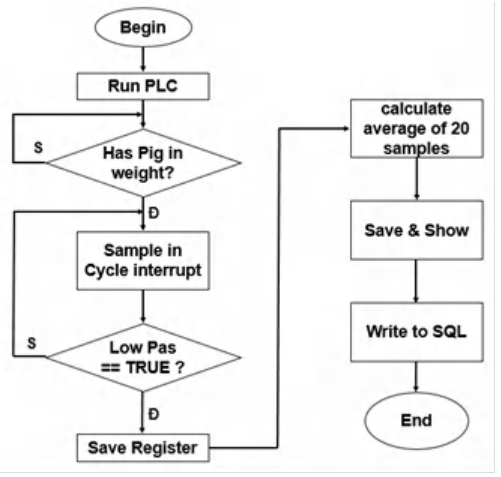


Figure 10. Diagram of dynamic weight-Pig algorithm

Figure 9 depicts the activity diagram of the ID tag module. Figure 10 depicts the dynamic weighing program algorithm using the PLC module on individual pigs.

III. COMPLETING THE MODEL AND EVALUATING THE SYSTEM OPERATION

A. Completing the weight growth monitoring and management system of Pig Farms

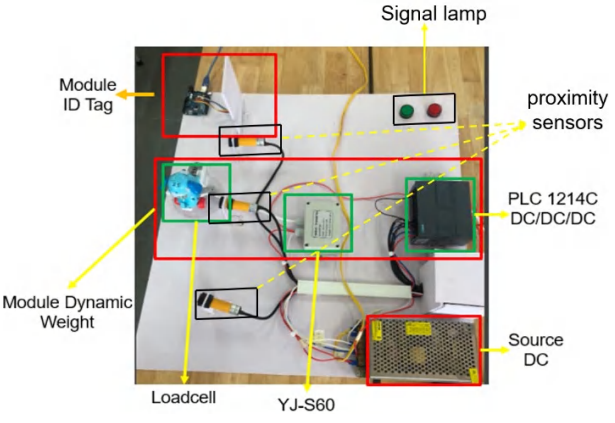


Figure 11. Hardware model of the system

Figure 11 depicts the hardware model designed based on the block diagram (Figure 2). The system consists of DC power supplies for control devices, dynamic weight modules (loadcell, YJ-S60 amplifier circuit, and PLC S7-1200), proximity sensors, ID tag modules, and actuators (Figure 11).

B. System operation results

The Module ID Tag reads data from the RFID tag, and the Dynamic Weight Module performs the task of weighing individual pigs and sending the data back to WinForm for building a control, monitoring, management, and data storage interface. The proximity sensors are responsible for detecting the pig's ID tag, detecting the pig on the weighing table, and detecting when the pig leaves the weighing area. The operator or manager can control and monitor the entire system on one computer. For the Dynamic Weight Module, the author is building a test model using a 5kg Loadcell. Therefore, the test sample here is an electronic toy, a moving object with additional weights attached to move on the weighing table to achieve the most accurate results when implemented in reality.

On the system monitoring interface (Figure 12), users can monitor pig information weighed in real-time (data_stt, shift, data_time, data_real). In addition, the interface also supports users to search for pig weight data over time. From there, helping farmers promptly handle problems arising from uncontrolled weight gain or insufficient weight, reducing pork quality and seriously affecting the economy of pig farms.

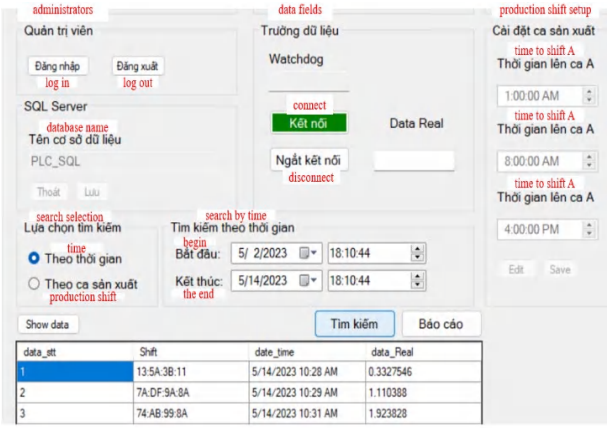


Figure 12. System monitoring interface

Table 1. The weighing results of 2 values with actual weights of 0.33 kg and 1.11 kg (Unit: kg)

Real Value (kg)	Model Value (kg)	Real Value (kg)	Model Value (kg)
0.33	0.3335317	1.11	1.1077788
0.33	0.3304625	1.11	1.1017742
0.33	0.3396409	1.11	1.1117599
0.33	0.3264891	1.11	1.1060341
0.33	0.3335607	1.11	1.1143987
0.33	0.3279153	1.11	1.1172405
0.33	0.3286841	1.11	1.1117638
0.33	0.3225288	1.11	1.1193841
0.33	0.3320002	1.11	1.1133531
0.33	0.3327211	1.11	1.1060695

Table 2. The weighing results of two values with actual weights of 1.91 kg and 2.87 kg (Unit: kg)

Real Value (kg)	Model Value (kg)	Real Value (kg)	Model Value (kg)
1.91	1.9014107	2.87	2.8636309
1.91	1.9014433	2.87	2.8633557
1.91	1.9038629	2.87	2.862306
1.91	1.9142973	2.87	2.8625145
1.91	1.9177466	2.87	2.8731498
1.91	1.9009194	2.87	2.8639959
1.91	1.9102969	2.87	2.8786411
1.91	1.9155745	2.87	2.8631015
1.91	1.9013732	2.87	2.8680198
1.91	1.9067001	2.87	2.8749265

IV. CONCLUSION

The paper presents a solution to build a pig farm weight growth tracking and management system on Visual Studio C# software. With the system's model and test results partially meeting the application requirements, it can be implemented into real-life models. The system is designed to be easily upgraded on a larger scale or can be put on control and monitoring on the Internet, with data sent to the cloud via MQTT protocol through Kepware OPC (KEPServerEX). From there, farm owners can monitor all their small farms or scientists in the livestock agriculture industry can rely on the collected data to analyze and evaluate the best regimen to achieve high economic efficiency.

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DESIGN, IMPLEMENTATION AND TESTING OF AN AUTOMATIC CONTROLLER FOR THE COCOA BUTTER PRESS MACHINE

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Abstract: This paper introduces a press machine's automatic controller to control pressing processing. The hydraulic oil temperature and pressure and the movement time of the pressing cylinder were controlled by a programable logic controller (PLC). The pressure sensor produces analog signals while the pressure is rising. The analog signals will be transferred to the PLC to control the pressing. The thermal sensor was used to send an on/off signal to the PLC. When the oil temperature exceeds the setting temperature, the PLC will stop the hydraulic pump to protect the system. The cylinder pressure and oil temperature will be simultaneously indicated on analog gauges and the HMI screen. The Ladder diagram is used to control the speed of the pressing cylinder through the screen to optimize the pressing process, maximize the cocoa butter, and minimize the pressing time. And, the HMI touchscreen interface was also designed and coded so that operators can interact more accurately with the system. The controller will be tested with a cocoa butter press machine with a 50 kg per hour capacity.

Keywords: *Automatic controller, PLC, cocoa butter press, cocoa processing*

I. INTRODUCTION

Nowadays, automation technology is widely applied in manufacturing to improve productivity, product quality, and reduce wastage, labor cost… (Gunasekaran, 2009). Especially in the food processing industry, food safety management is very important. All of the food factories have to be certified in food safety certification HACCP and prerequisite programs (Stephen T. Beckett et al., 2017).

The chocolate industry is a part of the food industry. This industry is one of the many sectors within the food industry that produces and sells chocolate products. The main manufacturers of chocolate in the world are Mars Wrigley Confectionery, Ferrero Group, Mondelēz International, Meiji Co Ltd (ICCO, 2020). The production is fully automated in their factories. However, bean-to-bar chocolate production has become a trend in recent years. It is known as craft chocolate and started as a way for small chocolate makers to distinguish their chocolate from both chocolatiers and mass-produced chocolate. The technology is shown in Figure 1 (ICCO, 2020). Most of the manufacturers produce using this technology are small-scale by manual or semi-automatic methods.

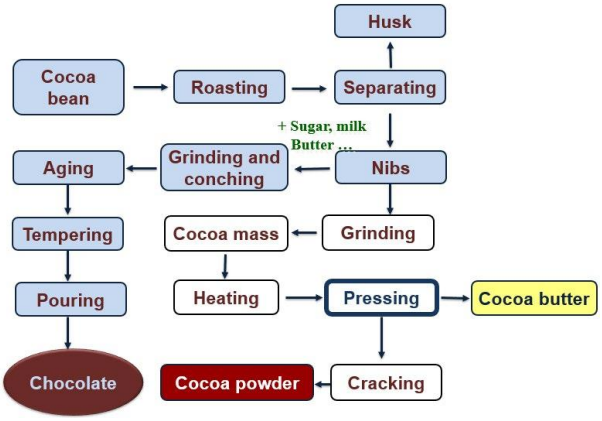

Figure 1. Bean To Bar technology

In this work, we focused on designing and implementing an automation of a press machine for the pressing process.

Cocoa butter is relieved from cocoa mass in this process. Cocoa mass usually contains some 47 – 56 % of cocoa butter and normally, the cocoa powder produced has residue butter containing 10 – 24 %, (Stephen T. Beckett et al., 2017).

Hydraulic presses are normally applied for cocoa butter pressing. There are two types of presses: horizontal presses or vertical presses.

In horizontal presses, the pressing chamber is horizontal and they are often used in mass production. A structure of the press is shown in Figure 2 (Stephen T. Beckett et al., 2017).

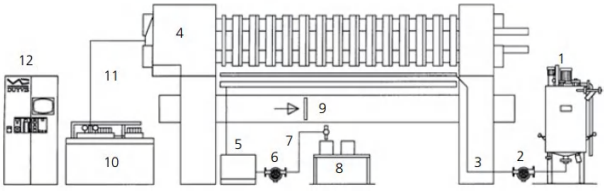

Figure 2. Horizontal hydraulic press

(1) Cocoa mass conditioning tank; (2) cocoa mass pump; (3) pipe for cocoa mass; (4) hydraulic cocoa press; (5) cocoa butter scales; (6) cocoa butter pump; (7) cocoa butter pipe; (8) cocoa butter blocking off; (9) cocoa cake pushing conveyor; (10) hydraulic pumping unit; (11) hydraulic pipe; (12) electric control with panel

The pressing chamber is vertical in vertical presses and they are often used in small production. A structure of the press is shown in Figure 3.

Quantity of butter extracted bases on temperature and pressure of cocoa liquid. It is proportional to temperature and pressure as shown on Table 1, (V. Ganesan, 1982).

Table 1. Quatity of butter extracted at various temperature and pressure

Pressure (kg/cm²)	**99.5**	**149.2**	**198.2**	**248.7**
Temperature (°C)				
50	33.8	37.4	41.1	43.0
60	35.3	38.6	41.8	43.6
70	36.1	40.1	43.1	44.8

II. METHODOLOGY

The application environment

The design and implementation works were done in a machine construction company (Saigon Cocoa Company - SGC). This company designs and manufactures manual cocoa butter press machines and many machines for cocoa processing.

The testing work was done in a chocolate manufacturing company (Marou chocolate company). The company considers being of automation of machines to increase quality and food safety.

A. Material

1. The manual cocoa butter press machine

The manual cocoa butter press machine at 50 kg/h is a hydraulic press machine (Figure 3). The hydraulic system is the core working of the machine. The pressure is controlled by

a manual adjustable valve and displayed on the pressure gauge. The valve to move the cylinder up or down is turned on or off by a switch.

2. Machine operating

The pneumatic cylinder opens and closes the lid of the pressing bin to feed cocoa liquid bags. After feeding and closing the lid, the switch turns on to move the hydraulic cylinder up for pressing with the following periods:

The first: The adjustable valve opens so that the pressure is minimum (lower 0.5 MPa) and keeps it until after cocoa butter runs out 3 minutes.

The second: Adjust the valve until the pressure gauge indicates the pressure value of 50 MPa, and stop within around 6 minutes.

The third: Adjust the valve until the pressure gauge indicates the pressure value of 100 MPa, and stop within around 6 minutes.

The last: Adjust the valve until the pressure gauge indicates the pressure value of 125 MPa, and stop within around 8 minutes.

When the machine works with this process, cocoa butter releases from cocoa mass around 33 – 38 % and the time consumption of the pressing process is 25 minutes (*source: SGC*)

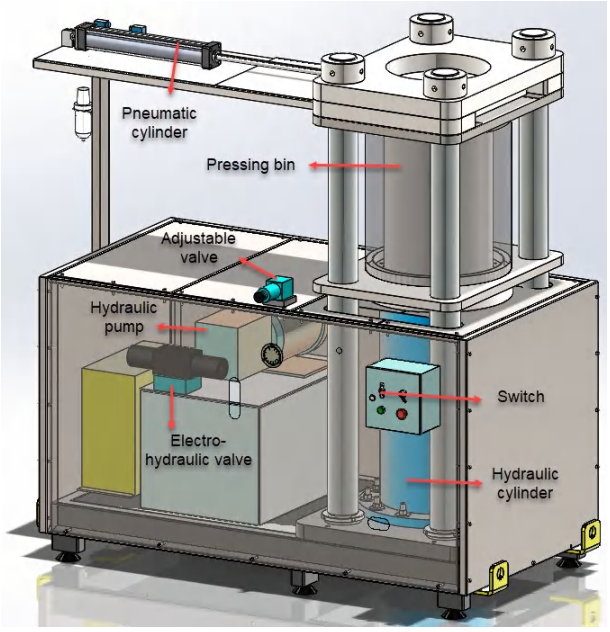

Figure 3. The manual cocoa butter press machine at 50 kg/h (Photo by SGC)

3. Hardware and software components

Both hardware and software components are required for the implementation of the control box for the automated press machine.

a) System hardware

The whole system consists of a power supply unit, a controller system and actuators:

- The controller system includes a PLC FX3u and an FX3u-4AD to read the analog signal from the pressure sensor and calculate the nearly exact pressure value in the cocoa pressing chamber to display the value to the monitor and execute the logically programmed steps via IO points, or X, Y terminals; an HMI screen GS2107 was also used to aid operators to interact with the PLC.
- The actuator system consists of pneumatic solenoid valves controlled by intermediate

relays, hydraulic solenoid valves, and pressure relief valves controlled by solid state relays.

- Buttons are also used to send input signals to the PLC to start, stop and reset the process.
- Limit sensor is a type of sensor used on pneumatic cylinders to receive the position signal of the piston sharp at the setup length. To be specific, when the magnet ring at the inner end of the piston goes past or stops at the position of the limit sensor, the internal circuit of the sensor will sense a magnetic signal and close the normally open contact point, thus creating an On signal (Tubaishat, M., & Madria, S, 2003).
- A pressure sensor is a type of transducer that is used to convert the physical value of the pressure into electrical signals, which usually are voltage or current. For measuring the pressure in the pressing chamber, the pressure sensor used in this project is an SR1 series with the pressure sensing limit ranging from 0 to 250 bar, or 25 MPa. The output signal type of the sensor is an electrical current, ranging from 4 to 20 mA, corresponding to the pressure measuring range, of 0 to 25 MPa.
- The temperature sensor includes a K-100 thermocouple and an AX4 controller. The K-100 thermocouple applied the thermoelectrical phenomenon to measure the environmental temperature, it is consisting of two wires of different metals joined at each end, and when the temperature change, a differential in voltage appeared at the two junctions of the metal wires (Stephenson, D. 1993). The AX4 unit is operated in On/Off mode and is set up to read the temperature in the hydraulic tank from the K-100 sensor and display the current value when the temperature goes up to a certain point, which is preset by the operator, the AX4 will send a signal from an internal relay output point to the PLC the inform that the system is overheated.
- Solenoid valves are a type of instrument that are used to give the controller accessibility to Cylinders or to convert electrical signals into pneumatic/hydraulic controlling signals (Van Varseveld, R. B., & Bone, G. M, 1997).
- Relay is another type of instrument that is widely used in industrial applications, mainly used for signal isolation and voltage signal conversion (Zimmerman, K., & Costello, D., 2010). In this system, the relays are used to isolate the controller with the actuator to prevent overload in the controller unit. The relays operated on 24 VDC via PLC output signal to control solid state relay, or SSR for short, and a buzzer using 24 VDC signal. The SSRs are used to control high wattage 220 VAC current and separate the 24 V rated components from the high-power 220 V rated components.
- HMI, Human-Machine Interact GS2107 is a control and display type instrument and often assemble on a control panel for operators to interact with the machinery, for example, input setpoints, monitoring system value, or setup operating mode. The HMI screen is also used to aid operators to interact with the PLC.

b) System software

There are two separate software used to program the controller unit: GX Works 2 for

PLC ladder programming, and GT Designer 3 for HMI screen designing.

B. Method

For the methods, a flowchart for the operation of the automated press machine is developed and presented in Figure 4.

1. Flowchart for the operation of the automated press machine

PLC programming was used to connect the cylinder and sensors and the advantage of the PLC was that it did not need a complicated circuit design because of assigning variables directly to the input and output values and then it connected them for control. The PLC also helps the operator to ensure that the cylinder is working properly according to the set pressure, so the hydraulic cylinder operates according to the steps below:

Firstly, before operating the machine, the pneumatic cylinder switch is turned to the right to close the lid. Then, the operator uses the HMI touchscreen interface to select pressing mode, there are four pressing modes, and the default setting parameters for each. However, the user can enter their own parameters after logging into the program. The default setting values are shown in Figure 5.

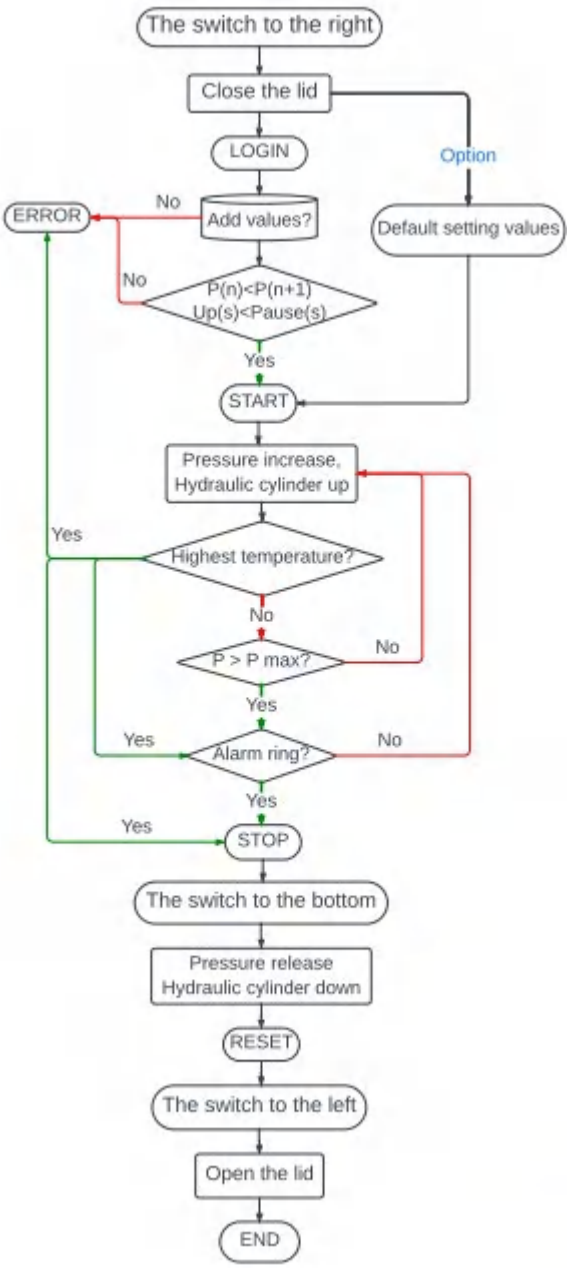

Figure 4. Control flowchart

P is the pressure, and Mode 1, 2, 3, and 4 are the symbols for one, two, three, and four bags of cocoa written in order. Furthermore, the pressure sensor creates analog signals while the pressure is rising, so when the hydraulic cylinder is in each mode, the pressure increase. In addition, the value of the pressure assigned

to the algorithm "Zone Compare (ZCP)" in GX Works 2 is shown in Figure 6.

Time for the cylinder up and pause was based on experiences so that time consumption for each program is similar for each step in the manual operation.

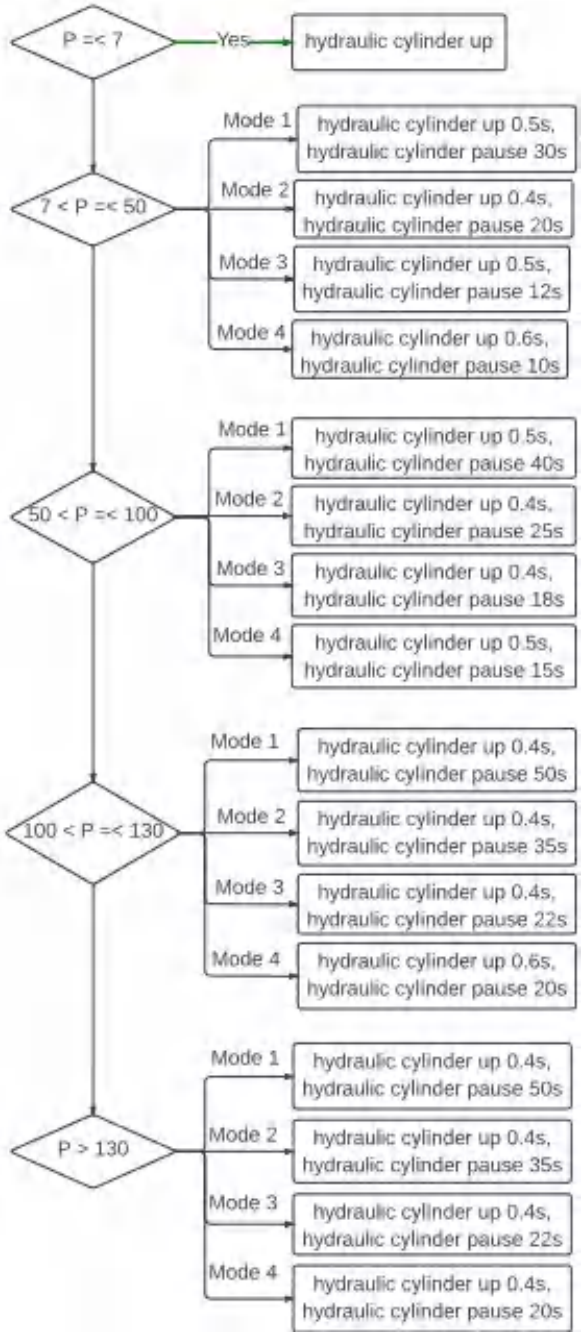

Figure 5. Default setting value

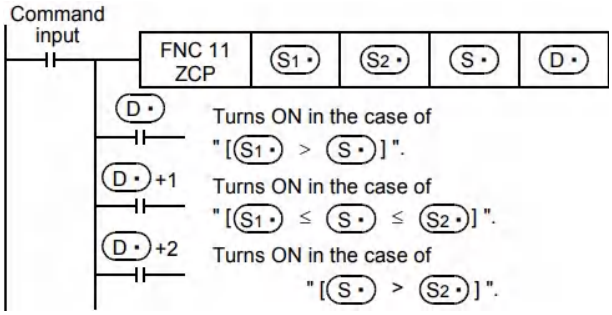

Figure 6. Zone Compare (ZCP)

(Source: Mitsubishi user manual)

ZCP is a 16-bit operation and this helps PLC programming be logical, simple, and easy to follow the process because it operates in sequence from low-pressure value to high-pressure value, and when the latter program works, the previous program will stop automatically. For example, assigning pressure parameters less than or equal to seven is program 1, when program 1 runs, the hydraulic cylinder will push up, and the pressure value will also increase, and if the pressure value increases to eight, program 1 will stop and program 2 (7< P =< 50) will operate.

Secondly, after having parameters, the user presses the start button, and cocoa pressing time, the value of pressure displayed on the HMI touchscreen interface. Moreover, the thermal sensor was used to send an on/off signal to the PLC and if the oil temperature exceeds the setting temperature, the PLC will stop the hydraulic pump to protect the system. At the same time, the alarm ring and HMI touchscreen interface display "ERROR". However, if the oil temperature is smaller than the setting temperature, the machine will run normally. After that, when pressure parameters are greater than 130, the hydraulic cylinder will push up and stop for a user-set time and repeat the cycle within 480 seconds. Then, the

hydraulic cylinder stops automatically, and the alarm ring.

Finally, the user presses the stop button, and the hydraulic cylinder switch is turned to the bottom because it activates the pressure relief valve for three seconds, before lowering the hydraulic cylinder back to its original position, and the HMI touchscreen interface display "DONE". Then, pressing the reset button and the pneumatic cylinder's switch is turned to the left to open the lid and the user will get the product.

2. Ladder programming

Ladder programming is a circuit programming language combined with the graphical logic of mathematics.

GX Works2 programming software has basic instructions that can be found at the top of the software. There are main instructions as follows:

- F5 instruction is a normally open contact.
- sF5 instruction is a normally closed contact.
- S7 instruction is an output instruction.
- F9 instruction creates a horizontal line.
- sF9 instruction creates a vertical line.

3. Design program and simulation

To start GX Works2 programming software, click the desktop icon. Next, click on the project menu and then click on "new" to create a new project. When these steps are completed, Figure 7 will appear.

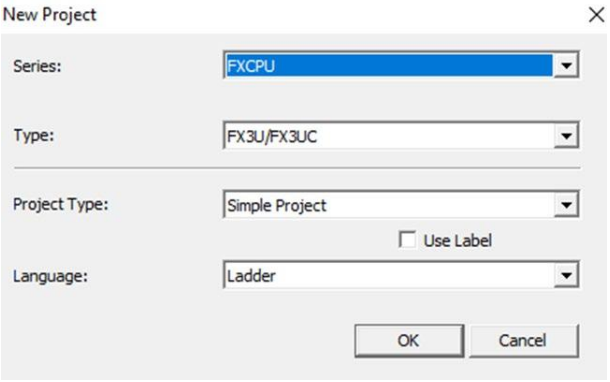

Figure 7. CPU and Project configuration in GX Works 2

Because of using PLC Mitsubishi FX3U, so choose the FXCPU series with the ladder language. In PLC programming, the cocoa butter press machine has six inputs (start, stop, reset, thermal sensor, and two manual modes) and four output values (cylinder up, cylinder down, alarm, and exhaust valve).

Table 2. Program description

I/O device name	Device No.	I/O type
Manual	X0	Input
Manual	X1	Input
Start	X2	Input
Stop	X4	Input
Reset	X3	Input
Thermal sensor	X5	Input
Cylinder up	Y0	Output
Cylinder down	Y1	Output
Alarm	Y4	Output
Exhaust valve	Y5	Output

There are two manual inputs because of using a 3-position ON-OFF-ON toggle switch. To explain, 3-position (on–off–on) toggle switch is used to select the control-valve solenoids. Normally closed limit switches are placed in each circuit between the toggle switch and the solenoids. Their placement is such that the power screw traveling collars contact the limit switch at the limits of the stroke, thus

breaking the circuit and returning the control valve to the center position.

In the simulation function, the program can execute without a CPU module, so the user can test the program visually and then the user can detect the error and correct it.

At the top of the software, click on "Debug" and then choose "Start/Stop Simulation" to execute the program. After appearing two messages, this program is simulated. In addition, select "Online", then click on "Monitor" and choose "Monitor Mode", it helps users monitor input and output values.

4. Design interface of the touch screen

At the right of GT Designer3 software programming software, there are text, switch, lamp, and numerical display/input objects. Choose an object and click anywhere on the screen design area to place the object.

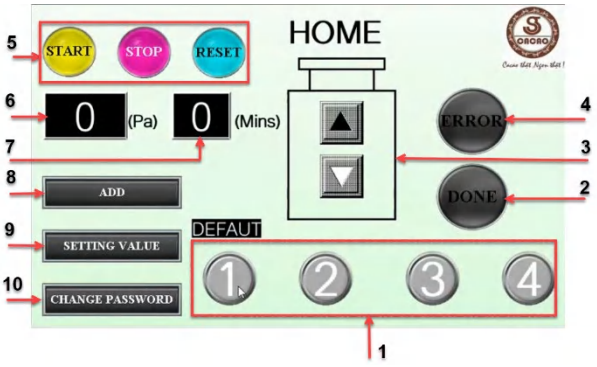

Figure 8. Home page of the control screen

(1) Pressing condition (2) Pressing finish indicator (3) Cylinder status indicator (up–down) (4) Error indicator (5) Control tags (6) Pressure indicator (7) Pressing time indicator (8) Add program tag (9) Setting value tag (10) Change password tag

In Figure 8, the user can operate the cocoa butter press machine without logging and there are tags, indicators, and conditions on this page:

- Pressing condition: the worker presses the button that matches the number of bags of cocoa.
- Pressing finish indicator: when the process is done and the hydraulic cylinder switch is pushed down, this light turns red.
- Cylinder status indicator (up-down)
- Error indicator: this light display when the user enters the wrong or does not enter the time and pressure values. In addition, if the oil temperature exceeds the setting temperature, this light will turn yellow.
- Control tags: the user can press the button on the touch screen if the external button cannot be operated.
- Pressure indicator: displays the value of pressure.
- Pressing time indicator: displays the time of press machine operation
- Add program tag: after pressing the condition, the worker needs to add all values in the algorithm
- Setting value tag: only when the user logs in with the correct password, the system will redirect the page to the setting value page.
- Change password tag: when press this tag, the setting password page will appear.

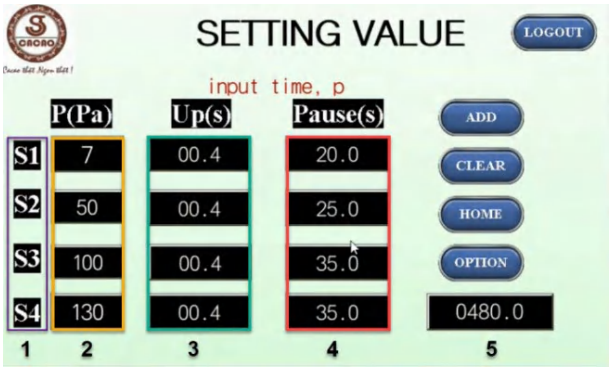

Figure 9. Setting value page

In Figure 9, there is a default program

for each pressing condition. There are five instructions:

1. Pressing step (cannot change)
2. Pressure value of each step
3. Moving the uptime of the cylinder
4. Pause the time of the cylinder
5. Working time of pressing after pressure equals max value

In the indicator from 2 to 5, it will depend on the pressing condition on the home page of the control screen or the user can create new values. This means, if the operator needs to change the parameters, does the following step:

Firstly, click the home program tag and the home page of the control screen will appear. Then, select the pressing condition (1, 2, 3, or 4) and press the setting value tag on this page. Next, input new parameters and choose the add program tag before clicking the option program tag.

Figure 10. Option page

In Figure 10, before clicking the save record tag, parameters will be saved permanently unless the delete record tag is pressed. Moreover, the operator can change the product's name and choose the rename record tag to save this name.

Figure 11. Setting password page

In Figure 11, only the administrator password can log in to change the password, add or remove the worker's machine operation. After logging successfully, the administrator clicks on add tag or edit tag and then inputs a new name and password. In addition, the manager also selects the old operator name and deletes it, so this operator name cannot log in again in this HMI touchscreen interface.

5. Design electrical layout

The electrical layout was designed based on the control flowchart and specifications of the equipment. The electrical layout of the controller is shown in Figure 12 and the panel is shown in Figure 13.

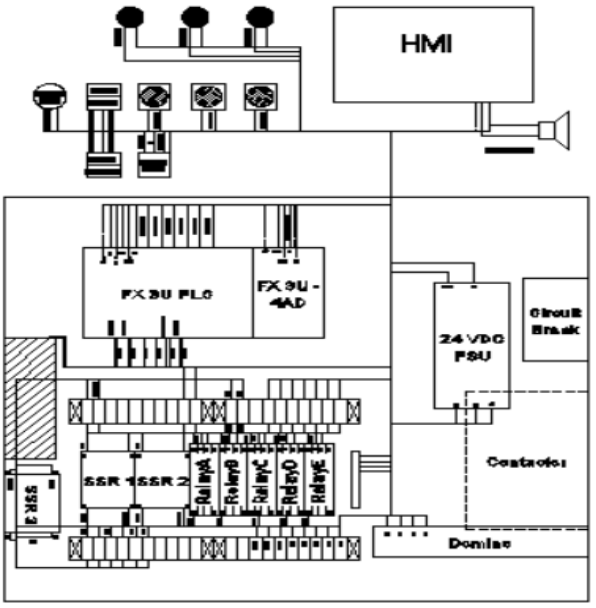

Figure 12. Electrical Layout

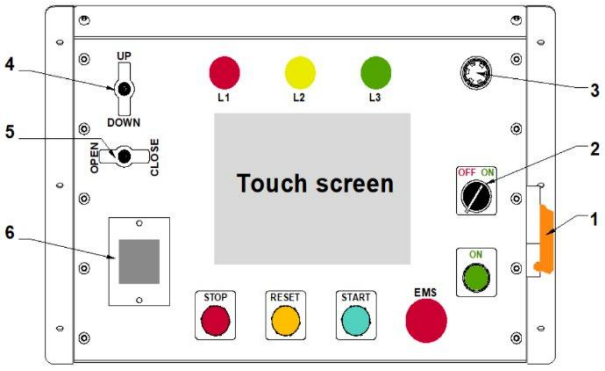

Figure 13. Control panel of the control box

Where: (1) is MCB; (2) is Switch power of control circuit; (3) is Buzzer; (4) is Switch of hydraulic valve; (5) is Switch of pneumatic valve, and (6) is Temperature of hydraulic oil indicator.

III. RESULTS

After design and implementation, the control box was installed in the cocoa butter press machine with a capacity of 50 kg/h for testing.

1. Unloading testing

In this test, the pressure and limit temperature were inputted directly from the keyboard to evaluate the response of the programming. The hydraulic pump was stopped and the buzzer sounded when the temperature input was higher limit value. The pressure input was changed following each program (program 1 to program 5). The system changed the program immediately when changing the pressure input.

2. Testing in production

The testing in production was done in Marou Chocolate factory, Figure 14.

Figure 14. Testing the machine in the Marou chocolate factory

The machine was operated as normal production. The temperature of the cocoa mass input was the same as the production process of the factory (75°C). The quantities bags of the cocoa mass input were fixed as same as the programming required (Mode 1 to Mode 4) and the weight of cocoa mass of each bag was 8 kg. The testing results are shown in the Table 3.

Table 3. Result testing of the machine

Bag Q'ty	Pressing time (minute)	Weight of butter out (kg)	Weight of cocoa powder (kg)	Rate of butter out (%)
1	20	3.3	4.6	41.8
2	22	6.6	9.1	42.0
3	22	10.0	13.8	42.0
4	23	13.4	18.3	42.3
Average	**21.8**	**8.3**	**11.5**	**42.0**

An analog pressure gauge was also installed in the cylinder pressing chamber to compare its pressure value indicator with the pressure value indicator on the screen (from the pressure sensor, Figure 15). The pressure value was similar in all testing times.

Figure 15. The analog pressure gauges

IV. CONCLUSION

The research presented the design and implementation of a control system for a cocoa butter press machine. The working of the system was evaluated by unloaded testing and production testing. The result testing show that the controller completely meets requires of cocoa butter press processing.

In addition, the automation controller press machine has some advantages over with manual press machine as follows:

- Quality management is better because the pressing process does not depend on the operator (according to Marou quality manager)
- The butter extracted from the cocoa mass is 42 % and this is much more than manual pressing (33 – 38 %). It means that the quality of the cocoa powder is better.
- Pressing time is reduced from 25 minutes when pressing by manual to 21.8 minutes, equal 13 %. It means that applying the automation controller can improve the machine productivity.

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EASTERN INTERNATIONAL UNIVERSITY
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PROCEEDINGS

FIELD-ORIENTED CONTROL STRATEGY FOR INDUCTION MOTOR DRIVES

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Abstract: In most civil and industrial applications, induction motors (IMs) play a crucial role due to their simple configuration, high reliability, and cost-effectiveness. Researchers have consistently focused on enhancing control techniques for these motors. Among these techniques, Field-oriented control (FOC), also known as vector control, has been extensively studied and refined to achieve optimal performance and accuracy for IMs. This research article introduces an improved control strategy using the FOC technique with a hysteresis current (HC) controller in the induction motor drive. The proposed method involves comparing reference currents with measured currents to generate switching pulses for controlling the inverter. By incorporating the FOC method with the HC solution, significant advancements in control quality and cost-effectiveness are achieved across various applications. Simulation studies were conducted using MATLAB/Simulink software to validate the proposed approach, and the results demonstrate the effectiveness of the FOC technique with HC for induction motor systems.

Keywords: *induction motors, field-oriented control (FOC), vector control*

I. INTRODUCTION

The induction motor (IM) is one of the most extensively utilized machines, offering remarkable advantages such as cost-effectiveness and robust durability. It finds widespread application in industrial settings requiring a fixed operating speed (Chan et al., 2011). Moreover, the field of power electronic inverters has witnessed remarkable advancements, presenting a diverse range of robust solutions that effectively enhance the performance and efficiency of electric motor operations. These advancements are of great significance to both industrial and domestic applications, where precise speed control and stable motor operation are critical requirements. Recent research endeavors have been dedicated to exploring modern control algorithms aiming to achieve superior control performance in induction motor drive (IMD) systems.

Two-speed control methods exist for induction motors: scalar control (SLC) and vector control. SLC maintains a constant voltage-to-frequency ratio, corresponding to the rated

value, by adjusting the voltage and frequency to regulate torque and speed (Vladimir et al., 2018; Travieso-Torres et al., 2020). This method does not necessitate feedback sensors and remains unaffected by variations in machine parameters during operation, resulting in rapid control responses. However, despite its advantages, the SLC method lacks precision in controlling the torque and speed of the rotor (Kohlrusz et al., 2011).

Field-oriented control (FOC) represents a contemporary technique well-suited for applications that require precise speed control. FOC utilizes a space vector of current to regulate the flux and torque of the motor independently (Tran et al., 2018, 2020, 2022; Farah et al., 2017), thereby simplifying the control of induction motors and reducing the complexity of the nonlinear structure. Although FOC exhibits high efficiency in speed control, its control model is more intricate than SLC (Kumar et al., 2015; Tran et al., 2021). Consequently, FOC finds widespread application in complex control domains. Moreover, with the continuous development and optimization of electronic technology, the implementation of FOC becomes not only more accessible but also highly effective in enhancing and optimizing motor control systems.

In the motor control strategy utilizing the FOC method, incorporating information from current and speed sensors (Pavel et al., 2015; Tran et al., 2020) assumes a pivotal role in the control process. This data, combined with predetermined parameters such as flux, rotor speed, and control algorithms, generates reference control signals. When the reference control signal forms a voltage signal, the pulse width modulation method produces switching pulses, thereby governing the inverter. Conversely, if the reference signal is a current signal, the hysteresis current control (HC) method can generate switching pulses (Banerjee et al., 2016; Tran et al., 2021; Purnata et al., 2017). Despite the HC method's higher ripple, its simplicity and rapid response render it preferable in practical applications (Harshitha et al., 2017).

Furthermore, a significant advantage of the FOC method lies in its capacity to regulate current and output voltage efficiently, achieving high performance and enhancing precision in controlling motor speed and torque. The FOC system implemented in an induction motor drive relies on current and speed sensors to furnish feedback information to the FOC unit. Subsequently, the FOC controller processes this feedback and generates control signals based on the desired control objectives, such as speed or torque regulation. Depending on the specific output signal required from the FOC controller, namely current or voltage, two methods are employed: the HC method and sine pulse width modulation (SPWM) to generate control pulses (Haq et al., 2015; Tran et al., 2018). These control pulses effectively regulate the operation of the inverter, providing the requisite voltage or current to the IMD and ensuring precise control of the speed and torque of the motor. Consequently, the system attains outstanding performance and efficiency in its operations, making it well-suited for precision-demanding and high-performance applications, particularly in industrial and domestic settings.

Based on the advantages of the FOC strategy and the HC method (Tran et al., 2018; Tran et al., 2021), this paper presents a new improvement for the FOC strategy in the IM systems. The proposed enhancement entails a refined current model used to estimate the stator current, which is subsequently compared with the actual stator current of the motor.

The efficacy and feasibility of this solution are verified through simulation studies conducted with MATLAB/Simulink software.

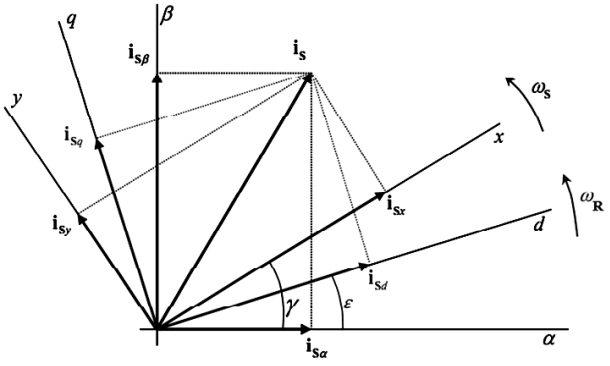


Figure 1. Diagram of the transformation vector

II. PROBLEM FORMULATION AND CONTROL TECHNIQUE

The concise mathematical model of the induction motor is presented herein. The FOC strategy for the induction motor is also introduced in this section. The relationship between the electrical parameters of the induction motor involves various nonlinear quantities, and the following equations can represent the mathematical model of the motor

$$\begin{cases} R_S \boldsymbol{i}_S^S + \dfrac{d\boldsymbol{\Psi}_S^S}{dt} = \boldsymbol{u}_S^S \\ R_R \boldsymbol{i}_R^S + \dfrac{d\boldsymbol{\Psi}_R^S}{dt} - j\omega_r \boldsymbol{\Psi}_R^S = 0 \\ \dfrac{1}{L_S}\boldsymbol{\Psi}_S^S - \dfrac{L_m}{L_S}\boldsymbol{i}_R^S = \boldsymbol{i}_S^S \\ \dfrac{1}{L_R}\boldsymbol{\Psi}_R^S - \dfrac{L_m}{L_R}\boldsymbol{i}_S^S = \boldsymbol{i}_R^S \end{cases} \quad (1)$$

where

$\boldsymbol{u}_S^S$: stator voltage vector;

$\boldsymbol{i}_S^S$: stator current vector; $\boldsymbol{i}_R^S$: rotor current vector;

Υ_S^S : stator flux vector; Υ_R^S : rotor flux vector;

R_S : stator resistance; R_R : rotor resistance;

L_S : stator inductance; L_R : rotor inductance;

L_m : magnetizing inductance; p : pair of pole.

The torque produced by the induction motor can be expressed by

$$T_e = \frac{3}{2}\frac{p}{2}\frac{L_m}{L_R}\left(\psi_{R\alpha} i_{S\beta} - \psi_{R\beta} i_{S\alpha}\right) \quad (2)$$

In this study, the FOC method is implemented to regulate the speed of the motor by independently managing the flux and torque. This is achieved through the separation of the stator current vector into two orthogonal components [x, y]. Specifically, the current component i_{Sx} is utilized as a reference value for flux control, enabling speed regulation, while the current component i_{Sy} is employed to control the torque (Tran et al., 2018). For a visual representation of this process, refer to Figure 1, which illustrates the detailed separation of the stator current vector.

The Clarke transformation is applied to convert real-time current [i_a, i_b, i_c] into a fixed-coordinate system [α, β], and this process is carried out as follows

$$\begin{cases} i_{S\alpha} = \dfrac{2}{3} i_a - \dfrac{1}{3} i_b - \dfrac{1}{2} i_c \\ i_{S\beta} = \dfrac{\sqrt{3}}{3} i_b - \dfrac{\sqrt{3}}{3} i_c \end{cases} \quad (3)$$

According to the FOC control technique, the current components in the [α, β] coordinate system are transformed into the rotating coordinate system [x, y] using the Park transformation formula as

$$\begin{cases} i_{Sx} = i_{S\alpha}\cos(\gamma) + i_{S\beta}\sin(\gamma) \\ i_{Sy} = -i_{S\alpha}\sin(\gamma) + i_{S\beta}\cos(\gamma) \end{cases} \quad (4)$$

The reference component i_{Sx}^* is estimated from the set value of the rotor flux using the following equation

$$i_{Sx}^{*} = \frac{\psi_R^{*}}{L_m} \quad (5)$$

Equation (6) provides the relationship between rotor flux - torque and the stator components in the [*x, y*] axis coordinate system.

$$i_{Sy}^{*} = \frac{1}{p}\frac{2}{3}\frac{L_R T_e^{*}}{L_m \psi_R} \quad (6)$$

where $\psi_R = \frac{L_m}{1+T_R} i_{Sx}$

The rotor flux angle "γ" can be calculated based on the measured rotor speed and the slip speed, which is determined by

$$\gamma = \int (p\omega_m + \omega_{sl})dt \quad (7)$$

where $\omega_{sl} = \frac{L_m}{T_R}\frac{i_{Sy}}{\psi_R}$

The reference current in the [*x, y*] coordinate system is combined with the rotor flux angle and transformed into the [*a, b, c*] system. This depiction is presented in the block diagram shown in Figure 2. Following this transformation, the [*a, b, c*] system is then forwarded to the hysteresis current controller, where switching pulses are generated.

The control pulses of the inverter are generated by comparing the actual three-phase currents with the reference three-phase currents. This process ensures that the actual currents are maintained within the corresponding sensitivity range (Zhang et al., 2017), as depicted in Figure 3.

III. RESULTS

This section presents the simulation results of the HC control implemented with the FOC method, which regulates the speed of the IMD. The simulations were carried out using MATLAB/Simulink software. The main parameters of the motor are listed as P_r = 3.5 (kW), f = 50 (Hz), U_r = 380 (V), p = 2, R_S = 3.288 (Ω), R_R = 2.358 (Ω), $L_S = L_R$ = 0.216 (H), L_m = 0.195 (H). This study conducted simulations under both no-load and 5 Nm load conditions, corresponding to different speed regions. The simulation results included the stator current, rotor speed, electrical torque, and rotor flux responses for the model. Three specific cases were studied: The first case involved the induction motor operating at 1000 rpm speed, the second case had the IM remaining at 1000 rpm speed and then reversing at the same speed, both under no-load conditions, and the last case examined the motor operating at 1000 rpm speed with a 5 Nm load. These simulations allowed a comprehensive analysis of induction motors' performance and behavior under various operating conditions.

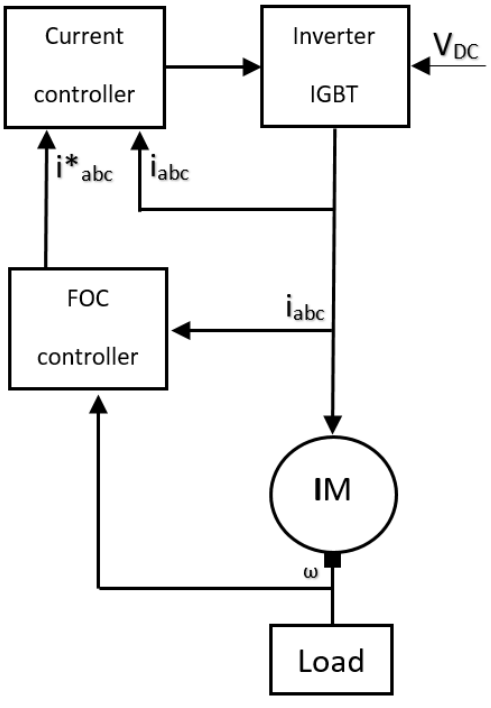


Figure 2. Block diagram of the FOC technique with HC controller

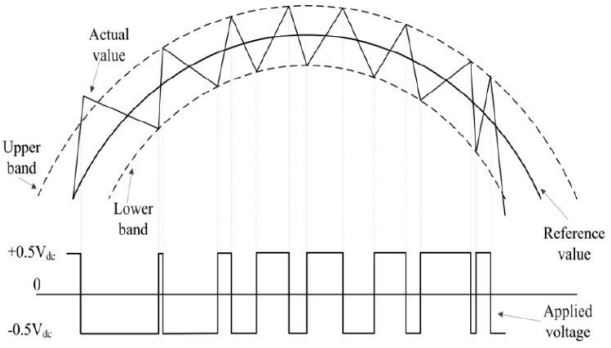


Figure 3. Hysteresis current control technique

A. Case study 1

The motor maintains a constant speed of 1000 rpm during the entire no-load simulation. Figure 4 illustrates the performance of the FOC method with the HC controller. Figure 4(a) shows an initial surge in current intensity in the first 0.05 seconds. From 0.5 seconds onwards, the motor current stabilizes and remains constant until the end of the simulation. The current has relatively high noise. As for the motor speed, it gradually increases from 0 to 1000 rpm within 0.5 seconds. Figure 4(b) depicts the rotor speed accurately and quickly following the set rate, with a slight overshoot that is not excessively high, corresponding to the characteristic of the HC control method, and then adheres to the set speed. The motor demonstrates a relatively good tracking capability, despite Figure 4(c) showing strong oscillations in the torque produced by the proposed FOC method. The magnitude of the torque quickly increases and maintains a constant level during the FOC operation, as shown in Figure 4(d).

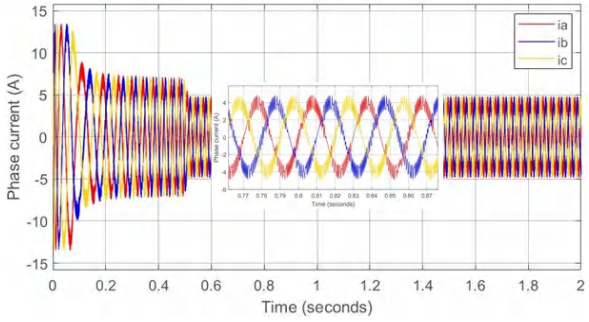
B. Case study 2

The motor operates at the reference speed of 1000 rpm, and then the motor is reversed and runs at -1000 rpm in a no-load condition until the end of the simulation. Figure 5 illustrates the performance of the FOC method. In Figure 5(a), the current exhibits a pattern similar to Case 1 from 0 to 1.0 seconds. Subsequently, from 1.0 to 1.5 seconds, the motor decelerates, undergoes a reversal, and continues to operate steadily. The speed and torque of the motor operate as required, closely following the set values, as shown in Figures 5(b) and 5(c), respectively. The magnitude of the rotor flux, as shown in Figure 5(d), also quickly stabilizes at a constant level during the operation.

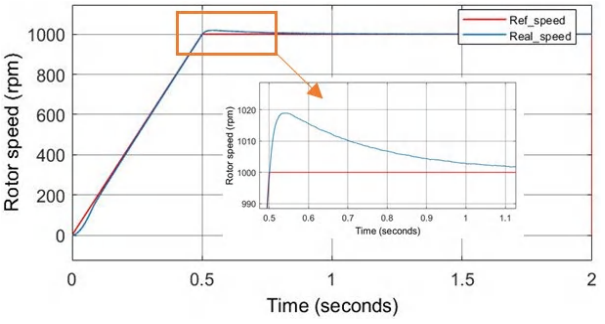
C. Case study 3

In the final case, speed control is simulated at 1000 rpm with a 5 Nm reference speed. The motor demonstrates rapid acceleration and achieves stability, aligning with the desired speed. The results of this investigation are presented in Figure 6.

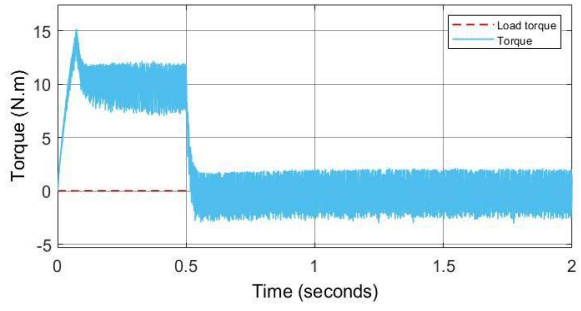
The simulation results confirm the stability and robustness of the proposed IMs control system. Across three distinct control modes, the proposed method effectively maintains the stator current while gradually increasing the flux from 0 to approximately 1 Wb. The motor's speed and torque consistently adhere to the desired set value, satisfying all the specified control requirements.



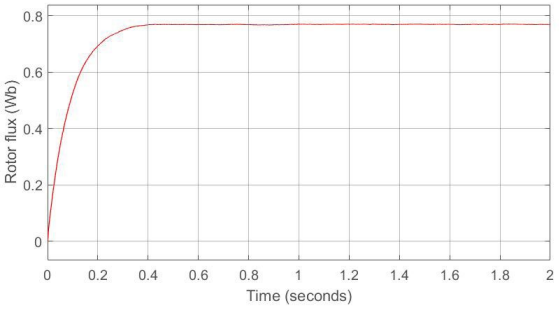
(a) Phase current.



(b) Reference and actual rotor speed.

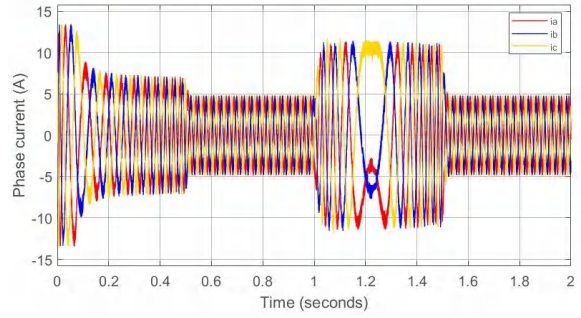


(c) Torque.

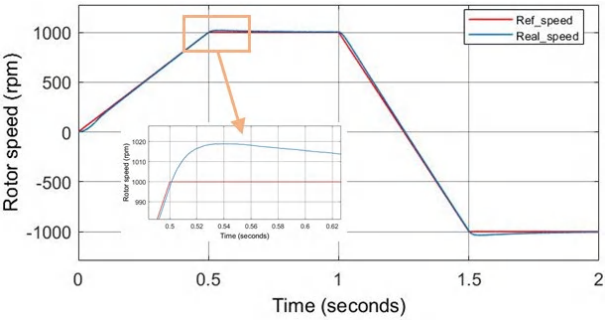


(d) The amplitude of rotor flux.

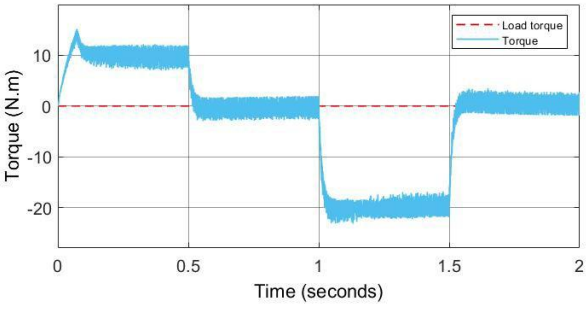
Figure 4. The FOC strategy for hysteresis current controller at 1000 rpm and a no-load condition



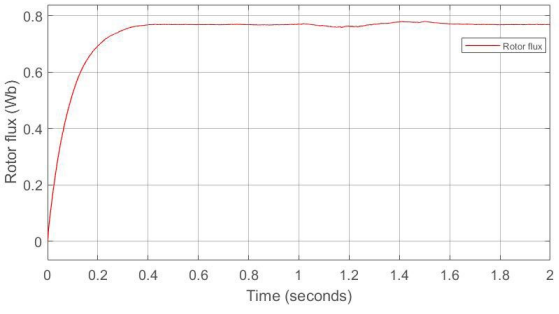
(a) Phase current.



(b) Reference and actual rotor speed.

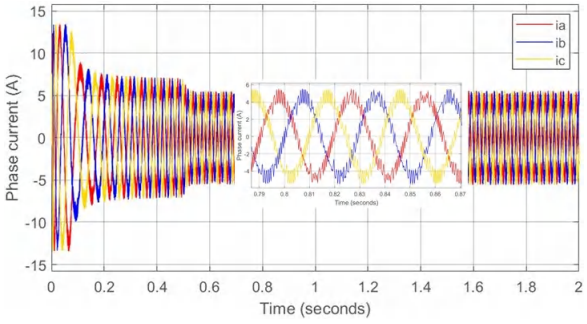


(c) Torque.

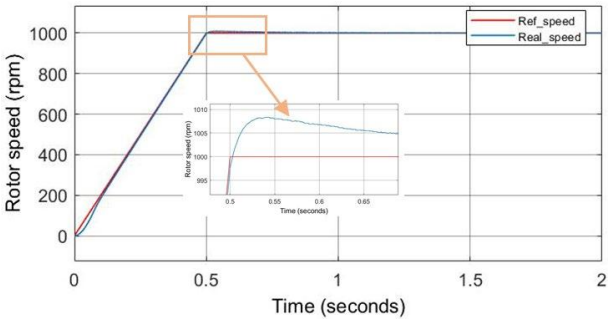


(d) The amplitude of rotor flux.

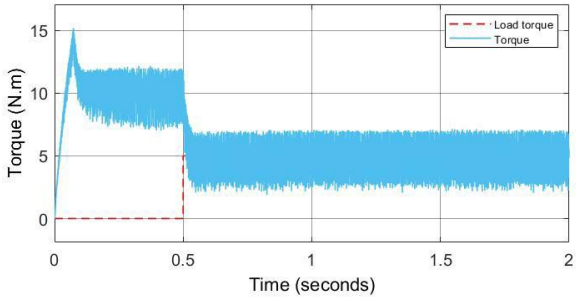
Figure 5. The FOC strategy for hysteresis current controller at 1000 rpm, -1000 rpm, and a no-load condition.



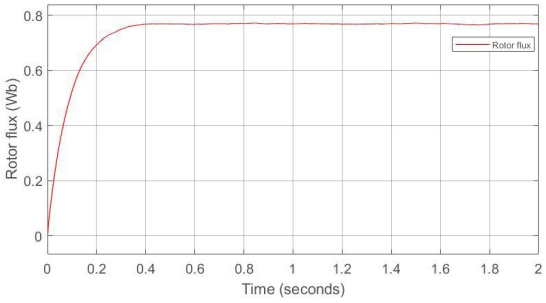
(a) Phase current.



(b) Reference and actual rotor speed.



(c) Torque.



(d) The amplitude of rotor flux.

Figure 6. The FOC strategy for hysteresis current controller at 1000 rpm and a load of 5 Nm condition

IV. CONCLUSION

In this paper, a novel enhancement is presented where the current model is integrated into the FOC method using a hysteresis current controller for an induction motor drive. Through simulations, the efficacy of this proposed approach has been showcased. Notably, the improved model exhibits rapid and precise control characteristics regarding rotor speed, stator current, and rotor flux response over a wide speed range.

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PROCEEDINGS

MATHEMATICAL CAPABILITIES OF LARGE LANGUAGE MODELS ON VIETNAMESE HIGH SCHOOL MATH TEST

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Abstract: In this paper, we explore the mathematical capabilities of three prominent LLMs – ChatGPT, BingChat, and Bard – on the VNHSGE dataset. The results show that ChatGPT is identified as the optimal choice for addressing "knowledge" level questions, BingChat excels in "comprehension" level questions, and Bard proves proficient in addressing questions classified as "application" and "high application". Furthermore, LLMs showcase enhanced proficiency in the topics of "combinations and probability" and "number series" while demonstrating comparatively lower proficiency in addressing "spatial geometry" and "derivatives and applications" topics. Through analyses, we provide insights into the LLMs' mathematical capabilities and recommendations to students, teachers, and educators regarding which LLMs they should use corresponding to the difficulty of the question as well as the topic involved.

Keywords: *large language model, mathematical education, mathematical capabilities, OpenAI ChatGPT, Microsoft BingChat, Google Bard*

I. INTRODUCTION

Large Language Models (LLMs) have achieved remarkable success in a wide range of natural language processing (NLP) tasks, including text generation, translation, sentiment analysis, and more (OpenAI, 2023), (Bubeck et al., 2023). However, mathematics remains one of the challenges for LLMs because mathematical problem-solving requires the application of logical reasoning, symbolic manipulation, and pattern recognition to arrive at accurate solutions. Many studies have been conducted to improve the mathematical abilities of LLMs such as (Drori et al., 2021), (W. Chen et al., 2022), (Arora et al., 2023), (X. Wang et al., 2022) as well as to evaluate the mathematical abilities of LLMs (Bubeck et al., 2023), (Arora et al., 2023), (Collins et al., 2023), (Dao & Le, 2023), (Wei et al., 2023), (Wu et al., 2023), (Yuan et al., 2023), (Frieder et al., 2023), (Hendrycks et al., 2021).

The landscape of NLP has witnessed a relentless evolution marked by the progressive refinement of LLMs. Notable exemplars of these advancements include models such as GPT-3 (Brown et al., 2020), LaMDA (Thoppilan et al., 2022), LLaMA (Touvron et al., 2023) and GPT-4 (OpenAI, 2023). Their development has not only engendered significant technological breakthroughs but also catalyzed paradigm shifts in the ways in which language is processed and communicated. In parallel with their developmental trajectory, these advanced LLMs have begun to find tangible integration

within the fabric of daily life. Commercial platforms, educational institutions, and digital assistants are embracing these models to enhance communication, streamline content creation, and offer intuitive solutions.

Within the realm of education, the burgeoning advancement of LLMs has left an indelible mark, profoundly altering the dynamics of teaching and learning. Their ability to comprehend and generate contextually relevant text empowers educators to tailor their teaching materials to diverse learning styles, fostering a more inclusive and engaging learning environment (Kung et al., 2022), (Dwivedi et al., 2023), (Baidoo-Anu & Owusu Ansah, 2023), (Rudolph et al., 2023), (Gilson et al., 2023), (Sallam, 2023), (Zhai, 2023), (Pavlik, 2023). These models can seamlessly elucidate complex concepts, clarify intricate subject matter, and offer personalized explanations that cater to individual students' needs. In the realm of research and study, LLMs function as virtual repositories of information, capable of swiftly retrieving and synthesizing vast knowledge repositories. This functionality extends beyond traditional search engines, enabling teachers and students to engage in more profound exploration and analysis (DAO, 2023). Despite their transformative potential, it is imperative to approach the integration of these models in education with circumspection. Challenges related to bias mitigation, data privacy, and fostering critical thinking warrant thorough consideration (Kasneci et al., 2023), (Qadir, 2023), (Mhlanga, 2023), (Tlili et al., 2023).

One of the important questions in the field of education is the capability of LLMs and the appropriate selection of language models for specific purposes by students and teachers. In this paper, we delve into the mathematical capabilities of three prominent LLMs: ChatGPT[1] (based on GPT-3.5), BingChat[2] (based on GPT-4), and Bard[3] (based on LaMDA). Our aim is to understand how these models perform on the VNHSGE dataset, shedding light on their strengths and limitations in mathematical comprehension, problem-solving, and content generation. Through analyses, we provide a comprehensive overview of the LLMs' mathematical reasoning abilities and their potential applications in education, research, and practical problem-solving scenarios.

The contributions of the paper encompass the following aspects:

- In-depth and comprehensive analysis of the mathematical capabilities exhibited by language models concerning the degrees of complexity in questions as well as the thematic content of the questions.
- Recommendations for students, teachers and educators regarding the selection of appropriate language models for addressing questions associated with specific topics and varying levels of complexity.

The remainder of this paper is organized as follows: Section II discusses related work in the domain of LLMs' evaluations and LLMs' mathematical abilities. Section III outlines the methodology we employed for evaluating ChatGPT, Bing, and Bard on the VNHSGE dataset. Section IV presents the results of our experiments and analyses. In Section V, we discuss the recommendation for students,

[1] https://chat.openai.com/chat

[2] https://bing.com/chat

[3] https://bard.google.com/

teachers and educators in leveraging LLMs for mathematical problem-solving in education. Finally, a conclusion is given in section VI.

II. RELATED WORKS

A. Large language models

LLMs are a type of artificial intelligence (AI) that can understand and generate text, perform language translation, create various types of creative content, and provide comprehensive answers to questions. They have undergone significant advancements in recent years and are now being employed in various applications, including translation, chatbots, and language assistants. Some key LLMs (Zhao et al., 2023) that have been developed in recent years are GPT-1, BERT, GPT-2, T5, GPT-3, Codex, InstructGPT, ChatGPT, LLaMA, and GPT-4. Specifically, GPT-1 (Radford et al., 2018), GPT-2 (Radford et al., 2019), and GPT-3 (Brown et al., 2020), developed by OpenAI in 2018, 2019, and 2022 respectively, were trained on massive datasets of text and code and can generate text, perform language translation, and create various types of creative content. BERT (Devlin et al., 2018) and T5 (Xue et al., 2020), by Google AI in 2018 and 2020 respectively, can understand and generate text much better than GPT-1 by considering bidirectional context. Codex (M. Chen et al., 2021), InstructGPT (Ouyang et al., 2022), and ChatGPT[4] are tools developed by OpenAI that use GPT-3 as their core language model. These LLMs allow you to generate code, perform language translation, create various types of creative content, provide comprehensive answers to questions, and engage in conversations with you on a variety of topics. LLaMA (Touvron et al., 2023), developed by Meta AI, can perform language translation, create various types of creative content, and provide comprehensive answers to questions. GPT-4 (OpenAI, 2023), developed by OpenAI, is expected to be the largest language model ever created and will be able to generate more realistic and engaging text compared to current LLMs.

B. Evaluation of LLMs

LLMs have undergone assessments across various domains and subjects (Chang et al., 2023) encompassing areas such as NLP, natural sciences and engineering, medical applications, agent-based applications, and other domains. In the context of NLP reasoning, certain studies have concentrated on examining the inferential capacities of LLMs (Bang et al., 2023), (Bian et al., 2023), (Liu et al., 2023), (Orrù et al., 2023), (Qin et al., 2023). Within the realm of education, a compendium of investigations (de Winter, n.d.), (R. E. Wang & Demszky, 2023) has been undertaken to discern their implications and efficacy.

C. Evaluation of LLMs on mathematics

Prior investigations have delved into the proficiency of LLMs in mathematical endeavors, encompassing tasks such as the resolution of equations, arithmetic operations, and symbolic mathematical manipulations. GPT-4 is currently the best LLMs in math problem solving. Indeed, GPT-4 is better than ChatGPT, Minerva (Bubeck et al., 2023) on GSM8K dataset, MATH dataset and MMMLU-STEM dataset. GPT-4 also outperforms InstructGPT, Galactica, LLaMA (Yuan et al., 2023) or Chinese-Alpaca, Moss, Ziya-LLaMA-13B, Baichuan-7B, RWKV-7B (Wei et al., 2023). The math capabilities of LLMs can be diminished when applied to different languages (Dao & Le, 2023), (Wei et al., 2023)

[4] https://openai.com/blog/chatgpt/

or when dealing with complex problems (Arora et al., 2023), (Wu et al., 2023) or changing over time (L. Chen et al., 2023). The most outstanding mathematical performance achieved by LLMs is attributed to GPT-4, which attained a remarkable accuracy of 89% on the SAT examination (OpenAI, 2023).

III. METHOD

A. Dataset

The VNHSGE mathematics dataset (Dao et al., 2023) has been curated as a benchmark to assess the mathematical capabilities of LLMs. By evaluating LLMs on the VNHSGE dataset, we can gain insights into their capacity to comprehend, solve, and generate mathematical content across different difficulty levels and mathematical subdomains. The VNHSGE math dataset was divided into four difficulty levels based on Bloom's Taxonomy and ten topics shown in Figure 1.

B. Prompt and Grading

The zero-shot evaluation was used, where LLMs were tasked with answering questions directly without any prior data or example questions. The assessment of LLMs performance in question-answering involved a binary grading system. This system involved comparing the LLMs' responses to a predetermined "ground truth" and classifying their answers as either accurate or inaccurate. To capture the best and worst cases among the answers of LLMs, two variables were introduced: LLM_B represents the case with the highest graded answer among the LLMs, while LLM_W represents the case with the lowest graded answer among the LLMs. These variables allow for an analysis of the upper and lower bounds of the performance of LLMs in terms of grading their answers.

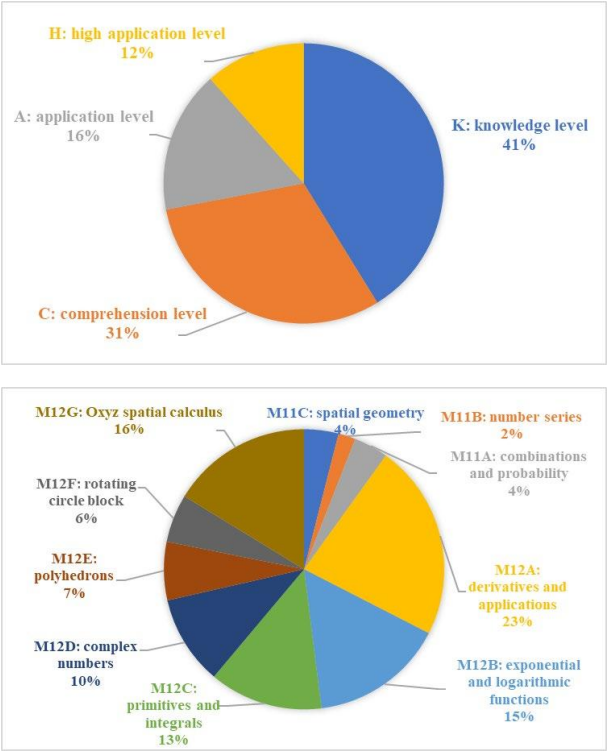

Figure 1. VNHSGE mathematics dataset in levels and topics

IV. RESULTS

A. LLMs performance

Table 1 presents the performance outcomes of LLMs over the years 2019 to 2023, along with their respective average values. The results underscore the LLMs' efficacy in mathematical test scenarios, wherein their performance is delineated as 58.8%, 60%, 48%, 28.8% and 80.8% for ChatGPT, BingChat, Bard, LLM_W and LLM_B, respectively. Comparatively, the mathematical capabilities among the three models, ChatGPT, BingChat, and Bard, exhibit negligible distinctions. Moreover, the best-performance LLM_B achieved a remarkable 80.8% accuracy. This outcome is similar compared to the scenarios where GPT-4 achieved performance levels of 89%, 87.1%, and 84% on SAT Math (OpenAI,

2023), GSM8K (Bubeck et al., 2023), MATH 401 (Yuan et al., 2023).

Table 1. Performance (%) of LLMs

	ChatGPT	BingChat	Bard	LLM_W	LLM_B
2019	52	56	50	26	76
2020	66	56	36	22	86
2021	60	66	54	30	84
2022	62	60	48	36	78
2023	54	62	52	30	80
AVG	**58.8**	**60**	**48**	**28.8**	**80.8**

Figure 2 illustrates the stability of LLMs. Their performance across the years exhibits a notable level of stability and concentration. It is discernible that these LLMs demonstrate a consistent level of stability within the domain of mathematics.

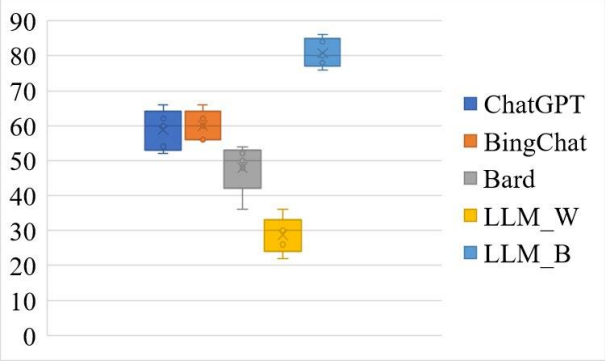

Figure 2. Stability of LLMs performance (%)

B. Performance in question levels and question topics

Question levels: Table 2 shows the performance of LLMs in the question difficulty levels. Generally, there is a discernible reduction in LLMs' performance as the complexity of the questions increases (see Appendix, Figure 1 for more details). Notably, ChatGPT emerges as the most proficient model for addressing questions categorized under the K-level, whereas BingChat excels in handling questions at the C-level. Bard, on the other hand, demonstrates superior performance in addressing questions categorized under the A- and H-levels. This intriguing finding underscores the fact that, despite having the lowest overall performance, Bard exhibits the highest capability in addressing the most challenging questions. Furthermore, LLM_B attains performance rates of 62.56% and 43.33% for questions categorized under the A and H levels, respectively. This achievement holds promise for the potential of LLMs to evolve into valuable support tools for addressing mathematics-related challenges, as well as for enhancing the pedagogical and learning dimensions of mathematics education.

Table 2. Performance of LLMs in question levels

	ChatGPT	BingChat	Bard	LLM_W	LLM_B
K	**82.52**	77.67	60.20	48.65	**94.23**
C	62.34	**67.53**	37.87	22.34	**84.21**
A	26.83	24.39	**40.09**	4.50	**62.56**
H	10.34	27.59	**28.67**	3.33	**43.33**

Topics: Table 3 depicts the performance of LLMs across different topics (see Appendix, Figure 2 for more details). Notably, Bard did not produce any correct answers for the "M11C: spatial geometry" topic, registering a null percentage. In contrast, ChatGPT achieved a perfect accuracy rate of 100% for the "M11B: number series" topic. LLM_B exhibited a performance of 63.16% in the "M12A: derivatives and applications" topic, while attaining accuracy rates ranging from 80% for the remaining topics.

Table 3. Performance of LLMs in question topics

	ChatGPT	BingChat	Bard	LLM_W	LLM_B
M11A	70.00	60.00	**70.00**	**50.00**	90.00
M11B	**100.00**	**80.00**	60.00	40.00	**100.00**
M11C	50.00	62.50	**0.00**	**0.00**	87.50
M12A	**34.95**	**36.33**	**40.51**	**11.43**	**63.16**
M12B	71.79	69.64	43.57	30.71	87.50
M12C	64.57	64.57	58.86	36.00	87.43
M12D	71.33	60.00	64.00	**50.00**	81.33
M12E	66.00	76.00	48.00	41.33	86.67
M12F	60.00	56.67	**70.00**	26.67	**93.33**
M12G	58.89	75.56	41.39	31.67	80.56

Subsequently, we present a ranking of the mathematical topics that LLMs exhibit proficiency in, arranged in ascending order as delineated in Table 4 (see Appendix, Figure 2 - Figure 7 for more details of ranking in topics). Notably, "M11B: number series" emerges as the topic where both ChatGPT and BingChat demonstrate the highest proficiency, whereas Bard excels in "M11A: combinations and probability." The least mastered topic for ChatGPT and BingChat is "M12A: derivatives and applications," while for Bard, it is "M11C: spatial geometry." In a holistic assessment, LLMs exhibit the highest proficiency in the "M11A" and "M11B" topics, and the least proficiency in "M11C" and "M12A" topics. M11C and M12A are questions related to images. Therefore, LLMs need to be improved in visual question answering.

Table 4. Ranking of topics

	ChatGPT	BingChat	Bard	LLM_W	LLM_B
1	**M11B**	**M11B**	**M11A**	**M11A**	**M11B**
2	**M12B**	M12E	**M12F**	M12D	**M12F**
3	M12D	M12G	M12D	M12E	M11A
4	M11A	M12B	M11B	M11B	M11C
5	M12E	M12C	M12C	M12C	M12B
6	M12C	M11C	M12E	M12G	M12C
7	M12F	M11A	M12B	M12B	M12E
8	M12G	M12D	M12G	M12F	M12D
9	**M11C**	M12F	**M12A**	**M12A**	M12G
10	**M12A**	**M12A**	**M11C**	**M11C**	**M12A**

V. DISCUSSION

The mathematical proficiencies of LLMs carry significant potential for enhancing mathematics education by facilitating processes such as offering detailed explanations, step-by-step solutions, and personalized tutoring. Additionally, these capabilities extend to diverse applications encompassing research, automation of routine mathematical tasks, and provision of assistance to professionals in fields requiring mathematical reasoning. Owing to the varied performance of LLMs across different difficulty levels and thematic contexts, we propose tailored utilization strategies for corresponding LLMs.

Presented in Table 5 is a ranking of LLMs across question levels, thus guiding their appropriate deployment. For instance, at the "knowledge" level, it is recommended to use ChatGPT, BingChat, and Bard. Conversely, at the "high application" level, the recommended sequence is Bard, BingChat, and ChatGPT.

Table 5. Ranking of LLMs in question levels

Levels	Best performance <= Worst performance		
K	**ChatGPT**	BingChat	Bard
C	**BingChat**	ChatGPT	Bard
A	**Bard**	ChatGPT	BingChat
H	**Bard**	BingChat	ChatGPT

Similarly, we present a ranking of LLMs based on question topics in Table 6. For each question topic, there is an associated LLM recommended for use. For instance, when addressing the "M11A" topic, the recommended sequence of utilization is ChatGPT or Bard, followed by BingChat. Similarly, in the context of the "M12A" topic, the suggested order of deployment is Bard, BingChat, and ChatGPT.

Table 6. Ranking of LLMs in question topics

Topics	Best performance <= Worst performance		
M11A	**ChatGPT ~ Bard**		BingChat
M11B	**ChatGPT**	BingChat	Bard
M11C	**BingChat**	ChatGPT	Bard
M12A	**Bard**	BingChat	ChatGPT
M12B	**ChatGPT**	BingChat	Bard
M12C	**ChatGPT ~ BingChat**		Bard
M12D	**ChatGPT**	Bard	BingChat
M12E	**BingChat**	ChatGPT	Bard
M12F	**Bard**	ChatGPT	BingChat
M12G	**BingChat**	ChatGPT	Bard

It is important to note that the mathematical capabilities of LLMs undergo changes over time, and their proficiency levels may vary at different intervals (L. Chen et al., 2023). Consequently, real-time assessments are essential to provide corresponding recommendations, as the capabilities of these models evolve.

VI. CONCLUSION

In this study, we delved into the mathematical capabilities of prominent LLMs – ChatGPT, BingChat, and Bard – using the VNHSGE dataset. Our analysis illuminated their performance in mathematical comprehension, problem-solving, and content generation across various difficulty levels and topics. We revealed that ChatGPT is apt for knowledge-level questions, BingChat for comprehension, and Bard for application and high application. Moreover, we ranked LLMs' proficiency across different topics, with ChatGPT and BingChat excelling in number series and Bard in combinations and probability. Our findings provide valuable guidance to students, teachers, and educators seeking to leverage LLMs effectively in their mathematical endeavors.

In the realm of education, LLMs hold immense potential for personalizing instruction, elucidating complex concepts, and aiding both educators and learners. As the landscape of LLMs continues to evolve, their potential to reshape mathematical education and problem-solving is undeniable, offering unprecedented opportunities for both learners and educators alike. As LLMs' capabilities evolve over time, the real-time use recommendations based on LLMs' capabilities become indispensable for optimal utilization.

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APPENDIX

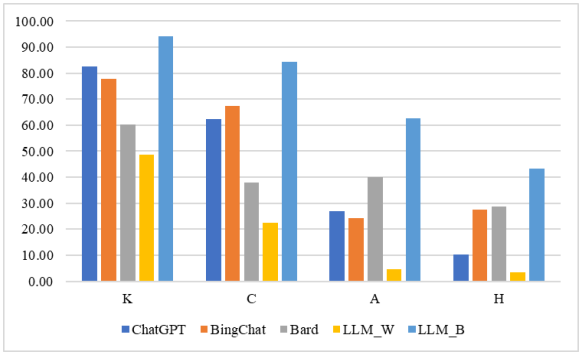

Figure 1. LLMs' performance in levels

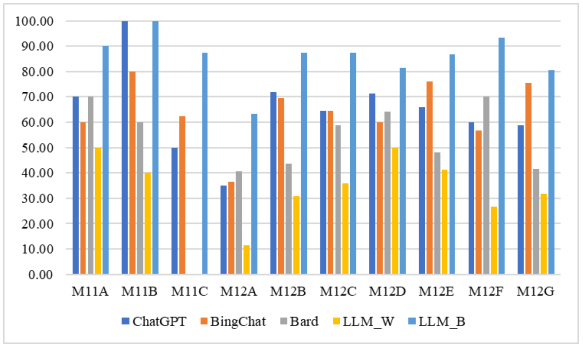

Figure 2. LLMs' performance in topics

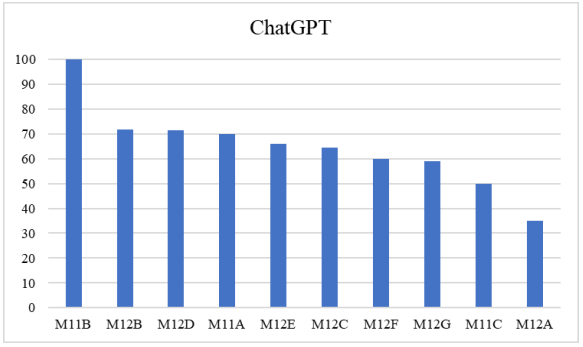

Figure 3. ChatGPT's performance in topics

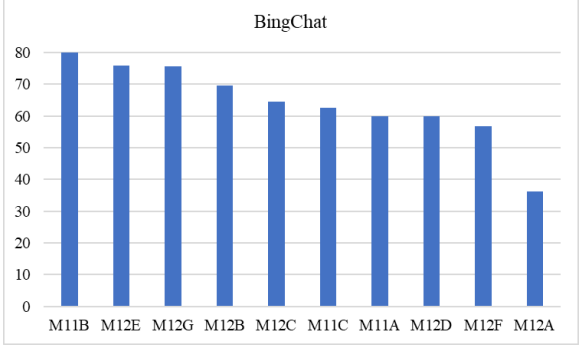

Figure 4. BingChat's performance in topics

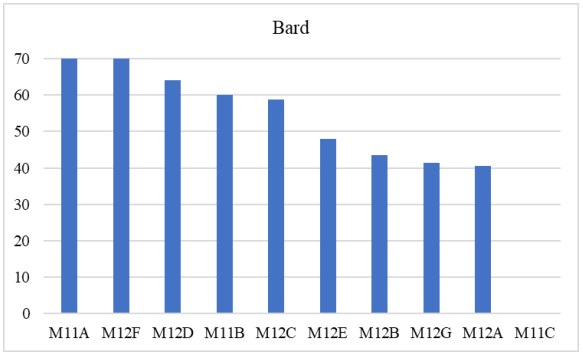

Figure 5. Bard's performance in topics

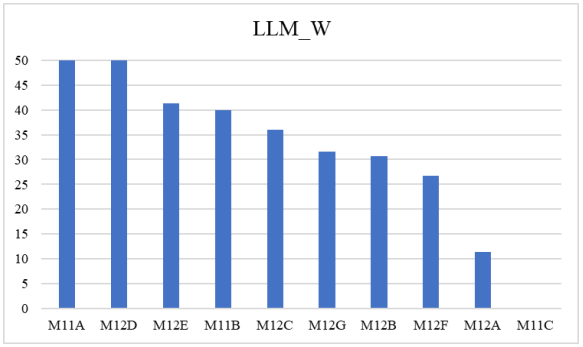

Figure 6. LLM_W's performance in topics

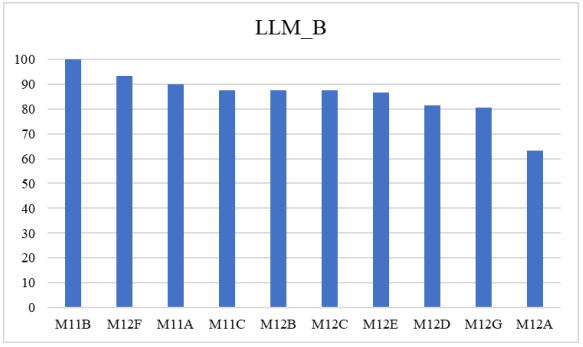

Figure 7. LLM_B's performance in topics

MEASURING THE ENERGY OF STORAGE CELL TO PREDICT THE HARDWARE FAILURE OF THE SMART WAREHOUSE SYSTEM

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Abstract: There are many methods to predict the condition of devices in a control such as temperature, vibration, pressure, current, voltage, and other relevant parameters depending on the type of device. In this paper, our team proposes a new method that measures the energy of the AGVs for moving to each storage cell and compares it with other cells of the remaining AGVs to predict hardware failure. The authors applied data communication by RS485 between PLC and servo motor drivers to ensure the most accurate data. From the collected samples, the data can be reported and compared so that the authors can catch up on the problems that the system is having.

Keywords: *PLC, RS485, Smart Warehouse, energy*

I. INTRODUCTION

Currently, the issue of optimizing energy consumption in the warehouse is always a top priority. Researchers have developed mathematical models for routing order pickers through the aisles of a warehouse, assigning products to storage locations, and/or restructuring customer orders in batches that can then be picked in individual tours (de Koster et al., 2007), smart lighting systems (SLS) can significantly reduce the energy consumption of warehouses (Füchtenhans et al., 2023), optimized interaction with a Thermal Energy Storage (TES) (Široký et al., 2011), surplus heat recovery (Chua et al., 2010) and optimized time-of-use with simultaneous access to local renewable energy resources (Wu & Wang, 2018). Implementing an Intelligent Energy Management System (IEMS) allows the building operator to automate the process of continuously choosing actions with the highest cost-reduction or energy-savings potential (Remani et al., 2019) or Data logging and Analysis (Natarajan, 2014) involve the systematic collection, storage, and examination of various data points generated within the warehouse environment.

From the research works, it can be observed that the Data logging and Analysis method has been widely applied in the industry, bringing significant benefits in managing energy consumption as well as environmental protection. Therefore, in this article, we also use the Data logging and Analysis method to manage the energy consumption of Automated Guided Vehicles (AGVs) in smart warehouse

systems. These AGVs are operated by PLC S7-1200. We measure the energy consumption levels of AGVs from their starting position to designated destinations, thereby providing data on the energy consumption of the smart warehouse, and proposing solutions to address energy-saving issues during operation.

II. METHODOLOGY

A. Mathematical modeling for a smart warehouse system

A smart warehouse consists of two main components: the storage area and AGVs. The specifications of the storage area: Length = 2260 mm, Width = 2042 mm, Number of Cells = 98(one side) - 196(both side). Mentioned in Figure 1, here are some typical parameters of racks.

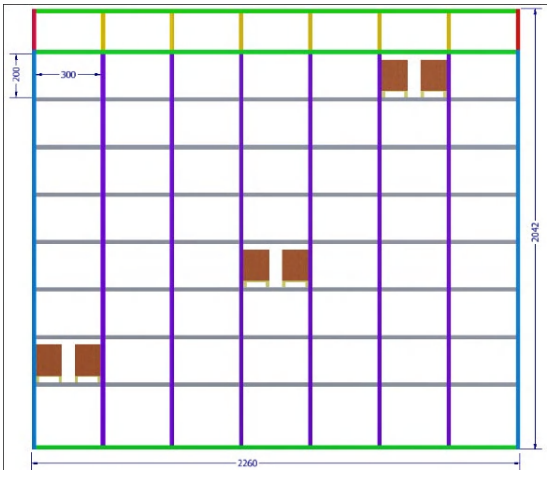

Figure 1. 2D models of Rack

Next in Figure 2. This is the arrangement of cells in a smart warehouse.

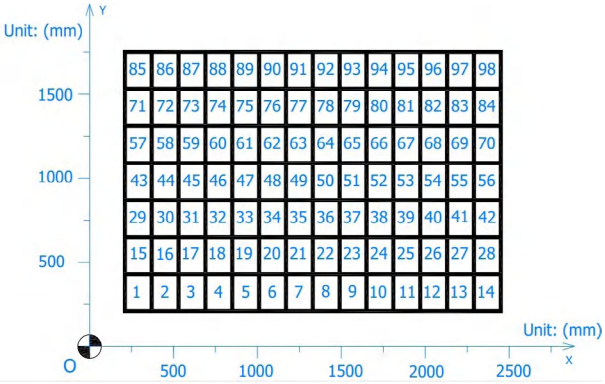

Figure 2. 2D drawing of Rack

Followed in Figure 3 is the 3D drawing of the smart warehouse shown below.

Figure 3. 2D drawing of Rack

AGV specifications: Long = 848 mm, Width = 158 mm, Height = 1957. These are the typical parameters for us to calculate and design shown in Fig. 3 and Fig. 4.

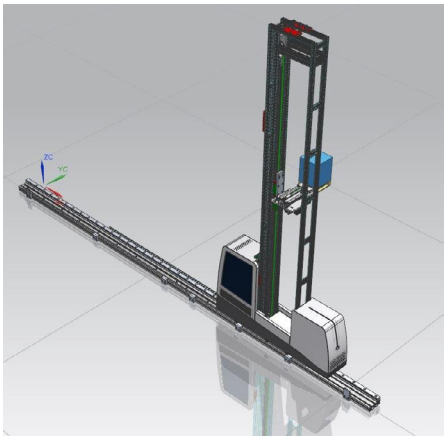

Figure 4. 3D model on CAD software

B. Flow chart

One of the important problems of the system is the software. Figure 5 shows the control algorithm diagram in this paper.

As shown in Figure 5, when we press the "Start" button, the system starts working. Next, we press the "Home" button to return the AGV to the Home position. When the home position is successful, we can start to enter the number of cells we need. Next we press "Run", the AGV moves from the home position to the desired cell and at the same time the timer is also turned on. When the AGV moves to the cell position, the timer stops. In addition, we also use a kit to measure the current when the AGV moves. We have the time and current we can apply this A = (U.I.t.cos)/3600 (Wh) formula to calculate the energy consumption of the AGV.

C. Sorting algorithms

Sorting algorithms are ways to organize an array of items from smallest to largest. These algorithms can be used to organize messy data and make it easier to use. Furthermore, having an understanding of these algorithms and how they work is fundamental for a strong understanding of Computer Science which is

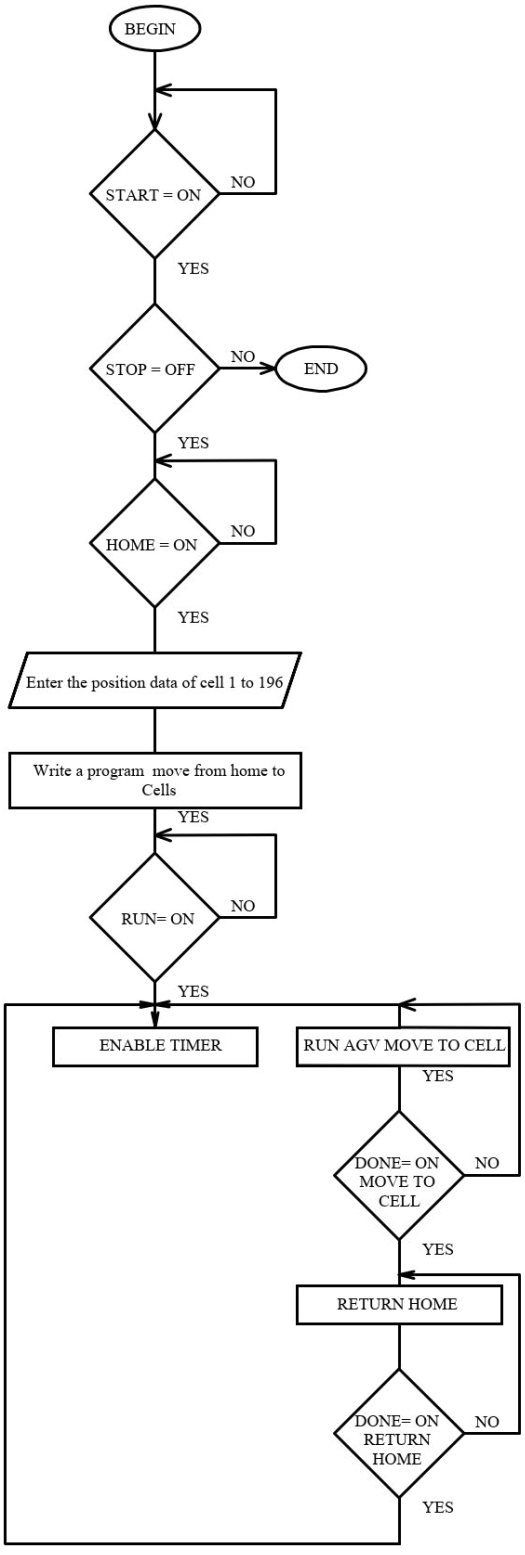

Figure 5. Flow chart of AGV

becoming more and more critical in a world of premade packages. This blog focuses on the speed, uses, advantages, and disadvantages of specific Sorting Algorithms. Figure 6 below shows how the program works Sorting Algorithms.

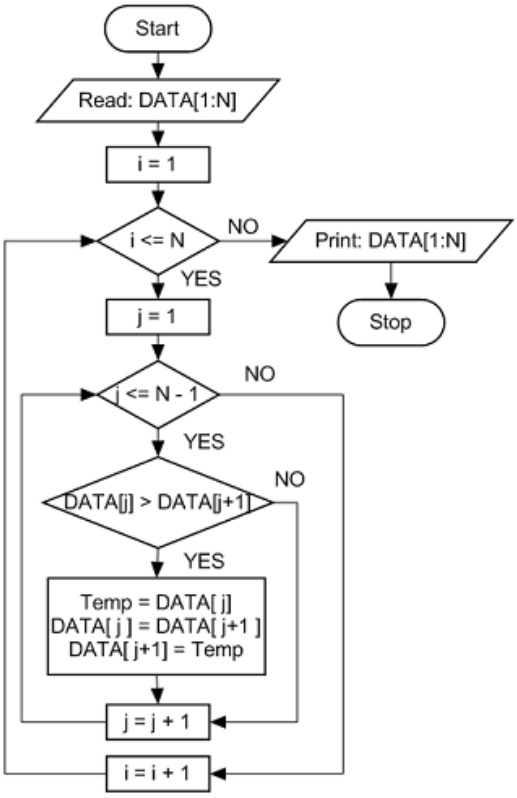

Figure 6. Flow chart for Sorting Algorithms

Before we go to write an algorithm for Selection Sort, we must know what it is and how it works. Selection Sort is a process of sorting numbers either in ascending order or in descending order. We can divide its process in Passes. If there are N number in an Array then there will be N – 1 Passes to Sort the Array. In the first Pass the First number of the Array is compared with rest of the numbers of the Array one by one. And according to the requirement the first number of the Array is replaced with one of the rest numbers of Array. For example if we want to Sort an Array in Ascending Order then the smallest number will be replaced with the first number. And if we want to sort the same Array in Descending Order then the largest number interchanges its position with the first number of that Array.

Pass 1: In the First Pass 12 will be compared with 34 but 34 is greater than 12 so no alteration will take place. Again 12 will be compared with 10 and this time an alteration will take place because 10 is less than 12. Then 10 will be compared with 36. Since 36 is greater than 10, no interchange will take place. Now the first place of the Array is sorted, and the order is as: 10, 34, 12 and 36

Pass 2: As the first place is sorted so it will start comparing from the second place. It will compare 34 with 12. Since 12 is less than 34 alterations will take place here. Now it will compare 12 with 36. Since 36 is greater than 12, thus no alteration will take place. Finally, the Second place is sorted. Now the Partially sorted Array is as: 10, 12, 34 and 36.

Pass 3: Now 34 will be compared with 36 and here no alteration will occur because 34 is less than 36. Thus, the Array is fully sorted now and it is as: 10, 12, 34 and 36

Now the numbers are sorted in ascending order. Similarly, the Array can be sorted in descending order too. The Selection Sort Flowchart and Selection Sort Algorithm are given under.

III. RESULTS

A. Energy consumption statistics

From the above results, we completed the statistics of the cell's energy consumption of 98 cells, shown in the Table 1.

From this table we use the Sort algorithm to rearrange the ascending energy levels shown in the figure below.

The figure below is showing the total energy consumption of 98 cells. With pink is equivalent to 20% of the total 98 cells and the next colors are plus 20% until 100%.

For easy observation, we convert the statistics table to a chart for easy observation of the energy consumption of each cell shown below.

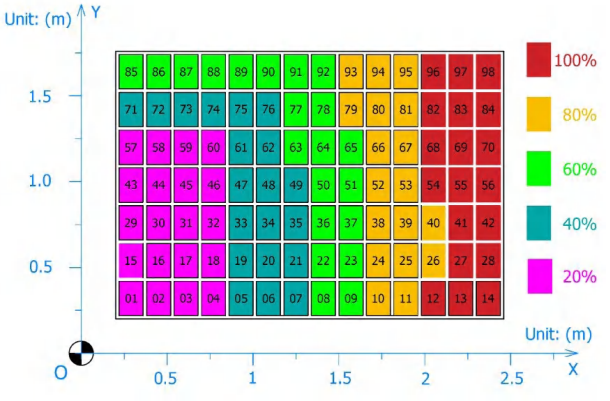

Figure 7. Power consumption chart of 98

From the chart in Figure 7 we can calculate the total energy consumption of 20%, 40%, 60%, 80%, 100% respectively when applying Sort Algorithm. shown below.

Table 1. The statistics of the cell's energy

Cell	Time(s)	Energy Consumtion (Wh)	Cell	Time(s)	Energy Consumtion (Wh)
1	2.2	0.319	50	5.3	0.769
2	2.8	0.406	51	5.8	0.842
3	3.3	0.479	52	6.1	0.885
4	3.7	0.537	53	6.5	0.943
5	4.1	0.595	54	6.9	1.001
6	4.5	0.653	55	7.4	1.074
7	4.9	0.711	56	7.7	1.118
8	5.4	0.784	57	3.8	0.552
9	5.7	0.827	58	3.8	0.552
10	6.2	0.900	59	3.8	0.552
11	6.5	0.943	60	3.8	0.552
12	7.0	1.016	61	4.1	0.595
13	7.4	1.074	62	4.5	0.653
14	7.8	1.132	63	4.9	0.711
15	2.2	0.319	64	5.3	0.769
16	2.8	0.406	65	5.7	0.827
17	3.3	0.479	66	6.1	0.885
18	3.7	0.537	67	6.5	0.943
19	4.1	0.595	68	6.9	1.001
20	4.5	0.653	69	7.4	1.074
21	4.9	0.711	70	7.7	1.118
22	5.3	0.769	71	4.4	0.639
23	5.7	0.827	72	4.4	0.639
24	6.1	0.885	73	4.4	0.639
25	6.5	0.943	74	4.3	0.624
26	6.9	1.001	75	4.4	0.639
27	7.4	1.074	76	4.4	0.639
28	7.8	1.132	77	4.9	0.711
29	2.5	0.363	78	5.2	0.755
30	2.8	0.406	79	5.7	0.827
31	3.3	0.479	80	6.1	0.885
32	3.7	0.537	81	6.5	0.943
33	4.1	0.595	82	6.9	1.001
34	4.5	0.653	83	7.3	1.060
35	4.9	0.711	84	7.8	1.132
36	5.3	0.769	85	5.0	0.726
37	5.7	0.827	86	5	0.726
38	6.1	0.885	87	4.9	0.711
39	6.5	0.943	88	4.9	0.711
40	6.9	1.001	89	4.9	0.711
41	7.4	1.074	90	4.9	0.711
42	7.8	1.132	91	4.9	0.711
43	3.3	0.479	92	5.3	0.769
44	3.2	0.464	93	5.7	0.827
45	3.3	0.479	94	6.1	0.885
46	3.7	0.537	95	6.5	0.943
47	4.0	0.581	96	6.9	1.001
48	4.5	0.653	97	7.3	1.060
49	4.9	0.711	98	7.7	1.118

Meanwhile, the smart warehouse is currently applying an ascending sort algorithm based on cell position, shown in Figure 8 below.

Cell	Energy Consumption(Wh)	Cell	Energy Consumption(Wh)
1	0.319	78	0.755
15	0.319	22	0.769
29	0.363	36	0.769
2	0.406	50	0.769
16	0.406	64	0.769
30	0.406	92	0.769
44	0.464	8	0.784
3	0.479	9	0.827
17	0.479	23	0.827
31	0.479	37	0.827
43	0.479	65	0.827
45	0.479	79	0.827
4	0.537	93	0.827
18	0.537	51	0.842
32	0.537	24	0.885
46	0.537	38	0.885
57	0.552	52	0.885
58	0.552	66	0.885
59	0.552	80	0.885
60	0.552	94	0.885
47	0.581	10	0.900
5	0.595	11	0.943
19	0.595	25	0.943
33	0.595	39	0.943
61	0.595	53	0.943
74	0.624	67	0.943
71	0.639	81	0.943
72	0.639	95	0.943
73	0.639	26	1.001
75	0.639	40	1.001
76	0.639	54	1.001
6	0.653	68	1.001
20	0.653	82	1.001
34	0.653	96	1.001
48	0.653	12	1.016
62	0.653	83	1.060
7	0.711	97	1.060
21	0.711	13	1.074
35	0.711	27	1.074
49	0.711	41	1.074
63	0.711	55	1.074
77	0.711	69	1.074
87	0.711	56	1.118
88	0.711	70	1.118
89	0.711	98	1.118
90	0.711	14	1.132
91	0.711	28	1.132
85	0.726	42	1.132
86	0.726	84	1.132

Figure 8. Sorting Algorithms for energy consumption of 98 cells

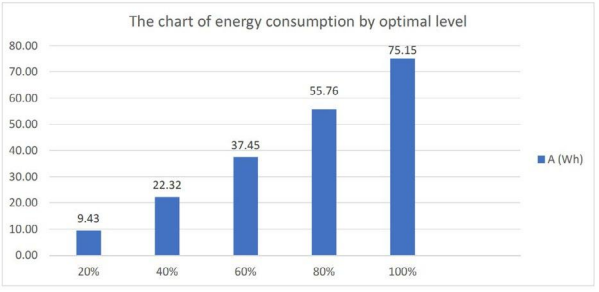

Figure 9. The chart of energy consumption by Sort Algorithm

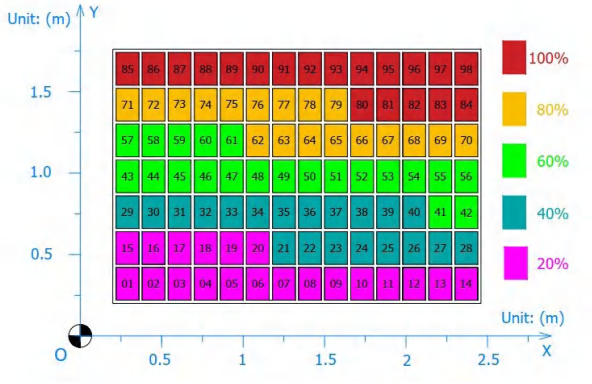

Figure 10. Sort algorithm based on cell position

From that arrangement also gives different distribution of energy consumption, shown in Figure 11 below.

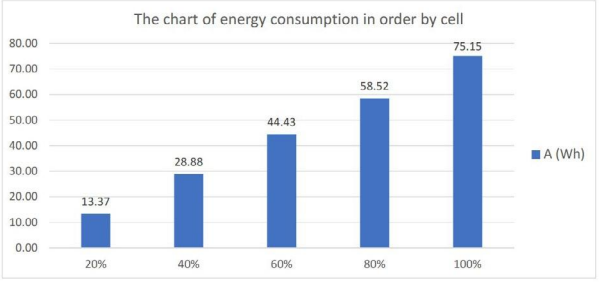

Figure 11. The chart of energy consumption in order by cell

B. Effective energy

From Figures 9 and 11 we can calculate the energy efficiency of applying the Sort Algorithms algorithm shown in Figure 12 below.

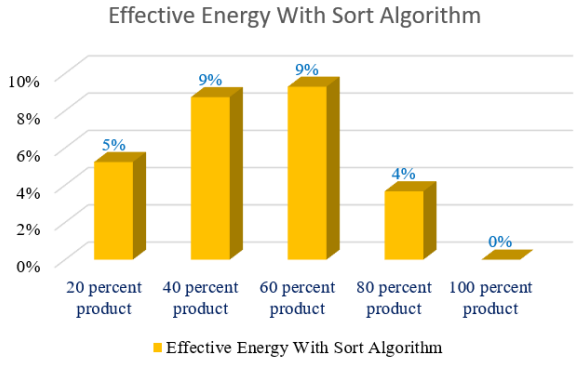

Figure 12. Effective energy with sort Algorithm

Figure 12 shows that applying the Sort Algorithm brings significant efficiency to the system, helping the system save about 5% when using up about 20 percent product. Next to 9% when using up about from 40 to 60 percent product.

IV. CONCLUSION

Through experimental results and trial runs, in this article we have successfully applied the Sort Algorithm to control AGVs for smart warehouses and achieved many successes, including reducing energy consumption quantity.

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MONO VISION-BASED FACIAL MIMIC ANALYZING FOR DIFFERENTIAL ROBOT CONTROL TOWARD A SMART WHEELCHAIR SYSTEM SUPPORTING FULL BODY LOCOMOTION PARALYSIS PATIENTS

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Abstract: Full-body locomotion paralysis negatively affects both the personal and professional lives of the involved patients. In this disease, the patients have difficulties performing locomotion using their upper and lower limbs, so they must be based on the support of wheelchairs for their daily moving. However, conventional wheelchair-controlling techniques based on hand motions are not suitable for this type of disease. Especially, the rate of facial paralysis is smaller than that of locomotion paralysis, so the facial mimic-based controlling technique is a typical replacement. Consequently, in this study, we proposed a novel wheelchair-controlling technique based on facial movements. In particular, a mono-vision system was employed for capturing facial features in real-time. The facial features in mouth regions were focused on for analysis. Wheelchair-controlling signals were computed from the left and right symmetrical movements of the facial features on the mouth region and the vertical opening range of the mouth. For validating the proposed controlling technique, we design a differential robot system connected wirelessly to the host controller. The host controller applies the developed controlling technique using the mono-vision system for controlling the differential robot system. As a result, we successfully controlled the remote-connected robot using our mouth motion. In perspective, we will employ the proposed controlling methods for a smart wheelchair system supporting patients with full-body locomotion paralysis. We also compared the proposed controlling method with the conventional controlling interfaces, such as joysticks and steering wheels, for proving its advantages.

Keywords: *Facial mimics-based control, smart wheelchair control, mono-vision-based facial analysis, full-body locomotion paralysis, facial features-based control*

I. INTRODUCTION

Full-body disabilities are mainly caused by strokes, birth defects, or accident injuries (François et al., 1998). In this study, full-body patients are referred to people who have disabilities in both upper and lower limbs. Consequently, in these types of disabilities, the involved patients usually could not control their upper and lower limbs (Shi, Zhang, Zhang, & Ding, 2019). Consequently, their locomotion must be based on the support of clinicians and their relatives. Conventional mobility aids, such as wheelchairs, could not help in this case because the patients could not use their hands or legs for controlling these vehicles (van der Woude, Veeger, Dallmeijer, Janssen, & Rozendaal, 2001). Automatically navigated wheelchairs could not help much in these issues because subjects still need to select a target position before motions (Ding & Cooper, 2005). The selecting actions must be controlled by hand motions. Consequently, novel controlling methods should be studied so that full-body disabled people can use them.

Controlling interfaces are one of the most important components in human-machine interaction applications (Heng, Solomon, & Gao, 2022). Based on the interaction devices, we could classify these interfaces into physics-, electronics-, and vision-based controlling methods. In physics-based methods, people can use their hands for moving a steering wheel (Greatbatch, Kim, Doerzaph, & Llaneras, 2020). Motions of the steering wheels were then transmitted to the actuators physically helping to turn left or right during the navigation. In electronics-based methods, electronic devices, such as buttons and joysticks, were employed to generate controlling signals for controlling the steering actuators (Wang, Ma, & Hao, 2017). However, these types of controlling still need hand movements for transferring commands from the brain. In vision-based methods, hand gestures were mostly detected in 2-D images acquired by cameras (Chakraborty, Sarma, Bhuyan, & MacDorman, 2018). The detected gestures were then converted to motion signals for controlling the target actuators. However, these controlling interfaces could not be used by upper-limb-disabled patients. In the literature, some studies also tried to control wheelchairs using tracked head motions by contactless depth sensors, such as the Microsoft Kinect sensor (Gerling et al., 2016). However, full-body disabled patients usually could not control their heads also.

Body motions are the resultants of muscle activations controlled by neural signals emitted from the brain (Castermans, Duvinage, Cheron, & Dutoit, 2013). Injuries of some nerves can cause disabilities for muscles controlling body motions. In the case of full-body disability, the spinal nerves were mostly injured (Nas, 2015). Fortunately, the rate of facial nerve injuries is usually lower than those of the injuries in nerves controlling the upper or lower limp motions (Gates, 1987). Consequently, in most full-body disabled patients, they might still be able to control their facial mimics. A controlling interface, which is based only on facial mimics, is therefore very useful. In the literature, some studies also tried to employ facial expressions for controlling wheelchairs. For instance, Yassine et al., 2018 (Rabhi, Mrabet, & Fnaiech, 2018), employed a mono camera in a smartphone for detecting 68 facial points on a human face. These points were used for classifying facial expressions by analyzing relative differences between the eyebrow & mouth features and the centroid point of the face. However, the

controlling commands are separated, so they could only control the wheelchair by turning left, right, upward, and forward directions with the maximum speeds of the wheelchair. Consequently, the wheelchair could not move according to complex navigation paths, especially for the linear control of both going forward and steering motion. Some studies also tried to control wheelchairs using brain signals acquired by EEG devices (Fernández-Rodríguez, Velasco-Álvarez, & Ron-Angevin, 2016). However, these types of controlling methods are computation-cost, and patients must wear additional device(s) to interface with the wheelchair.

Because of all the above reasons, we would like to develop a novel vision-based controlling method based on facial mimic analysis supporting wheelchair controlling of upper and lower limb locomotion disabilities. In particular, we employed a contactless image sensor, such as a mono webcam, for acquiring high-definition facial points in real time. The features around the mouth regions of the tracked features were used for generating controlling signals. The controlling signals included angular and linear velocity parameters. These parameters which ranged from 0 to 1 were computed thanks to mouth movements. The vertical motion of the mouth varied the linear velocity parameter. The horizontal motion of the mouth controlled the angular velocity parameter. The wheelchair, which was designed as a differential robot, was controlled by these angular and velocity parameters. For evaluating the proposed methods, we utilized these controlling signals for controlling a differential robot. The robot was connected to a mobile workstation, which was responsible for face feature tracking, facial mimic analysis, and controlling signal computation. As a result, we could successfully control the target differential robot via a wifi connection to move forward, left, and right at different speeds linearly. In perspective, we will implement this controlling method in a real wheelchair system. The whole wheelchair system will also be validated with healthy subjects and patients for being enhanced based on their feedback.

In the following, we will describe clearly the prototype system coupled with the new controlling method in Section II. The results of differential robot controls will then be presented in Section III. Discussion and further enhancement of our method will also be discussed in Section III.

II. METHODOLOGY

A. Overall Processing Procedure

The overall processing procedure of the mono vision-based wheelchair controlling system is illustrated in Figure 1. In particular, the system execution includes three main processing parts: (1) face analyzing, (2) control signal computing, and (3) differential robot controlling.

(1) Regarding the face analysis, we used a mono camera for acquiring face image sequences in real time. The acquired mono images were fed into a CNN Mediapipe framework (Lugaresi et al., 2019) for detecting and tracking high-definition face features in real time. The face features around the mouth region were utilized for computing controlling signals.

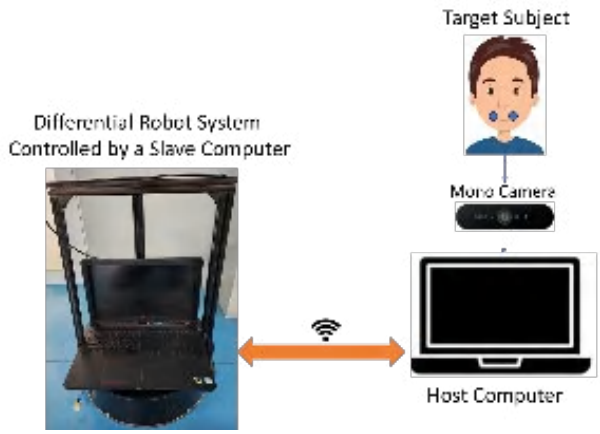

Figure 1. Overall processing procedure of the facial mimic-based robot controlling technique

(2) Regarding the control signal computation, the controlling signals included two main parameters: linear and angular velocities. The linear velocity was proportional to the vertical opening range of the mouth feature points. The angular velocity parameter was depended on the differences between the left and right smiling ranges.

(3) Regarding the differential robot control, the prototype of the wheelchair was tested as a differential wheeled robot. Each wheel of the robot was controlled by a direct current motor. The left and right motor speeds were computed through the differential wheeled motion model.

Face image acquisition, face feature detection & tracking, and controlling signal computation were executed on a mobile workstation. This workstation was connected wirelessly to the wheelchair prototype via wifi local area network.

B. Facial mimic analysis

Facial mimic analysis was conducted by analyzing the facial feature points detected and tracked from mono images acquired by a mono camera. The acquired mono-image sequences

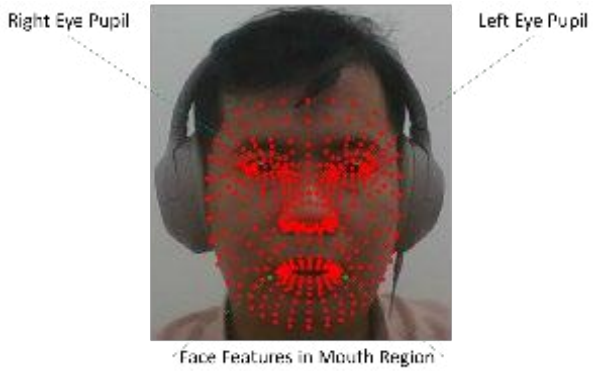

Figure 2. An example of the positions of 478 face features on the face detected and tracked based on the Mediapipe framework

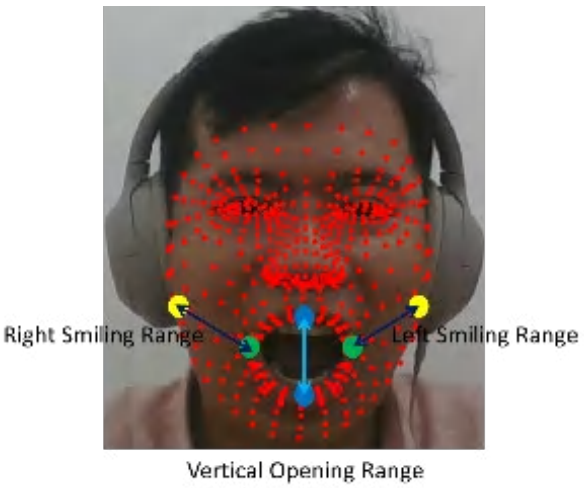

Figure 3. Face feature points and their utilization for computing controlling signals

were inputted into the CNN Mediapipe framework (Lugaresi et al., 2019). This framework employed attention Deep-CNN networks for detecting and tracking separate regions of the face, so it can achieve optimal accuracy with a relatively high framerate. In this study, the image frame had the dimension of width×height = 1280×720. The number of acquired face features was 478. Their positions on the face are shown in Figure 2. During the facial movements, these facial features could be tracked in real-time with the framerates up

to 30 frames per second (FPS). Note that with the Mediapipe framework, the estimated face features were in the 3-D relative coordinate system.

As described in Figure 2, we only employed face feature points around the mouth region for generating the controlling signal. As shown in Figure 3, we selected the left & right cheilion, upper & lower lip, and left & right gonion features for estimating controlling signals. The opening range was computed as Eq. 1. The left and right smiling ranges were computed as Eqs. 2,3. The vertical opening range was used for controlling the linear velocity parameter of the wheelchair. The left and right smiling ranges were used for controlling the angular velocity parameters of the wheelchair. For unifying the turning signals, we computed a difference between the left smiling range and the right smiling range, as shown in Eq. 4.

$$D_o = ||V_{UL} - V_{LL}|| \quad (1)$$

$$D_{LS} = ||V_{LC} - V_{LG}|| \quad (2)$$

$$D_{RS} = ||V_{RC} - V_{RG}|| \quad (3)$$

$$d_{LR} = D_{LS} - D_{RS} \quad (4)$$

In which, D_o, D_{LS}, and D_{RS} are the vertical opening, left smiling, and right smiling ranges. V_{UL} and V_{LL} are the upper lip and lower lip face features. V_{LC} and V_{LG} are the left cheilion and left gonion face features in x-, y-, and z-coordinates. d_{LR} is the difference between the left smiling range and the right smiling range.

For normalizing the controlling signals before being transmitted to the wheelchair system, we estimated the min and max values of D_o and those of d_{LR}. A graphical user interface was designed to instruct the user to follow the system calibration procedure. This procedure is illustrated in Figure 4. In particular, the procedure included four main stages: (1) neutral, (2) mouth max-opening, (3) left max-smiling, and (4) right max-smiling. In the neutral calibration state, as shown in Figure 4a. The subject was asked to perform a neutral mimic. In this mimic, D_o would have its minimum value, so-called D_{omin}. In the mouth max-opening mimic, as shown in Figure 4b, the subject was asked to perform an [o]-sound mimic as large as possible. In this mimic, D_o would have its maximum value, so-called D_{omax}. In the left max-smiling mimic, as shown in Figure 4c, the subject was asked to perform a left-smiling mimic. In this mimic, d_{LR} would have its minimum value, so-called d_{LRmin}. In the right max-smiling mimic, as shown in Figure 4d, the subject was asked to perform the right smiling mimic. In this mimic, d_{LR} would have its maximum value, so-called d_{LRmax}. Finally, the normalized opening range and the normalized left-right smiling difference were computed based on the min-max normalization, as shown in Eqs. 5,6. After being normalized, the mouth opening range and the difference between the left and right smiling range would have values ranging from 0.0 to 1.0.

$$D_{Onormalized} = \frac{D_O - D_{Omin}}{D_{Omax} - D_{Omin}} \quad (5)$$

$$d_{LRnormalized} = \frac{d_{LR} - d_{LRmin}}{d_{LRmax} - d_{LRmin}} \quad (6)$$

In which, $D_{Onormalized}$ and $d_{LRnormalized}$ are the normalized values of the mouth opening range and the difference between the left and right smiling ranges.

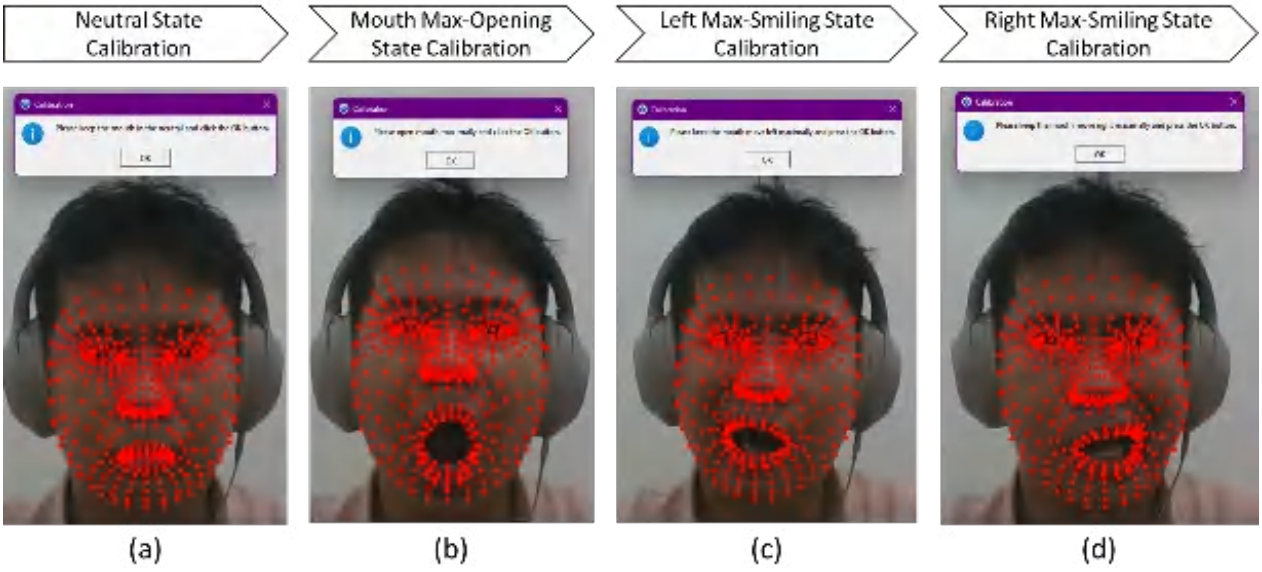

Figure 4. Data calibration procedure for estimating the min & max values of the opening range and those of the differences between the left smiling range and the right smiling range: (a) neutral state for estimating the min values, (b) mouth max-opening state for estimating the max opening range, (c) left max-smiling for estimating the max left smiling range, and (d) right max-smiling for estimating the max right smiling range. Note that due to the geometrical light structure of the mono camera, the images were flipped during the capturing.

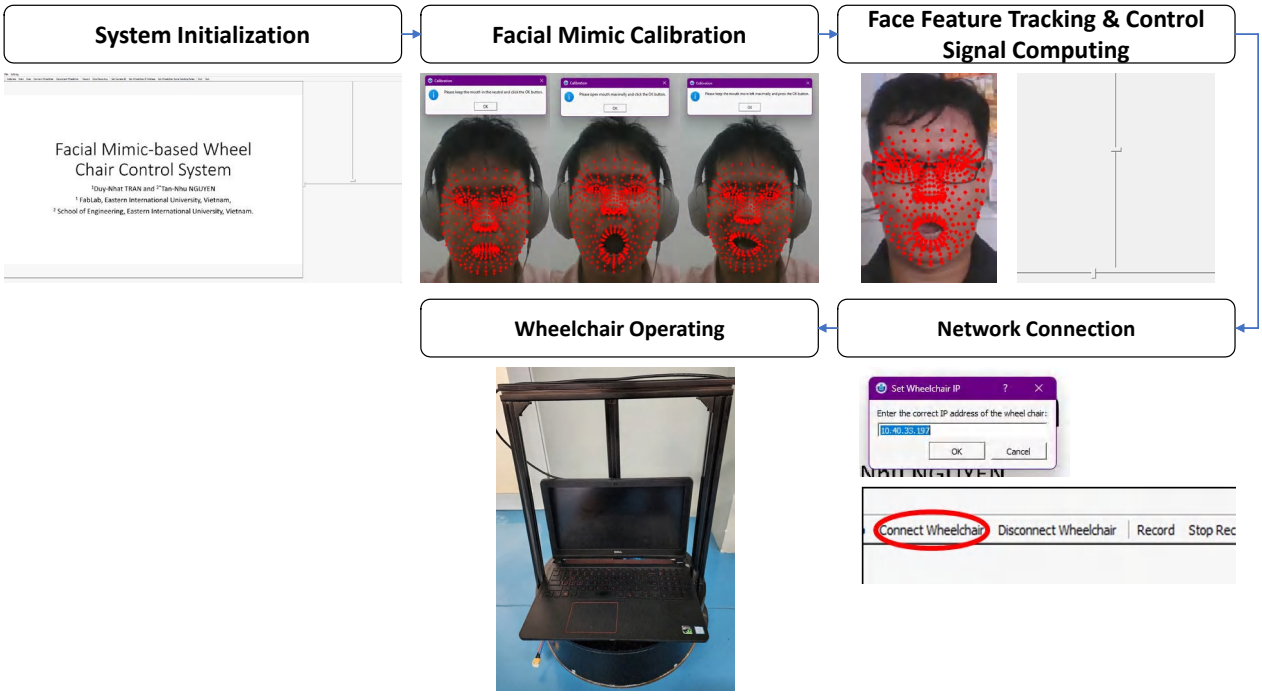

Figure 5. The controlling procedure of the proposed method

C. Differential robot design

In this study, we prototyped the wheelchair as a differential wheeled robot, whose design is illustrated in Figure 5, for testing the proposed controlling method. In particular, the distance between the left and right wheels was 45.0 cm. The radius of the left and right wheels was 10.7 cm. With these parameters, the motion model of the robot formed as Eq. 7.

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\varphi} \end{bmatrix} = \begin{bmatrix} \cos\varphi & 0 \\ \sin\varphi & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V \\ \omega \end{bmatrix} \quad (7)$$

In which, $\dot{x}$ and $\dot{y}$ are the differences between the x- & y-positions at the time step ith and those at the time step (i+1)th of the wheeled chair in the floor plan's coordinate system, respectively. φ is the angle between the heading line of the wheelchair and the Ox axis of the global floor plan's coordinate system. Eq. 7 was popularly computed based on the differential drive kinematics [ref].

Based on Eq. 7, the two controlling parameters of the wheelchair are linear velocity (V) and angular velocity (ω). The normalized opening range ($D_{Onormalized}$) and the normalized left-right smiling difference ($d_{LRnormalized}$) controlled V and ω, respectively. The inputted linear and angular velocity values were computed based on Eqs. 8, 9.

$$V_{in} = V_{max} D_{Onormalized} \quad (8)$$

$$\omega_{in} = \omega_{max} 2(d_{LRnormalized} - 0.5) \quad (9)$$

In which, V_{in} and ω_{in} are the values of the linear and angular velocity inputted to the differential wheeled robot. The V_{max} and ω_{max} are the maximum values of the linear and angular velocity of the robot. These values were computed based on the kinematic of the differential wheeled robot [ref]. Based on the inputting values of V_{in} and ω_{in}, the velocities of the left and right wheels were finally computed based on the differential wheeled robot's kinematic [ref].

D. Controlling procedure

The controlling procedure is illustrated in Figure 5. In particular, we designed a graphical user interface (GUI) for the mobile workstation system. When opening the GUI system, the face feature detector and the mono camera were first initialized and waiting for starting commands from a user. If a new user intended to use the wheelchair system, he/she must calibrate his/her facial mimics first by following instructions from the system. The calibrated results included the min and max values of the mouth opening range and the difference ranges between the left and right smiling ranges. During facial movements, controlling signals were computed according to their depended face features. The Internet Protocol (IP) address of the remote robot should also be then inputted by the user. Based on the inputted IP address, the connection between the mobile workstation and the differential wheeled robot would then be established. By default, the controlling signals were transferred to the mobile robots with a frame rate of 10 FPS. The data transmission speed could be set up by the user. Whenever the differential wheeled robot received the controlling signals from the mobile controller, the velocities of the left and right wheels were computed and updated to move the wheelchair robot.

E. Employment technologies

The GUI was designed using Qt 5.12.1 (Haavard & Eirik, 1995). The image processing was conducted with the support of the OpenCV

library (Bradski, 2000). The employed face feature detector was the Mediapipe framework developed by Google Cooperation. The WIFI-based Local Area Network (LAN) was supported by the Boost Asio library (Kohlhoff, 2013) and the socket library in Python (Hassan, Hussien, & Mohialden, 2023). The server workstation had the hardware configuration of HP ZBook 17 G5 Intel® Xeon E-2176 2.7GHz (12x2.7GHz)-32Gb- 8Gb DDR5 Nvidia Quadro P3200.

III. RESULTS AND DISCUSSION

The prototype of the facial mimic analysis-based wheelchair-controlling system is shown in Figure 6. We successfully designed a prototype of the wheelchair with a differential wheeled robot. The robot workstation included a mobile laptop for receiving the controlling signals emitted from the workstation and for controlling the velocities of the left and right wheels of the robot. The max velocity of the two wheels was 100 rounds per minute.

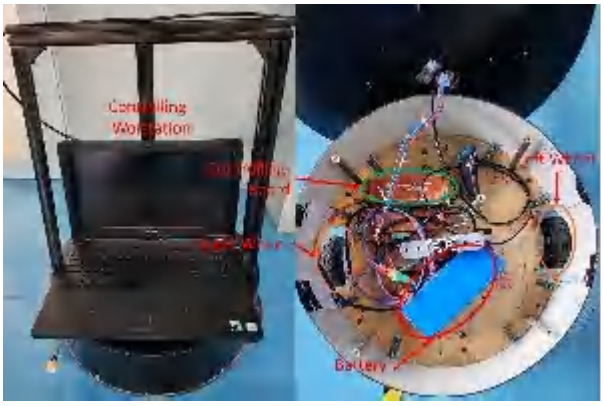

Figure 6. The designed prototype of the differential wheeled robot for the wheelchair system

The facial analysis results were described in Figure 7. The controlling signals: the vertical mouth opening range and the left-right smiling range difference were successfully generated based on the facial mimics: neutral, max mouth-opening, max left-smiling, and max right-smiling positions. In neutral mimics, the values of $D_{Onormalized}$ (Mean ± SD) were 0 ± 0.125. In the max mouth-opening mimics, the values of $D_{Onormalized}$ (Mean ± SD) were 1.0 ± 0.125. In the max left-smiling mimics, the values of $d_{LRnormalized}$ (Mean ± SD) were 1 ± 0.125. The max right-smiling mimics, the values of $d_{LRnormalized}$ (Mean ± SD) were 0 ± 0.125. Note that the user could both generate the mouth opening and left/right smiling mimics for controlling V and ω simultaneously.

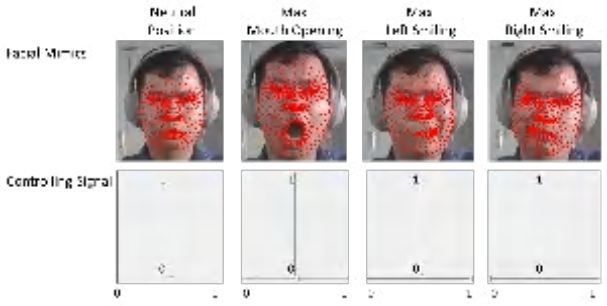

Figure 7. Facial analysis results for generating the controlling signals. The controlling signals were generated according to the facial mimic analyzed results for neutral, max mouth opening, max left smiling, and max right smiling positions

For each controlling signal, we successfully controlled the differential wheeled robots to go forward, turn left, and turn right. The reader can refer to the following links for the videos of these motions of the robot. With the employed hardware configuration, the face feature detection frame rates could be reached up to 30 FPS. The controlling signals could be transferred at the framerate of 10 FPS.

- Going forward: https://www.dropbox.com/scl/fi/wj53mi3n24v7o2t2tzjj9/GoingForward.mp4?rlkey=a5pmh2frwv4nazfq84vg5b7ro&dl=0

- Turning left: https://www.dropbox.com/scl/fi/hysg5wlwldcfkka2ttsdz/TurningLeft.mp4?rlkey=r3mo2argxvsoh123hrewxfbc5&dl=0
- Turning right: https://www.dropbox.com/scl/fi/uj0ung5n52d17zl3dol0d/TurningRight.mp4?rlkey=y3k7brpb199n844mwp9zdz0o0&dl=0

In this study, we proposed a novel controlling method for wheelchairs using facial mimic analysis. For the patients with both upper and lower limb disabilities, the facial mimic-based controlling methods were very necessary because the involved patients cannot use their limbs for other controlling methods. Previous studies also tried to use facial expressions for controlling wheelchairs, but the controlling signals were only separated into left, right, and forward turning commands [ref]. Consequently, the navigation paths were limited to simple shapes. In this study, we generated linear signals for controlling the linear and angular velocities of the differential wheeled robot. With the two parameters, the wheelchair could be moved following more complex navigation paths. However, this study remained drawbacks. First, we have not successfully generated the backward turning signal based on the current analysis of the facial mimics. In further research, we will integrate more mimics for controlling the backward turning of the wheelchair. Second, the accuracy of navigation paths has not been evaluated for comparison with other controlling methods. In the future, we will design a real wheelchair integrated with various controlling methods. The system will be validated with both healthy subjects and patients for evaluating the advantages of the proposed controlling method. Third, even though the employed face feature detector could emit 3-D coordinates of the face features. The x- and y-coordinates of the face features could also be affected by the head motions due to the mono-vision geometries. In perspective, we will take advantage of stereo-vision geometries for estimating real 3-D coordinates of the face features. Last but not least, a real wheelchair system will also be designed as a complete system and validated to be ready for commercialization.

IV. CONCLUSION

The design of control methods for disabled patients is relatively challenging, especially for full-body disabled cases. This is because they will have difficulties using their limbs to control the conventional controlling interfaces. Facial mimic-based controlling methods can be one of the most suitable replacements, but most previous studies just considered the classification of facial expressions. In this study, we first employed facial features for controlling wheelchairs with both linear and angular velocities. However, this study also remained some drawbacks relating to backward controlling and system validations with healthy subjects and patients.

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PART III.

HEALTH SCIENCES

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DEVELOPMENT OF A PULSE SEQUENCE FOR FAST OVERHAUSER-MRI IN MOUSE LUNGS[*]

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Abstract: Proteolysis plays an important role in the many processes in living organisms. In the general physiological condition, it is tightly controlled. However, the unregulated proteolysis may have detrimental to the tissues and can occur in many pathologies. Moreover, until now the knowledge about the role of many proteases is still lacking, thus it is necessary to develop a method that can visualize and assess the proteolysis activity in intact bodies. The aim of this study is to develop sequence that can be utilized for proteolysis imaging of mouse lung and can be applied for the Overhauser enhanced MRI (OMRI) experiments. At the end of this study, we expect to have image of the mouse lung with a good spatial resolution, 3D anatomic localization and high contrast and able to provide image of the proteolysis in mouse lung.

Keywords: *Proteolysis, OMRI, 3D anatomic, mouse, lung*

I. INTRODUCTION

Proteases, also called proteolytic enzyme or proteinase, are enzymes that catalyze hydrolysis of peptide bond. In the human genome, there are more than 500 protease-encoding putative genes (Chakraborti & Dhalla, 2013) which role and site-of-action are mostly unknown. Their activity is involved in many processes in living organisms in order to maintain cellular homeostasis. In physiological steady-state, it is tightly controlled by numerous intra- and extracellular protease inhibitors. However, multiple evidences show that up-regulated proteolysis, where the protease inhibitors are outnumbered plays a role in many inflammatory diseases (e.g., pancreatitis, tumors, cystic fibrosis, etc.). Thus, if abnormal proteolysis can be visualized and localized in vivo, it can become a diagnostic tool for monitoring treatments and diseases progression.

Nowadays, several molecular imaging (i.e. imaging of molecular processes in intact living systems) techniques are used to image protease activity in small animal pre-clinical research. Optical imaging with significant advances in targeted fluorescent probe technology were used for cathepsin B detection in mouse brain tumors (Edgington et al., 2009) or for the matrix metalloproteinase (MMPs) in tumors and in inflamed tissues (Shah & Weissleder, 2005). Although this method is sensitive with easy-to-design probes, there are certain drawbacks due to the scattering of visible or near-infrared light which limit penetration depth in living tissues

[*] Best oral presentation award - Lecturer session

and the lack of 3D resolution. Other approaches such as single-photon emission computed tomography (SPECT) and positron emission tomography (PET) imaging have been utilized for probing the presence of metalloprotease with good sensitivity and depth penetration, but there are problems of poor 3D localization, high cost and invasiveness through the use of radiopharmaceuticals even worsened with CT (Liu et al., 2014).

Magnetic Resonance Imaging (MRI) is a powerful bio-imaging modality, thanks to many advantages. Indeed, MRI experiments involve low-energy radio-frequency waves in a static magnetic field to excite atoms in the object under evaluation, without the requirement of any ionizing radiation, which makes it completely non-invasive at low fields. In addition, MRI is able to provide images with a good compromise of spatial resolution, three-dimensional anatomic localization, penetration depth and high contrast.

However, MRI severely lacks sensitivity (the ability to detect diluted species) and specificity (the ability to assess molecular events). In order to tackle the sensitivity issue for molecular imaging, an enhanced-NMR method was implemented at low field in the host laboratory, which uses the so-called Overhauser effect (Overhauser, 1953). This is a double electron-proton resonance experiment based on transferring a part of the higher magnetization of a free electron into the water protons at vicinity, which subsequently enhances the MRI signal. This approach can be named either Overhauser-enhanced MRI (OMRI) or DNP-MRI for Dynamic Nuclear Polarization-MRI or PEDRI for Proton Electron Double Resonance Imaging. More details can be found in the theoretical section.

OMRI in liquids was first performed in vitro by Lurie et al. in 1988 (Lurie et al., 1988) and in vivo the first time by Grucker et al. in 1990 (Grucker, 1990). Later, OMRI was applied in rodents in order to assess pH (Khramtsov et al., 2010) or oxygenation levels (Matsumoto et al., 2009) with dedicated radical probes. Recently, OMRI was successfully applied to molecular imaging of elastase activity in living mouse at 0.19T (Mellet et al., 2009). In this study, mouse was gavaged with OMRI-invisible nitroxide-labeled macromolecular elastin prior to the OMRI exam. In stomach no Overhauser effect was observed due to the absence of elastase whereas significant signal enhancement was observed in duodenum because of elastase-induced elastin breakdown into peptide fragments that were OMRI-visible due to shorter tumbling correlation times. More recently, new small radical probes for OMRI of proteolysis were designed, where the unpaired electron EPR frequency can be shifted from the substrate state (prior to proteolysis) to the product state (post proteolysis), meaning that both substrate and product can be detected through OMRI (Audran et al., 2015).

One of the goals of the host laboratory is OMRI of up-regulated proteolysis in lungs inflammation. Indeed, in lungs diseases such as cystic fibrosis or chronic obstructive pulmonary disease, strong recruitment of activated neutrophils eventually causes irreversible damages because of neutrophil proteases (elastase, proteinase-3).

The main issues of lungs MRI are short apparent transverse relaxation time (T2*) and low proton density because of airways as well as possible respiratory motions. Such drawbacks impede the use of conventional Gradient-recalled Echo (GRE) imaging. Alternative

approaches are Spin echo (SE) sequence or Ultrashort Echo-time (UTE) imaging. The SE sequence refocuses field inhomogeneity with the use of refocusing RF pulses and can be T2-weighed sequence. However, acquisition times of SE are generally longer when compared to equivalent GRE sequence, which prompted the use of accelerated paradigms with several echoes within the repetition time (Fast Spin Echo). Unlike the fast-SE sequence the UTE sequence uses non-Cartesian raw-data space (k-space) sampling where the NMR signal is sampled immediately after the RF pulse. Thus, the T2* decay is limited and permits lung imaging. An additional issue can be animal heating in OMRI experiments because of microwave irradiation. Thus, fast imaging is mandatory.

The aim of this study is to implement a 3D Fast Spin Echo (FSE) sequence and to evaluate its added-value with respect to UTE for mouse lung imaging in the context of OMRI at 0.19T in a newly acquired MRI system implemented with few basic sequences. Comparison will be made on phantoms before evaluation in vivo in mouse.

II. THEORETICAL BACKGROUND

Overview of OMRI principle

Electron (or proton) thermal (1/2) spin polarization (measurable signal) in a magnetic field is due to the spin-field Zeeman interaction. The energy gap hence the population difference between the alpha-state and the beta-state depend on the magnetic field and the gyromagnetic ratio which is 658 times higher for the electron than for the proton. The Overhauser effect (Overhauser, 1953b) is the transfer of the higher electron spin polarization of a radical to the proton nuclei by means of electron Zeeman states perturbation (saturation) i.e. Electron paramagnetic resonance (EPR) in Fig. 1.

In liquids, electron-proton interaction is mostly dipolar. At 0.19T, EPR occurs at 5.4 GHz and NMR at 8.25 MHz. Therefore a microwave cavity is used for electron spin saturation (population equalization) and a RF coil is used for NMR while electrons are saturated. Proton NMR signal enhancement depends on a variety of factors. A room temperature, the utmost enhancement value can reach 330 (dipolar interaction) and is divided by the number of lines in the radical EPR spectrum. With nitroxides the number of lines can be 3 if 14N is used or 6 with an additional 31P atom.

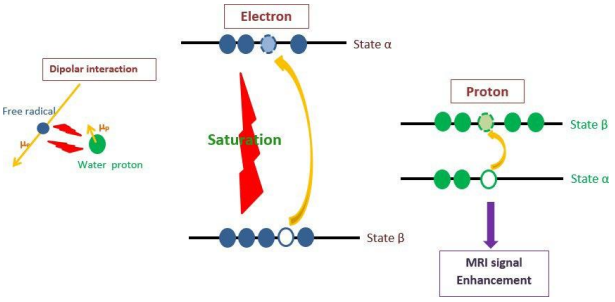

Figure 1. Principle of Overhauser-enhanced MRI

III. MATERIALS AND METHODS

A. Chemicals and Phantoms

A 5mm diameter tube filled with Oxo-TEMPO (4-Oxo-2,2,6,6-tetramethyl-1-piperidinyloxy) with a concentration of 5mM placed together with 4 tubes (5mm diameter) filled with Gadolinium with the concentration 0.68 mM, 1.67 mM, 3.34 mM and 6.68 mM respectively was used in OMRI assays.

B. Animal preparation

Mice were C57/Bl6 weighing 25 ± 5 g. Anesthesia was carried out with 1.5-2% isofluorane (Centravet, La Palisse, France)

mixed in air. They were positioned in a supine position, lying on a home-made thermo-regulated bed at 38°C. Respiration was monitored throughout the experiment with a sensor placed on the abdomen.

Instillation was carried out with 50 µL PCA (3-Carboxy-PROXYL) at 50 mM concentration. Strongly anesthetized mouse was hold by hand and slowly expelled PCA into the nostrils by the use of a micropipette. The instilled volume then travelled from the nasal airways to the lungs.

C. Instrumental

a) MRI system

All the experiments were carried out on a whole-body MRI system (Cirrus Open, Institute for Bio diagnostics MRI-TECH, Canada) equipped with a permanent magnet operating at 0.194 T (Fig. 2). Maximum value for the field-gradient strength was 20 mT/m.

The NMR home-made transmit-receive saddle-shaped coil (inner diameter and length of 26 mm) operating at 8.24 MHz was positioned in the microwave cavity (see below).

Figure 2. Illustration of the MRI 0.2T system, with the microwave cavity

b) EPR Microwave cavity

The EPR cavity (Fig. 3) was placed in the center of the magnet bore in order to induce the saturation of the electron spins in OMRI experiments. The sample is placed in a home-made transmit- receive saddle-shaped coil (inner diameter and length of 26 mm) in the center of the cavity. The coil was operated at the 1H resonance frequency of 8.24 MHz and the cavity was tuned at a frequency of 5.43 GHz with a network analyzer.

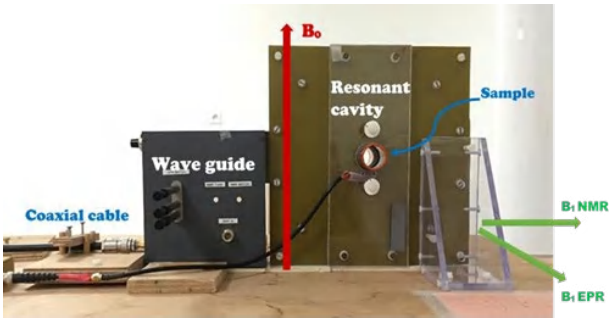

Figure 3. The EPR resonant cavity connected to a coaxial cable in order to transmit the HF electron frequency to the cavity via the wave guide component. In that, the B0 field (red arrow) was orthogonal to the B1 field.

D. Ultra-short TE sequence

The 3D UTE sequence (Fig. 4) was optimized by Angélique Rivot (PhD student in the host laboratory). Briefly, a RF pulse (50 µs) was applied before the readout of the free induction decay with concomitant application of gradients along the 3 directions of space, enabling a center-to- periphery k-space sampling. Echo time was 70 µs, TR was 20ms. The number of spokes was 845 for a single-shot low-resolution image or 11830 for a multi-shot high-resolution image. Spoke orientations were calculated with a golden angle distribution (Wu

et al., 2015), allowing under sampling with pseudo-random k-space filling. Raw data were gridded onto a Cartesian evenly-spaced matrix prior to Fourier Transformation. The gridding algorithm used a Kaiser-Bessel kernel (Jackson et al., 1991). Post-gridding digital resolution was 0.3 mm in high-resolution images and 0.6 mm in low-resolution images.

Acquisition time was 17 seconds (1 average) and 16 minute (4 average) for the low and high resolution images, respectively.

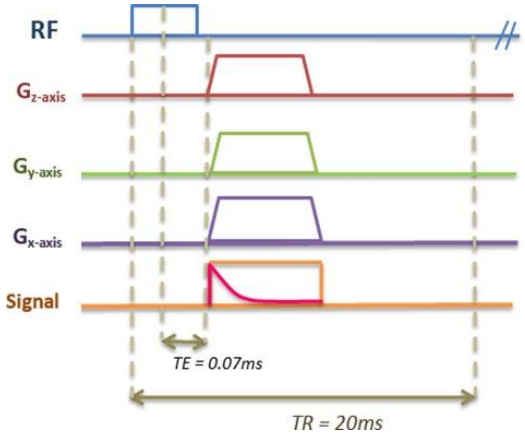

Figure 4. The non-slice selective 3D radial UTE pulse sequence with a hard rectangular pulse excitation

E. Fast Spin Echo sequence optimization

The 3D Fast Spin Echo sequence is depicted in Fig. 5. It used a series of 180°-refocusing pulses after a single 90°-pulse to generate a train of echoes in a single repetition time (TR). The filling of the k-space was carried out by changing the value of the gradient strength in the phase and the slice directions. Complete filling of the k-space was achieved by repeating the sequence with other gradient strengths. The first echo corresponded to the central k-space line, hence the effective echo time was the inter-echo delay. The number of echoes in one TR (acceleration factor) was 16. In order to decrease the total acquisition time in OMRI experiments partial k-space filling was performed by acquiring the central part of the matrix in the phase and slice directions. Under sampling factor was 2 in both directions. Fourier transformation of under sampled k-spaces gave low-resolution images. Low- to high-resolution image conversion was carried out by filling the missing lines of the undersampled matrix with lines of a reference full matrix acquired without EPR saturation (key-hole paradigm) (Lee et al., 2014). TE/TR was 9/600 ms, FOV was 64 × 32 × 32mm, number of data was 64 x 64 x 64 and resolution was 1000 × 500 × 500µm in read, phase, slice direction, respectively for the full matrix.

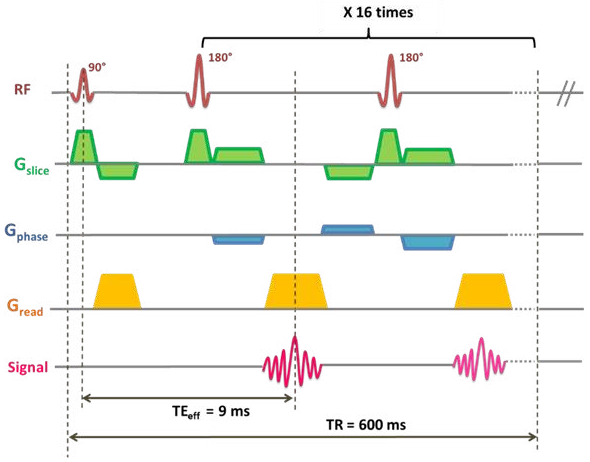

Figure 5. The timing diagram of the 3D Fast Spin Echo sequence. RF and G stand for Radiofrequency pulses and Gradient strength, respectively

Total acquisition time were 2m33s for the full matrix and 38s for the undersampled matrix.

F. In vitro OMRI experiments

A preliminary image was first generated in multi-orientations in order to position the phantom in the FOV. Then the 3D FSE sequence with optimized parameters was applied.

The first image was acquired with a full matrix (64 × 64 × 64) for the FOV of 64 × 32 × 32 mm. Its resolution was 1000 × 500 × 500 µm, the number of average (NA) of 2, the acceleration factor was 16, the TEeff/TR were 9/600 ms and the acquisition time was 5 minutes.

For the partial acquisition, an image was acquired with the same FOV, the other parameters such as TEeff/TR and the acceleration factor remained the same. However, the matrix was modified into 64 × 32 × 32, thus the resolution was 1000 µm3 and the NA was 1. The total acquisition time then became 38 seconds. The EPR mode was turned on right before MRI acquisition and was stopped at the end.

The reconstruction of the final image was performed in MATLAB software.

G. In vivo MRI experiments

All the MRI experiments were performed in the EPR cavity as they are intended for further OMRI experiments. Mouse used for experiments were prepared before the acquisitions and the respiration was followed until the end of the acquisitions.

The imaging session started with a set of localizers to position mouse lungs into the center of the FOV.

a) Partial acquisition using 3D FSE sequence

An image was acquired with a full matrix (64 × 64 × 64), the FOV of 64 × 32 × 32 mm and the resolution was 1000 × 500 × 500 µm. The TEeff/TR was equal to 9/600 ms, the acceleration factors were set to 16 and the NA of 2, then the acquisition time became 5 minutes.

For the partial acquisition, an image was made with the same FOV, TEeff/TR and the acceleration factors but the matrix was modified into 64 × 32 × 32 so the resolution was 1000 µm3 and the NA was 1, thus the total acquisition was 38 seconds.

b) OMRI experiment

Image of mouse lung was carried out inside the cavity right after instillation. A ring contained 100 µL PCA at 5 mM was put in mouse lungs position for the reference of the enhancement. Parameters for the acquisition were kept the same as for partial acquisition. The EPR mode was turned on before the acquisition and was stopped at the end.

c) Measurement T2 and T2 of mouse lungs*

Mouse was scanned with a 3D Spin echo sequence and 3D UTE sequence with various TEs for the T2 and T2* measurement respectively. The other imaging parameters were given in Table 1.

Signal intensities were measured within the regions of interests (ROIs) on the lower pulmonary lobes of the coronal images. T2 and T2* were calculated as the reciprocal of the decay constants of the signal intensities versus the TEs in the ROIs using a monoexponential function:

$$S(TE) = A \exp^{(-TE/T2^*)} + C$$

Where S (TE) is the signal intensity at echo time TE, A is the signal amplitude at a TE of zero, and C is a constant offset parameter.

IV. RESULTS

The work presented in this study is the first application of the 3D FSE sequence for the OMRI technique on the new 0.2T system. First, in vitro experiments were carried out to

evaluate the feasibility of partial acquisition using 3D FSE sequence for OMRI experiments. Then mouse lung imaging was evaluated with the same sequence without dynamic nuclear polarization. Besides, in order to obtain more information from the mouse lungs experiments, T2 and T2* value of mouse lungs was measured with the use of 3D Spin Echo sequence and 3D UTE sequence respectively.

A. In vitro OMRI experiments

Partial acquisition using 3D FSE was evaluated in a nitroxide phantom.

Axial anatomical slice extracted from 3D image acquired in 5 minutes with the full matrix is shown in Fig. 6A. This acquisition was used as a reference matrix for the partial acquisition. The SNR in the tube containing nitroxide was 15.

A low-resolution image with partial k-space filling acquired in 38 seconds and EPR mode turned on is displayed in Fig. 6B. The SNR in the tube containing nitroxide was 135 and was 12 when the EPR mode turned off (i.e. the signal was enhanced at 11.3 during the OMRI experiment).

Then Fig. 6C presents the low-to-high resolution image which was reconstructed using the peripheral parts of the k-space from the first acquisition and full k-space of the k-space during OMRI (keyhole reconstruction). In this image SNR was only 66 in the nitroxide tube. The signal enhancement in the nitroxide tube was 5.5. The discrepancy versus the enhancements measured from partial matrices (11.3) can be explained by the addition of noise when resizing the EPR-ON undersampled matrix with peripheral noisy k-space lines from the EPR-OFF full-sized matrix.

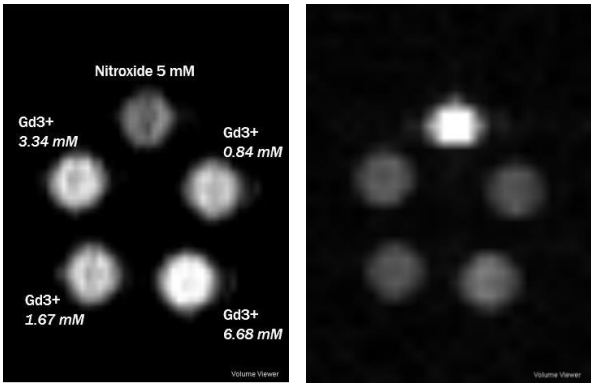

Fig. 6A Fig. 6B

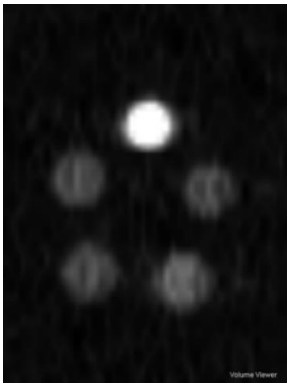

Fig. 6C

Figure 6. OMRI of a nitroxide phantom with a 3D FSE acquisition

A – Reference image without dynamic nuclear polarization. Concentrations of Gd3+ and nitroxides are indicated

B – Partial k-space filling image with dynamic nuclear polarization.

C – Image reconstruction using reference image and partial k-space filling image

B. In vivo MRI experiments

a) Measurement T2 and T2 of mouse lungs*

Fig. 7A shows the Spin Echo images of mouse lungs at two different TEs of 9 and 30 milliseconds. The images with shorter TE produced more MRI signals from lungs tissues in mouse. The signal intensities at the ROIs in

mouse lungs reduced as the TE reduced and showed excellent exponential fitting from TE of 9 ms to 80 ms (Fig. 7B). The average T2 value of mouse lungs was 26.6 ± 6.7 ms at 0.2T.

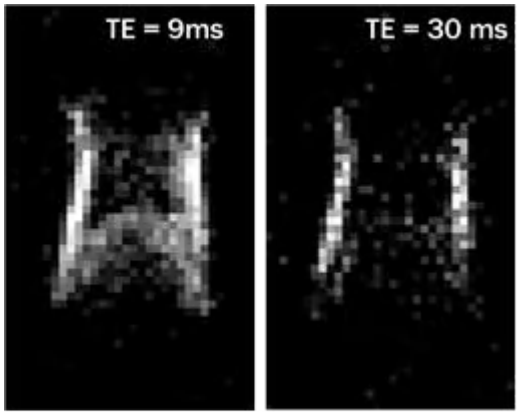

Fig. 7A

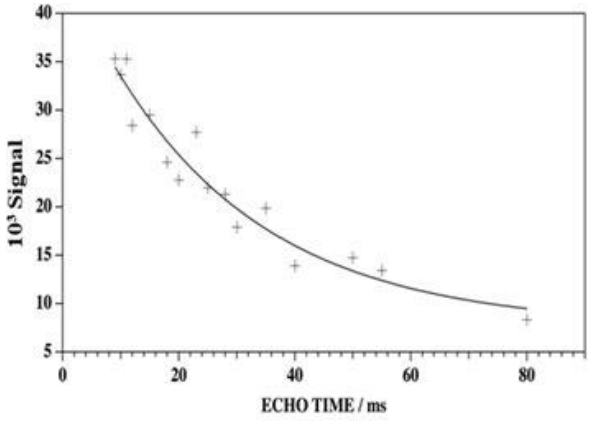

Fig. 7B

Figure 7. A – 3D SE imaging of mouse lungs with TE = 9ms and TE = 30m
B – Average signal intensity in mouse lungs as function of echo time. Curvefit is displayed as a continuous line.

Fig. 8A shows images of mouse lungs at TEs of 0.07ms and 10ms using 3D UTE sequence. Images darkened with increasing echo time through T2* decay. The average signal intensity lungs declined exponentially with echo time (Fig. 8B), produce a T2* of 2.47 ± 0.26ms.

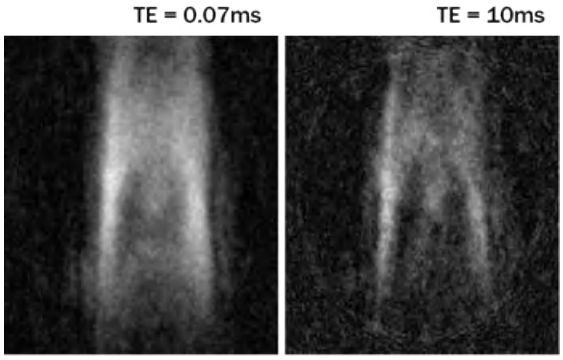

Fig. 8A

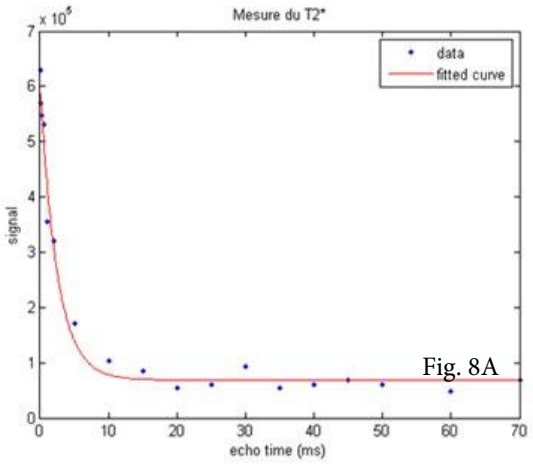

Fig. 8A

Fig. 8B

Figure 8. A – 3D UTE imaging of mouse lungs with TE = 0.07 ms and TE = 10 ms
B – Average signal intensity in mouse lungs as function of echo time. Curvefit is displayed as a continuous line

b) Partial acquisition using 3D FSE sequence

A coronal anatomical slice of mouse lungs extracted from a typical 3D data set acquired in 5 min with the 3D FSE sequence with the full matrix (64 × 64 × 64) is showed in Fig. 9A. The SNR was 4.4 in lungs and 8.3 in the liver.

In addition, a slice from a 3D image acquired in 38s with the partial matrix (64 × 32 × 32) is showed in Fig. 9B. The SNR was 6 in lungs and 12.8 in liver. This image with

the shorter acquisition time will butilized for further OMRI experiment to detect the free radical.

Both data sets acquired with full and partial matrices were used for a 3D image keyhole reconstruction combined between low- and high-resolution images. The SNR was 4.6 in lungs and 8 in the liver.

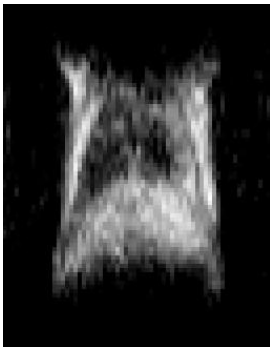

Fig. 9A

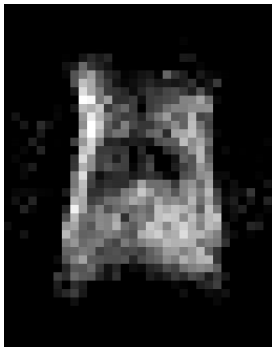

Fig. 9B

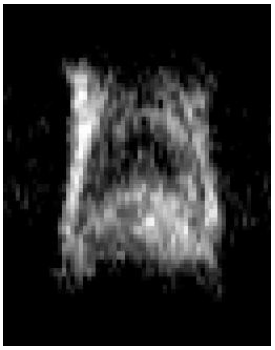

Fig. 9C

Figure 9. Partial acquisition and keyhole reconstruction of 3D FSE imaging of mouse lungs

A – Image with reference matrix (64 × 64 × 64). The spatial resolution is 1000 × 500 × 500 μm, number of average was 2 and acquisition time was 5 minutes.

B – Image with partial matrix (64 × 32 × 32). The spatial resolution is 1000 μm3, number of average was 1 and acquisition time was 38 seconds.

C – Image reconstruction of B with the peripheral lines of the full matrix (A)

c) OMRI experiment

3D FSE images of mouse lung images acquired when the EPR mode was turned off was showed in Fig. 10A. The SNR in the reference ring was 7.2 and the SNR in mouse lungs was 8.4

Fig. 10B shows 3D FSE images of mouse lung with the EPR mode was turned on. The SNR in the reference ring was 27.4, the enhancement was 3.8. In the mouse lungs there was a 30% reduction of signal with the SNR was 2.3. This signal decrease can be observed when the mitroxide concentration and/or EPR saturation efficiency are low.

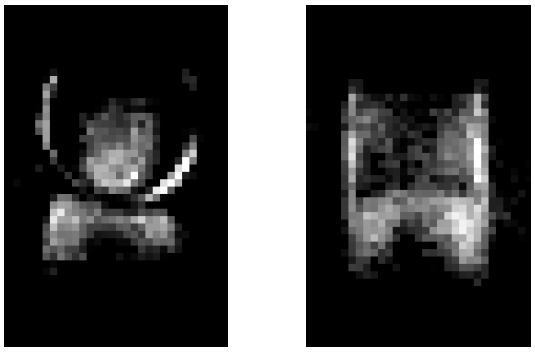

Fig. 10A

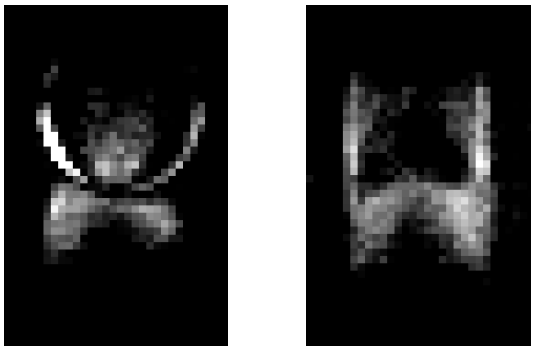

Fig. 10B

Figure 10. A – Image of mouse lungs (right) and a reference ring (left) without OMRI
B – Image of mouse lungs (right) and a reference ring (left) with OMRI

V. DISCUSSION

This study develops a useful technique for fast generation of 3D images of the mouse lungs, while preserving the lung signals and limiting artifact. There are several challenges to overcome in the study. Small size of mouse makes it mandatory to acquire high spatial resolution images at low field. Another challenge relates to the short acquisition time (i.e., less than one minute) required by future OMRI experiments, in order to prevent animal heating.

The T2 of mouse lungs is significant higher at 0.2T (26.6 ± 6.7ms) when compared with 4.7T (9.7± 0.7 ms) (Olsson & Hockings, 2016), so lung imaging can be performed at low field with the Spin Echo sequence. As expected, the T2* value was significant lower (2.47 ± 0.26 ms), indicating that conventional gradient echo imaging cannot be performed even at low fields.

A 3D FSE sequence with the major advantages of using a series of 180°-refocusing pulses in a single repetition time was optimized. The shortest attainable TEeff was 9 ms for a spatial resolution of 1000 × 500 × 500μm. The SNR in the lungs was 4.2 whereas the SNR of UTE imaging in the same region was 6.8. For future OMRI experiment, the UTE sequence has an advantage in acquisition time (17 seconds) when compare with FSE sequence (38 seconds).

The application of partial k-space filling and keyhole reconstruction provides an image with the low-to-high resolution which gives SNR and quality similar to the directly acquired image. As compared to the UTE regridded lung images (not shown), FSE images offer a better delineation of lungs. However, UTE imaging showed less affected by motion artifact than FSE imaging.

The 3D-FSE-OMRI experiments on phantom showed significant signal enhancement on the tube of nitroxide (the enhancement was 11.3 in low-resolution images) with the concentration at 0.5mM. The enhancement was also visible after keyhole reconstruction in high-resolution and no significant artifact was observed, except a decrease in the apparent Overhauser enhancement. This point is thought to be corrected for by using shorter echo times. This will be possible by upgrading gradient amplifiers.

The "negative" OMRI effect on mouse lungs 3D FSE imaging was observed (the reduction of the signal by around 30%) after 14 minute instillation of nitroxide at 50 mM. Refinement of instillation protocol and EPR cavity setup are thus necessary to increase local nitroxide concentration and efficiency of EPR saturation.

VI. CONCLUSION AND PERSPECTIVES

It should be highlighted that, due to the low level of support from the manufacturer, the host laboratory nearly started from scratch when starting sequence developments on the newly purchased system.

The present work helps to provide a basis for further developments. First, the shorter acquisition time for OMRI experiment should be achieved by increasing the acceleration factor. To do that, most of the parameters of this sequence must be modified to preserve image quality and restrict the presence of artifact.

The "last minute results" showed a significant OMRI effect on mouse lungs 3D FSE image. For the future works, the OMRI signal must be enhanced and OMRI experiments for

mouse lungs with partial 3D FSE acquisition will be evaluated.

The last objective concerns the identification of abnormal proteolysis associated with inflammation. Particularly, an OMRI exam after instillation of nitroxide-labelled peptide substrate should allow the detection of elastase through a signal enhancement provided by elastin proteolysis.

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APPLYING LEAN PRINCIPLES IN HOSPITAL MANAGEMENT TO OVERCOME THE CRISIS CAUSED BY NURSING SHORTAGE

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Abstract: Becamex International Hospital (BIH) is one of a few hospitals in Binh Duong province, offering advanced medical techniques such as spinal surgery, joint replacement, treatment of osteoarthritis with high frequency waves, and vascular interventions. The total number of full-time staff is 624, including 250 nurses. Nursing shortage are due to: 1.) Resignations following the COVID-19 pandemic; 2.) Migration, affected by population dynamics at Binh Duong Province; 3.) Nurses on maternity leaves and parental leaves. Nursing shortage can affect patient care and increase risk for patient. To address this, a comprehensive campaign with multiple projects is being implemented: focusing on IT systems, Lean methodology, process improvement, and resource optimization. Notable achievements have been realized, aiding the nursing department in effectively responding to nursing shortage crises. These achievements encompass precise predictions of maternity leave, decreased waiting durations in the Emergency Department, shortened wait times for abdominal surgeries, enhanced discharge procedures, heightened nursing efficiency, and elevated patient experience.

Keywords: *lean principles, nursing management, healthcare management, nursing shortage*

I. INTRODUCTION

After the COVID-19 pandemic, a significant number of nurses have resigned, related to psychological trauma following the pandemic. Nursing is a stressful career, despite the challenges they face, it is unfortunate that nursing salaries do not always reflect the intensity and importance of their work. In Ho Chi Minh City, the number of nursing students from prestigious nursing schools has decreased by 66% compared to the previous academic year (Phuong L., September 30, 2022). The supply of nurses to the market is very limited. If investment in nursing education is not increased, by 2030, Vietnam's healthcare system may face severe nursing shortage (Ha L., May 30, 2023).

At BIH, annual personnel fluctuations are comprised of:

Approximately 10% of nurses resign due to migration from one location to another, affected by the general population dynamics of Binh Duong province.

Female nurses of childbearing age account for 2/3 of the total nursing staff at the hospital. Approximately 8-10% of female nurses take maternity leaves and parental leaves every year,

significantly impacting patient care activities at the hospital. Research shows that significantly more nurses had stopped working earlier since gestation compared to office workers (Koemeester, A. P et al., 1997). This adds further challenges for the nursing workforce at BIH.

Additionally, about 5% of nursing staff are sent for training, while some nurses are retiring.

Nursing shortage can have tremendous negative impact on patient care (Gandi JC et al., 2011). Nurses may have to care for a higher number of patients, work longer hours, or take on additional responsibilities. This results in fatigue, burnout, lead to delays in responding to patient needs, longer wait times for medications or treatments, increase the risk of medical errors and adverse events (Hayes, L. J et al., 2012). The nursing shortage is a significant challenge for healthcare institutions around the world (Murray et al., 2002) and is one of the leading causes of stressful and fatigue for nurses at BIH. The shortage of nursing staff can have significant implications for patient care and safety.

Numerous studies have been undertaken to suggest approaches for managing maternity leaves among nurses and midwives (Konlan, K. D et al., 2023). Hiring and training fresh personnel to fill the gaps left by persistently resigning employees consumes a significant duration and is suboptimal. However, hiring new personnel is not a favored method for tackling the issue of employees going on maternity leave, as it leads to redundancy upon their return.

To tackle the issues, we conduct a comprehensive campaign with multiple simultaneous projects to address the crisis and enhance workforce effectiveness that include:

- Applying and developing information technology and data systems to build a personnel plan and manage the impact of human resource fluctuations.
- Increasing efficiency in nursing management by applying Lean principles, standardize of assignment, flexible work arrangements; promote improvement, patient pathway optimization and effectively utilizing the available resources.

II. METHODOLOGY

Nursing shortage significantly impact to provide healthcare services. The application of lean principles has gained significant popularity in enhancing healthcare and nursing performance (Johnson, J. E et al., 2012). At BIH, several measures have been implemented:

Firstly, developing software and data systems for personnel planning to monitor the number of nurses of childbearing age, maternity leaves, retirement, and workforce planning for replacements. Utilizing the BIH.HRM software to forecast the likelihood of resignation due to changes in residence and tracking maternity-management related nursing staff fluctuations can help the hospital maintain sufficient staffing levels.

Tracking the maternity status of female nurses throughout the year and tracking nursing shortage due to maternity leave positions in Table 1.

Table 1. Tracking the maternity status of female nurses throughout the year and tracking nursing shortage due to maternity leave positions

Maternity leave	Monthly											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Internal Medicine Dept.	2	2	2	2	2	2						
Surgery Dept.	1	1	1	1	1	1	1	1	1			
OB and Gyn.Dept.	1	1	1	1	1	1	1	1	1	1	1	1
Paediatric Dept.	6	6	6	6	6	6	5	5	5	5	5	5
Labor Ward	5	5	6	6	6	6						
Anesthesia Dept	2	2	2									
Emergency Dept	3	3	3	3	3	3	2	1	1	1	1	1
ICU	2	2	2	2	2	2						
OPD	1	1	1	2	2	2	2	2	2	2	1	1
Dialysis Unit				1	1	1	1	1	1			
Endoscopy Unit												

Secondly, increasing efficiency in nursing management by applying Lean principles can aid in standardizing nursing assignments and implementing flexible work arrangements. Providing training to ensure efficient and flexible task assignments, utilizing resources from practicing nurses at Eastern International University (EIU) and emphasizing staff capacity development can help to optimize the workforce.

Thirdly, promoting improvement projects to improve patient care: Reducing waiting time for emergency abdominal surgery. Statistic of waiting time for emergency abdominal surgery in Fig. 1; Improving the emergency triage system to enhance responsiveness; Expediting the hospital discharge process, reduce wasted time, increase efficiency and patient satisfaction; Implementing evidence-based Peripheral vein catheterization (PVC) management to reduce complications and frequency of care for patients at Pediatric Department; Improved nursing efficiency through the Shadow technique of Lean Management; Applying Time-Driven Activity Based Costing (TDABC) to efficiently manage human resources. Successful pilot testing in the housekeeping group.

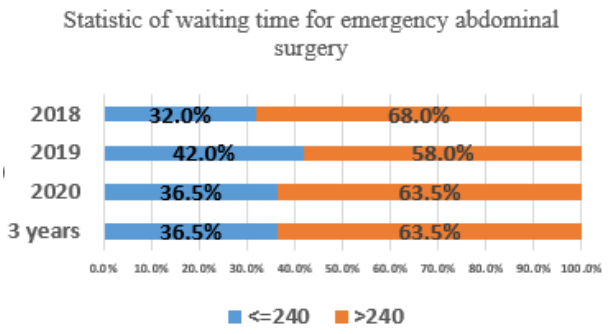
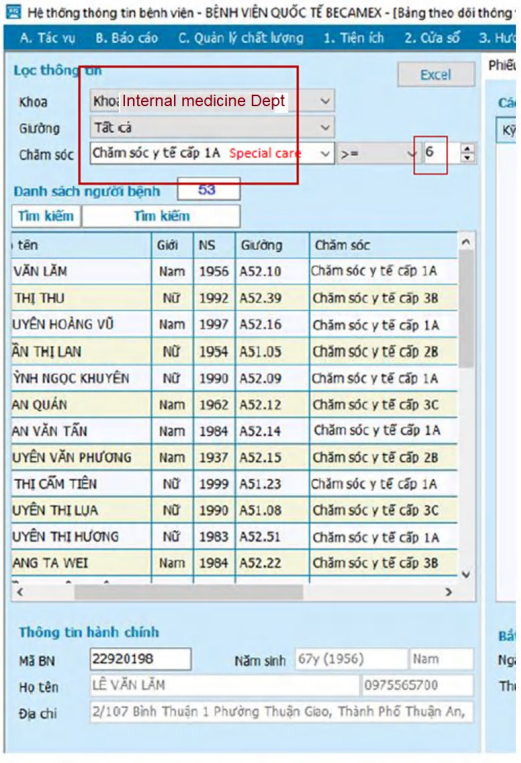


Figure 1. Statistic of waiting time for emergency abdominal surgery

Lastly, real-time monitoring of capacity and staff workload:

Utilize the BIH.HIS software to know the entire professional activities of the hospital and the number of cases requiring special care at a given time. Utilize the BIH.HRM software to indicate the total number of nurses in a shift and the number of nurses in each department (Fig. 2).



BIH.HIS software displays the unit with many patient requiring intensive care

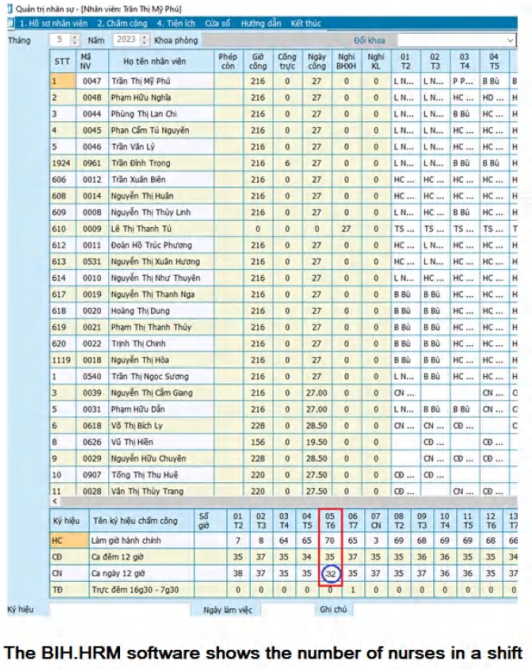


Figure 2. BIH-HIS software displays the unit with the number of patients requiring intensive care

Mobilize nurses to departments experiencing shortages to ensure adequate provision of patient care.

By implementing these measures, BIH can effectively address the shortage of nurses.

III. RESULTS

Improving the waiting time to triage at the Emergency Department from 10 minutes to below 5 minutes, can be performed when resources are limited.

Reducing waiting time for emergency abdominal surgeries, eliminating non-value-added time for patients, decreasing the percentage of patients waiting > 240 minutes from 63.5% to 29.1% (AIHW, 2017). Percentage of emergency abdominal surgeries patients waiting > 240 minutes is in Fig. 3.

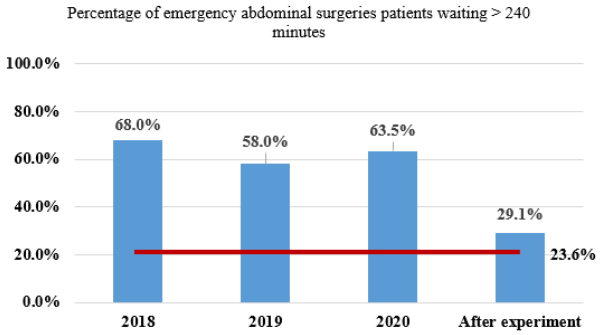


Figure 3. Percentage of emergency abdominal surgeries patients waiting > 240 minutes

- Improving discharge process to decrease discharge time (30 minutes), with proactive nursing preparation for receiving new patients
- PVC management at Pediatrics Department: increased the retention time of PVC in patients from 59.1 hours to 78 hours, reducing the number of catheter replacements.
- Applying the Shadow technique of Lean Management to improve nursing efficiency in patient care and adaptability of nurses when changing departments.
- Assigning nurses to suitable positions after competency assessments. It maximizes the utilization of nurses' skills, empowers nurses to contribute their ideas, which can lead to improved patient outcomes and decreased waste of time in problem-solving.
- 97% compliance rate with nursing procedures is a significant improvement compared to the previous year's rate of 90%.

Even with 10% nurse turnover affected by market changes, post covid issues,… BIH managed to maintain a very steady workforce and service level. Nurse satisfaction level achieved over 90%.

IV. CONCLUSION

The shortage of resources is always a challenge for management staff, not only in nursing but also in other areas of the hospital, such as physicians, other healthcare staff, and operation staff.

The lessons that we have learned from Covid-19 pandemic, regarding the management and utilization of resources in the context of a medical crisis, includes: Implementing a comprehensive campaign with multiple concurrent projects to address the crisis and enhance staffing effectiveness, focusing on identify solutions based on the practical work of staff, focusing on IT systems, Lean methodology, and resource optimization while still ensuring proper and safe patient care.

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EASTERN INTERNATIONAL UNIVERSITY
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PROCEEDINGS

VIRTUAL REALITY IN ANATOMY EDUCATION: EXPLORING APPLICATIONS AND EFFECTIVENESS

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Abstract: In the field of anatomy education, virtual reality (VR) has emerged as a promising technology that is altering conventional teaching techniques and offering uncommon potential for immersive learning experiences. Students can experience immersive learning environments via VR applications such as virtual dissections, interactive anatomy atlases, medical imaging visualization, virtual classrooms, and surgical simulations. VR in anatomy teaching has a broad range of benefits compared to conventional teaching methods. These advantages improve students' understanding of human anatomy, overcome the limitations of physical cadavers, expose students to diverse anatomical scenarios and be acquainted with surgical procedures, and foster inspiration in learning and collaboration among students. However, some challenges, such as cost, discomfort, and varying performance among students with lower spatial abilities, exist when using VR in teaching anatomy. Despite these drawbacks, the integration of virtual reality with traditional teaching methods might offer a more balanced and successful approach to anatomy instruction. The future of VR in anatomy education holds the potential for enhanced immersion, personalized learning through AI and adaptive systems, and global interactions facilitated by metaverse technology. With further advancements, VR has the capability to revolutionize anatomy education and equip future healthcare professionals with comprehensive knowledge of the human body. This study examines the application and impact of virtual reality technology in anatomy education.

Keywords: *VR, virtual reality, anatomy, education*

I. INTRODUCTION

The foundation of a healthcare professional relies on a solid knowledge base, with anatomy knowledge occupying a vital position in healthcare training (Turney, 2007). It offers a thorough comprehension of the complex structure of the human body, empowering medical professionals to correctly identify and treat illnesses (Singh et al., 2022). Healthcare practitioners can make wise clinical judgments by studying anatomy since it gives them knowledge of how different organs, tissues, and systems are organized and worked (Rosse et al., 1998). Furthermore, a thorough understanding of anatomical structures is necessary for surgeons to carry out surgeries safely and accurately. Anatomy education, therefore, builds the groundwork for surgical abilities. Additionally, understanding anatomy helps medical professionals communicate with patients in an efficient manner because they can utilize anatomical terms to describe diagnosis, possible hazards, and treatment options

(Triepels et al., 2018). A shared understanding of anatomy also considerably aids interdisciplinary communication among healthcare workers, facilitating efficient teamwork and coordinated patient care (Triepels et al., 2018; Turney, 2007). In essence, anatomy education is a crucial part of healthcare education, equipping medical practitioners with the expertise they need to provide the best possible patient care.

A technology known as virtual reality (VR) generates a simulated environment or experience that might be identical to or radically dissimilar from the actual world (Zheng et al., 1998). VR aims to give users a sensation of presence, making them believe they are actually there in the virtual world. VR technology is a combination of three technologies: motion tracking, which enables users to engage with the virtual environment by moving their bodies or using controllers; stereoscopic displays, which provide a three-dimensional visual experience; and spatial audio, which improves the aural immersion (Hamad & Jia, 2022). Virtual reality (VR) is used in many different fields, including entertainment, education, training, healthcare, and more. It presents exceptional chances for precise simulations, skill development, and group interactions (Cipresso et al., 2018).

Regarding anatomy education, virtual reality has become a potent tool for altering how students and medical professionals learn about and comprehend the human body (Samadbeik, 2018). Virtual reality offers an opportunity to explore and learn anatomy in a highly engaging and realistic way by constructing immersive and interactive virtual worlds (Moro et al., 2017). With the use of this technology, users are able to view intricate anatomical structures, interact with them in three dimensions, and learn more about how they relate to one another and how they operate. Virtual reality offers a safe and regulated setting for hands-on learning experiences previously restricted to textbooks, pictures, and conventional cadaveric dissections, whether examining the circulatory system, dissecting virtual cadavers, or viewing the inner workings of organs (Aasekjær et al., 2022). With its ability to visualize anatomical knowledge, recreate accurate anatomical settings and enable repeated practice, virtual reality improves human anatomy's understanding and memory retention. As virtual reality technology develops, it has significant potential to influence the future of anatomy education by providing a practical and affordable way to educate the next generation of healthcare professionals (Jiang et al., 2022).

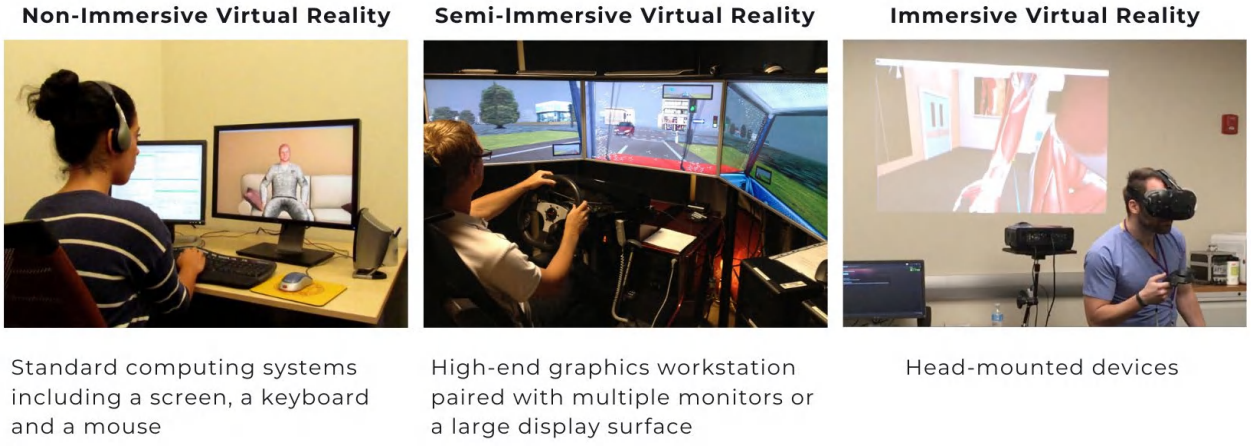

Figure 1. Types of virtual reality

II. OBJECTIVE

The overall goal is to make educators, researchers, and policymakers aware of the potential of virtual reality for improving anatomical learning experiences. In particular, this paper investigates how virtual reality is utilized, its advantages and disadvantages, and discovers its applications.

III. METHODOLOGY

This paper is a descriptive study based on information found in existing literature related to the selected topic. Comprehensive research was conducted through online databases such as Medline, Wiley Online Library, PubMed and Springer using the keywords "VR, virtual reality, anatomy, education" without applying any filter.

IV. RESULTS AND DISCUSSIONS

A. Types of virtual reality

The degree of immersion is a crucial factor influencing the user's experience and performance (Baus & Bouchard, 2014). Virtual reality can be categorized into three types based on the degree of immersion (Fig. 1): non-immersive, semi-immersive and immersive virtual reality.

According to Ma and Zheng (2011), while the non-immersive VR utilizes a standard graphics computing system including a screen, a keyboard and a mouse, the semi-immersive VR requires a high-end graphics workstation paired with multiple monitors or a large display surface. In terms of the immersive VR, the user needs to wear a head-mounted device to view the visual surroundings.

B. Applications of virtual reality in anatomy education

One of the primary objectives of education is to enhance learners' skills by rendering anatomical knowledge more applicable and useful (Karbasi et al., 2020). Karbasi et al. found that virtual technologies are valuable and effective approaches for training anatomy. In the field of anatomy education, VR has been deployed in a variety of applications, each providing unique benefits and experiences. The five basic types of VR applications commonly employed in teaching anatomy are as follows:

Virtual dissections (Fig. 2): With the support of VR technology, students are able to dissect a digital human cadaver in a virtual environment. To better study internal systems and structures, students can experience a wide range of features, including cutting, isolating, reconstructing, rotating, and zooming in and out different anatomical structures and systems (Kurul et al., 2020).

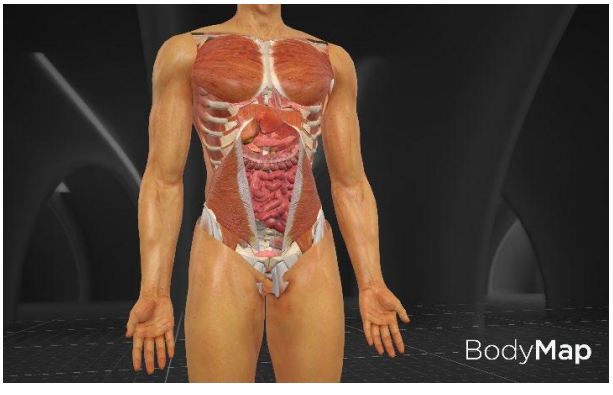

Figure 2. Virtual dissections

Interactive anatomy atlas (Fig. 3): VR technology facilitates the creation of interactive anatomy atlas, a collection of 3D geometrical models that users can interactively explore, manipulate and examine from different angles.

The atlases allow students to grab, move, pan, zoom and hide the models, often including annotations and explanations for better understanding (Gloy et al., 2021).

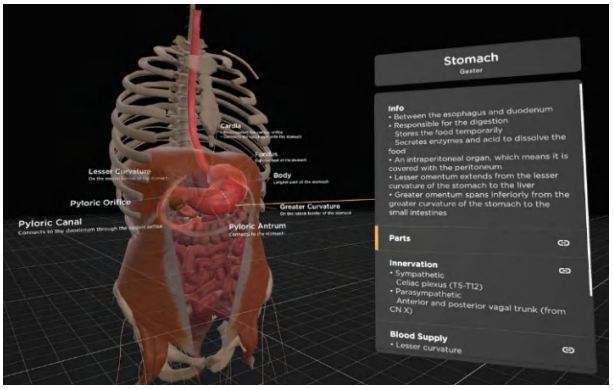

Figure 3. Interactive anatomy atlas

3D Reconstruction (Fig. 4): Learners can use VR technology to view medical imaging data in a 3D virtual environment. According to Alsofy et al. (2021), the VR software can reconstruct traditional computed tomography (CT) and magnetic resonance imaging (MRI) images (originally presented in 2D and screen 3D formats) into 3D models and visualize them in a VR headset or a regular computer. Through this VR technology, the users are able to gain a more comprehensive understanding of disease-related information and the spatial relationships of anatomical structures and identify optimal patient positioning and surgical approaches (Alsofy et al., 2021).

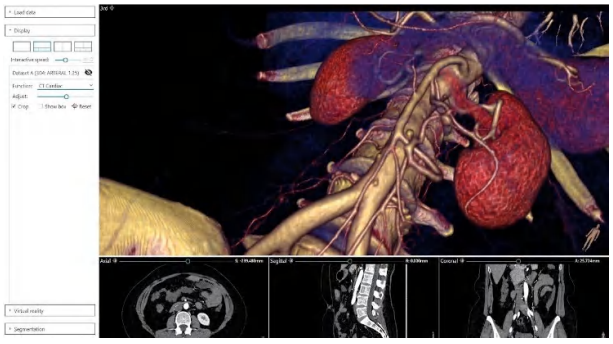

Figure 4. Medical Imaging

Virtual Classrooms (Fig. 5): Multiple users can attend virtual anatomy courses and engage with their professors and classmates in the same virtual environment using virtual reality (VR) to construct virtual classrooms or lecture halls (Nakai et al., 2021). Additionally, students have access to the lesson's materials from anywhere in the room, and they can move or enlarge interesting anatomical parts while seeing and comparing many models simultaneously. This encourages teamwork and collaboration, allowing students to learn from one another's knowledge and work together on anatomy-related tasks (Nakai et al., 2021).

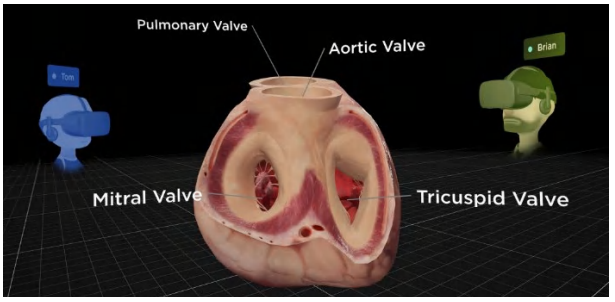

Figure 5. Virtual Classrooms

Surgery simulation (Fig. 6): Through VR technology, a virtual operating room can be simulated, along with realistic surgical instruments and step-by-step guides on surgical techniques for correct performance (Blumstein et al., 2020). This VR-based surgical simulation offers medical students and professionals the opportunity to practice surgical procedures and acquaint themselves with tools and equipment prior to operating actual surgeries (Seymour, 2007).

Figure 6. Surgery simulation

C. Advantages of utilizing virtual reality in anatomy education

Virtual reality has enormous benefits for anatomy teaching, altering how students learn and understand the complexity of the human body. VR's immersive and engaging learning experience in anatomy teaching is one of its primary advantages (Marougkas et al., 2023). Unlike traditional two-dimensional representations and diagrams, virtual reality allows students to explore three-dimensional anatomical structures, helping them more effectively comprehend and grasp spatial relationships. This immersive method promotes a more in-depth understanding of anatomical structures and their functions, resulting in better recall and comprehension of complicated topics.

Virtual reality reduces the limits associated with physical cadavers and dissection facilities. Students can engage in hands-on learning through virtual dissection sessions without the need for expensive or morally sensitive cadavers (Alharbi et al., 2020). They may manipulate virtual anatomical models, dissect tissues, and explore interior organs in a secure and controlled environment, gaining vital insights into the human body. This ease of access to virtual dissection experiences improves the efficiency of anatomy teaching and stimulates active involvement and critical thinking (Alharbi et al., 2020).

VR technology also allows for the simulation of numerous anatomical variations and diseases and provides students with exposure to a variety of scenarios they may encounter in their medical careers (Khor et al., 2016). These simulations back them to prepare for real-world clinical settings, improve their diagnostic and problem-solving abilities and practice surgery procedures. Furthermore, VR enables instructors to gamify the learning experience by including quizzes, challenges, and interactive content that inspire and engage learners (Al-Ansi et al., 2023). This gamified strategy promotes continuous learning and information retention by creating a positive learning environment and encouraging students to revisit subjects for improved performance.

Students can collaborate virtually to debate challenging cases, simulate surgical procedures, and solve anatomical riddles (Bilyatdinova et al., 2016). This cooperation improves their communication skills and prepares them for future interprofessional collaboration in healthcare.

D. The disadvatages of utilizing virtual reality in anatomy education

While virtual reality has shown great promise in educating anatomy, it has numerous drawbacks. To begin with, the VR technology can be expensive, making widespread application difficult for educational institutions with limited finances (Chen et al., 2020). Additionally, extended usage of VR headsets can produce discomfort or even motion sickness, making long study periods difficult (Moro et al., 2017; Müller-Stich et al., 2013). Finally, students with lower spatial ability using virtual learning tools perform less effectively than those studying with physical models (Khot et al., 2013).

E. Future perspectives of VR in anatomy education

The potential for employing virtual reality for anatomy instruction is quite promising. VR will become increasingly immersive and realistic as technology advances, allowing students to study anatomical components in unprecedented depth. AI and adaptive learning systems will

be integrated to personalize instructional content to individual needs, analyze and give feedback on clinical performances and improve the learning process (Pottle, 2019). The development of metaverse technology may make global interactions and interprofessional education feasible (Choi et al., 2022). When VR becomes more accessible and research-driven, it will transform anatomy education and train the next generation of healthcare professionals with a thorough grasp of the human body.

V. CONCLUSION

Virtual reality technology, classified into non-immersive, semi-immersive, and immersive variants, creates promising tools to revolutionize anatomy education. Various applications of VR in anatomy education, including virtual dissections, interactive anatomy atlases, medical imaging visualization, virtual classrooms, and surgical simulations, offer unique benefits and experiences for learners. As VR technology advances and becomes more accessible, students can effectively perceive anatomical knowledge and master their clinical skills to achieve successful careers in healthcare. By leveraging the benefits of VR and addressing its challenges, educators can harness this powerful tool to enhance the learning experience and shape the upcoming generation of skilled and knowledgeable medical professionals.

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PART IV.

INFORMATION TECHNOLOGY SYMPOSIUM

SCIENTIFIC COMMITTEE

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- *Dr. Huynh Tan Phuoc, Head of Department, School of Computing and Information Technology, Eastern International University*
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A STUDY OF FACE RECOGNITION SYSTEM USING MTCNN AND FACENET[❁]

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Abstract: Face recognition systems have been improved due to the development of machine learning technology. A lot of face recognition technology has been developed to improve accuracy and performance. There are two main challenges of face recognition: face detection and face verification. In this proposed system, we study Multi-task Cascaded Convolutional Networks (MTCNN) to detect the face of people in image frames and mark five landmarks through deep Convolutional Neural Network (CNN). We use FaceNet, a high-accuracy face recognition technology that is also based on CNN to verify the identity of people's faces in the desired frames. We hope to introduce a much more high-performance approach to solving such problems and improve the performance of face recognition systems.

Keywords: *deep learning, face recognition, face detection*

I. INTRODUCTION

A face recognition system is a technology where the system that can read a human face from the input digital image or video frames and detect the faces of people and recognize their identity by comparing the face feature with the store database. The human being can be identified using one's individual face. Identifying individuals' facial similarities can be achieved by visually comparing the matching appearance from the dataset. We provide a system that can identify a person's face through deep learning, which uses MTCNN (Zhang et al., 2016) and FACENET (Schroff et al., 2013). Also, we make use of Python and OpenCV as the mean computing aspect and algorithm generating aspect. This method is helpful in a diverse range of fields, such as smartphone technology, medication, business, automation, surveillance, online web applications, and so forth. This system provides an effective Python algorithm for face detection and recognition with the help of MTCNN to improve overall performance and accuracy. Finally, the main objective of this paper is to develop a system that utilizes the computer camera combined with the Open Face tool in OpenCV. The system would be able to detect and recognize the individual's face.

[❁] Best oral presentation award – Student session

How face recognition works

The main processes of face recognition technology have 4 parts: Detection, Computer Vision, Analysis and Recognition.

Detection is the process of finding the faces in the image. Face detection is supported by Computer Vision to identify the faces of individuals from images that have one or multiple individual faces.

Computer Vision is used to identify the person, places, and things in the image with the accuracy equal or greater than human senses at a significantly higher speed. Thanks to the AI technology (Artificial Intelligence), computer vision can automatically detect, analyze, classify, and summarize useful information from images. the data could be: frames, video, multi-dimensional data, views from different camera angles.

Analysis is the step where the system identifies the face model and analyzes the model. This system reads facial information as well as face expressions. The output will be key points of a human faces, these points will help the system distinguish one face from another. Face Recognition technology often cares about these details: distance between eyes, between forehead and chin, between nose and mouth, the depth of eyes, shape of cheeks, lips, ear and chin…. After that, the system will transfer facial data into an array of numbers or points known as "faceprint"; each individual face will have a unique faceprint, the same as a fingerprint. The faceprint can be used to re-create a digital face of the actual individual face.

Recognition is the end process of face recognition. The system can identify the individual by comparing the faces in many images and judge the matching accuracy of faces. For example, we use the phone camera to get an image of your face and we compare your face with the face in your driving license. Based on the matching rate, we can tell if that person is the same person or not. In the face recognition system, this step is done to compare the input image or video with the faceprint of the trained model from previous steps.

Benefits of face recognition

Effective Security: Facial recognition is a fast and effective verification system. This technology is faster and more convenient than other biometric technologies such as fingerprint or retina scanning. The number of touch points in facial recognition is also less than entering a password or PIN. This technology supports multi-factor authentication for additional security verification.

Accuracy: Facial recognition is a more accurate method of identifying individuals than simply using phone numbers, email addresses, mailing addresses or IP addresses. For example, today, most trading services from stocks to crypto currencies rely on facial recognition to protect customers and their assets.

High applicability: Facial recognition technology is compatible and integrates easily with most security software. For example, smartphones have built-in front cameras that support facial recognition algorithms or software codes.

Affecting factors

Facial recognition algorithms have near-perfect accuracy under ideal conditions. Controlled environments have higher success rates, but often real life has lower performance

rates. It is difficult to accurately predict the success rate of this technology because there is no single metric that can cover the whole picture.

For example, facial verification algorithms match people to clear reference images, such as driver's licenses or portraits, achieving high accuracy scores. However, this level of accuracy is only possible under the following conditions: appropriate positioning and lighting conditions, facial features are clear and unobscured, colors and background are controlled, high camera quality and image resolution.

Another factor that impacts error rates is the aging process. Over time, facial changes make it difficult to match photos taken many years ago.

Application of face recognition

Cheat detection: Companies use facial recognition to identify unique users who are creating a new account on an online platform. Once complete, facial recognition can be used to verify the identity of the actual person using the account in case there is suspicious or potentially risky account activity.

Network Security: Companies use facial recognition technology instead of passwords to strengthen cyber security measures. It is difficult to gain unauthorized access to a facial recognition system because your face cannot be changed. Facial recognition software is also a convenient and highly accurate security tool for unlocking smartphones and other personal devices.

Airport: Many airports use biometric data as passports, allowing passengers to avoid long lines and pass through an automated terminal to get to their gate more quickly. Facial recognition technology in the form of ePassport reduces wait times and improves security.

Banking: To authenticate a transaction, individuals simply show their face in front of their phone or computer instead of using a one-time password or two-step verification. Facial recognition is more secure because there is no password for hackers to compromise. Similarly, some ATM cash withdrawals and over-the-counter payments may use facial recognition to approve payments.

Healthcare: Facial recognition can be used to access medical records. This technology can streamline the patient registration process at a healthcare facility as well as automatically detect patient pain and emotions.

II. RELATED WORKS

First of all, a Face Recognition system must be able to achieve two major objectives that are face detection and facial recognition. There has been a lot of research on this topic and the technology for each aspect has been significantly developed to the point of high accuracy and effectiveness.

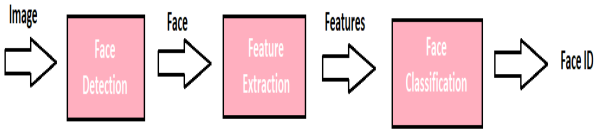

Figure 1. The Sequence of face recognition

Face detection

To detect a face, the machine must learn how to analyze and recognize the facial features and expressions of human faces. Moreover, in the practical context, human faces can be very different due to the variations of frame angles, occlusions, and lighting conditions, which are very challenging to any face detection system. In 2004, Viola and Jones proposed the cascade face detector (Zhang et al., 2016), which has

become an important foundation for later face detection methods; the accuracy of real-time detection is significantly higher compared to others in said time. Later on, to reduce the computation burden and cost in the training phase, using Convolutional Neural Networks (CNNs), Sun, Wang, and Tang introduce an image classification and face recognition system which achieve remarkable progress (Schroff et al., 2013) (2014). Yang et al. train deep CNN for facial attribute recognition to get the candidate of faces (Viola et al., 2004), the limitation of this method is time-consuming which is very practical (2016).

Face recognition development

To learn the effective feature representations of a human face, Sun, Wang, and Tang use deep neural networks (Sun et al., 2014), which have become the mainly used method at that time. In recent years, face recognition techniques have gone a long way. The accuracy and efficiency have improved rapidly. Taigman, et al. (2014) trained the system over the classification layer (Yang et al., 2016); the system will be trained using thousands of the material dataset in order to create an intermediate layer to detect the face base on that. This method is not perfect because it might be indirect and inefficient but it provides a relatively good result which is acceptable. Later on, a lot of research has been made to improve the performance and mitigate the limitations of said method.

III. PROPOSED METHOD

First, we apply the "Median Blur" algorithm to remove noise from the dataset materials. With better image quality, we utilize MTCNN (Zhang et al., 2016) to learn the facial features of a human face. MTCNN can detect whether there are human faces in the image and detect them. We also processed the material by resizing and creating newly processed images that only contain human faces. In the next step, FaceNet (Schroff et al., 2013) will use those processed images to learn about human identity and create a face model.

MTCNN and FaceNet are two very famous networks in handling the Face Recognition problem in general. And combining them, when the input is photos/videos with a lot of people and in real life situations, will give quite good results. Then, MTCNN will act as Face Detection/Alignment, helping to cut faces out of the frame as bounding box coordinates and edit/resize to the correct input shape of the FaceNet network. FaceNet will act as a Feature Extractor + Classifier network for each bounding box, providing embedding prior to distinguishing and identifying faces.

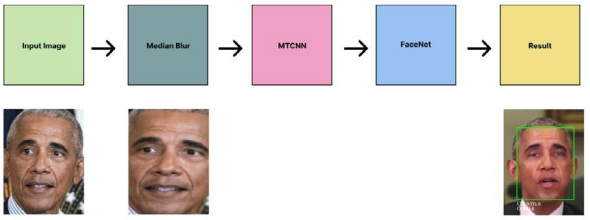

Figure 2. The proposed Method's Model

MTCNN (Zhang et al., 2016) includes 3 networks: P-Net, R-net, and O-net. The input images will be resized to different images which makes an image pyramid then the pyramid will be sent to P-Net then R-Net and finally O-Net. Each stage has its own role, P-Net can process many faces with fast speed but is unreliable and low accuracy, on the other hand, R-Net and O-Net stages will upscale and improve the final result, and the key difference between networks is the deep level and complexity of their models. After the training phase, the system will be able

to detect the face of a person or many people at the same time in a digital image or video frame in real-time.

The three main tasks of MTCNN are: Face classification, Bounding box regression, Facial landmark localization.

The Proposal Network (P-Net)

In the first step, we will use the FCN network (Fully Convolutional Network). The FCN network is different from the CNN network in that the FCN network does not use the dense layer. P-Net is used to get potential bounding boxes and coordinates of bounding boxes Bounding box regression is a technique to predict the location of bounding boxes when we need to detect objects (in this case, faces). After obtaining the coordinates of the bounding boxes, some refinements are made to eliminate some bounding boxes that overlap with each other. The output of this step is all bounding boxes after screening.

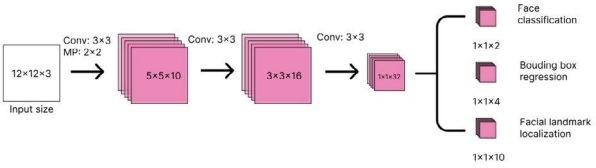

Figure 3. MTCNN Architecture (P-Net) (Zhang et al., 2016)

The Refine Network (R-Net)

All bounding boxes from P-Net are fed into R-Net. R-Net reduces the number of bounding boxes, refines the coordinates, and applies Non-max suppression. There are also two branches here to predict whether a face will appear or not and the coordinates of bounding boxes.

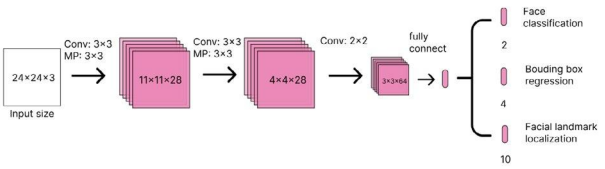

Figure 4. MTCNN Architecture (R-Net) (Zhang et al., 2016)

The Output Network (O-Net)

The output of R-Net is used as input of O-Net. In O-Net, the locations of facial landmarks (2 eyes, nose, 2 mouth locations) are given. We should focus on 3 things: the probability of a face appearing, the bounding box coordinates, the coordinates of facial landmarks (each location has x and y coordinates, this affects the number of units in the layer).

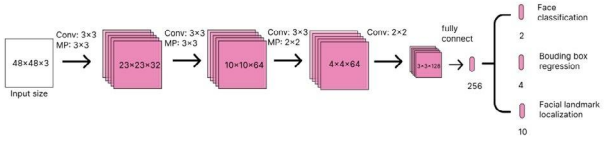

Figure 5. MTCNN Architecture (O-Net) (Zhang et al., 2016)

FaceNet

Next, using FaceNet (Schroff et al., 2013), the system will perform face recognition based on the position and face information from the face detection phase.

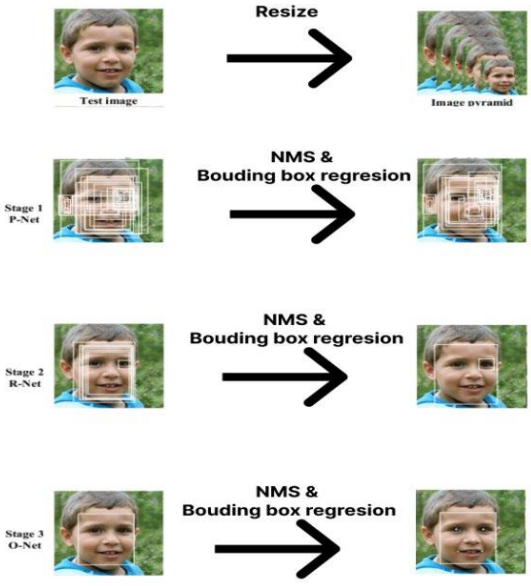

Figure 6. The Work Flow of MTCNN (Zhang et al., 2016)

FaceNet extracts the distinct feature of a human face into a vector of 128 numbers (this is called embedding). FaceNet will learn a wide range of data and randomly select and anchor. FaceNet can calculate the distance between different face embeddings and create a face representation and use it to identify positive and negative examples (triplet loss).

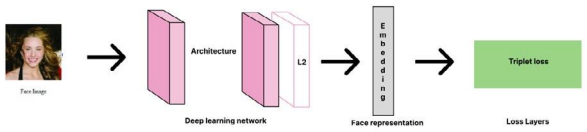

Figure 7. FaceNet Architecture (Schroff et al., 2013)

IV. EXPERIMENTAL RESULT

A. Dataset

We use a sample of 100 pictures of two human faces to train the system to learn facial coordination between them. The dataset must satisfy these requirements: they must include only the face of one person, and the angle, expression, and lighting conditions can be different but not too much, the worse the dataset the worse the result performance, that's why in a larger scale, we often see people their system with larger datasets, up to thousand or millions image, but in the scope of this research, with limited time and resource, we will perform with 100 images each identity.

The raw image will be stored in the folder name after the identity, after the training process, the Processed Image will only include the face of the identity.

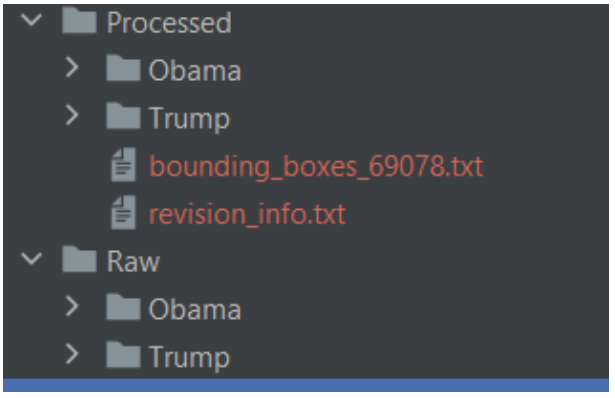

Figure 8. Dataset Storage

The facial information will be stored in the Model folder.

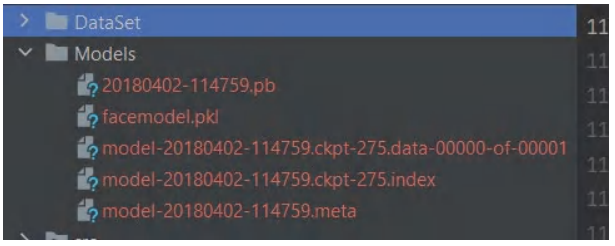

Figure 9. Face Model Folder

The dataset including 200 images were trained in 2 minutes with Intel Core I5 gen 8, and GPU GTX GeForce 1050. Which is relatively quick for machine learning.

B. Result and Discussion

We test the system with a 60 seconds video of various people's faces and the final result is quite good. The system can tell exactly whose face is on the image and create a thin border wrapped around their face to indicate, moreover, it can calculate the matching percentage of that face to the identity they have been trained to recognize that person.

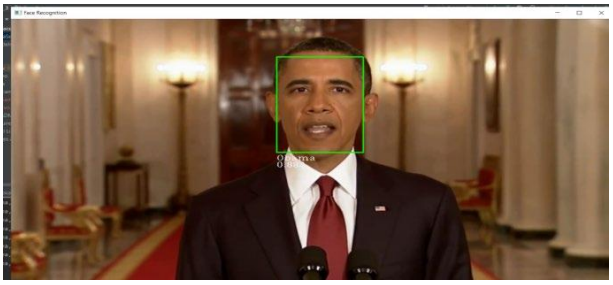

Figure 10. Face detection and calculating percentage

We also discovered that the result can be affected by many factors such as the camera angle and facial expression of the person in the image, in the example below, the facial shape of the person is not normal, which makes the algorithm lower the matching percentage of the recognition process.

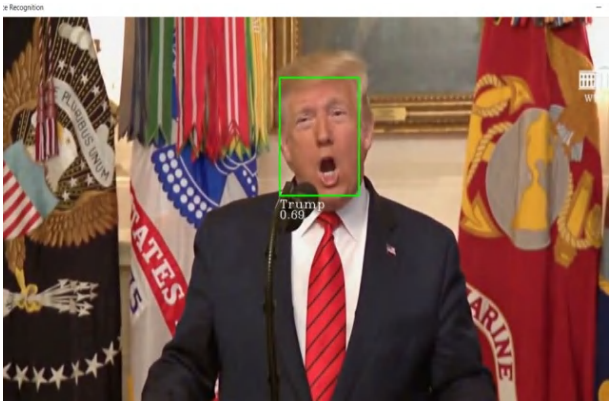

Figure 11. Low matching percentage due to facial expression

Finally, there are situations where the input data does not provide a clear view of the human face which makes it difficult to detect the face, thus lowering the reliability of the system. In the example below, the system cannot detect the faces of 3 people in front of the camera because the input is unclear.

Figure 12. Detect failure due to unclear facial input

We test 3 60-second videos, with a frequency of 1 image frame per second, and all of the frames have human faces. The result shows that the System is about to detect human faces and trace their identity (if stored in the database) 90% of the time, the system fails to detect a face when people change their facial direction too much or when they have odd expressions.

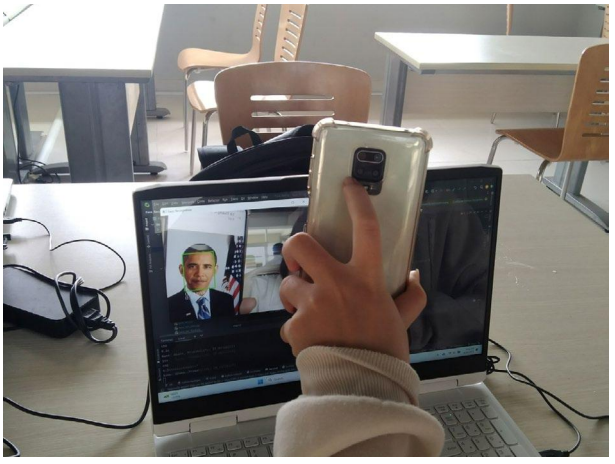

Figure 13. Detect in real lives using computer camera

IV. CONCLUSION

We successfully built a basic face detection and face recognition system which can be used to identify people from an image or video. We implemented MTCNN (Zhang et al., 2016) to detect and store facial features and use it to recognize faces by applying FaceNet Technology (Schroff et al., 2013). We also improve the input quality by applying Median Blur to remove the noise from dataset images which makes a significant improvement in the recognition rate. The result has a high accuracy and reliability, it is viable to make use of this system in different fields such as school attendance, airport check-in, workplace timekeeping, hospital, etc. However, the system just detects and recognizes faces based on the prepared data set. In the practical scene, it must be able to get the data themself, by asking for facial registration or auto-learning. The next limitation is that the system cannot handle odd camera angles which is a common problem for all detection systems. There should be more effect put into the system in order to boost the accuracy of face recognition.

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ADVANCING PYTHON LEARNING: AUTO-GRADING SOLUTIONS FOR DIVERSE MAJORS[*]

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Abstract: This study comprehensively investigates the practical deployment and comparison of auto-grading tools, focusing intensely on Codingrooms.com and nbgrader. As Python programming gains traction across diverse academic disciplines, educators face challenges in grading and timely feedback. This research explores the efficacy of these tools compared to traditional assessment methods, emphasizing their potential to mitigate biases, enhance feedback, and optimize teaching. By conducting an in-depth examination of the tools' attributes, deployment, and outcomes, this study contributes to educational technology and informed decisions for adopting auto-grading solutions in Python education.

Keywords: *auto-grading tools, Python programming, active learning, information technology*

I. INTRODUCTION

Integrating Python programming into educational curricula has surged across diverse academic levels and disciplines, offering students a versatile toolset applicable beyond traditional IT domains (Wymbs, 2016). While this adoption enriches the educational experience, it challenges educators, particularly in grading and timely feedback (Borade, Kiwelekar, & Netak, 2022; Wymbs, 2016). As the demand for student engagement and meaningful learning feedback intensifies, constrained evaluation timeframes can lead to inconsistent grading and diminished feedback quality (Price, Handley, Millar, & O'donovan, 2010). Historically, grading programming assignments relied on manual evaluation by educators, a process prone to inconsistencies in grading accuracy, feedback consistency, and the timely delivery of results (Staubitz, Klement, Renz, Teusner, & Meinel, 2015). The need to address these challenges has led to the growing popularity of automated grading tools, which offer consistent and efficient assessment and immediate feedback for extensive student cohorts. These auto-graders can serve as complete grading solutions and valuable aids in identifying potential grading issues (Manzoor, Naik, Shaffer, North, & Edwards, 2020). Automated tools streamline the grading process and empower educators to devote more time to effective teaching and mentorship. Moreover, by providing prompt and consistent feedback, these tools contribute to students' improved learning outcomes (Matuk, Gerard, Lim-Breitbart, & Linn, 2016). As adopting auto-grading solutions becomes more prevalent,

[*] Best poster presentation award

assessing their functionality, benefits, and limitations in the context of programming education becomes imperative.

This paper embarks on a comprehensive exploration comprising review, analysis, deployment, and comparison of prominent auto-grading tools, with a specific focus on the website codingrooms.com and nbgrader tool (Blank et al., 2019; Hackett, Wermelinger, Kear, & Douce, 2023). The study centers on their application to Python programming exercises, addressing crucial questions:

(1) *How was the pilot deployment of Codingrooms.com and nbgrader conducted for Python programming exercises?*

(2) *What are the strengths and limitations of these auto-grading tools, and how do they tackle challenges such as grading accuracy, feedback quality, and scalability when assessing extensive student cohorts?*

By thoroughly examining these tools' attributes, deployment methodologies, and outcomes, this research contributes to the evolving field of educational technology. Furthermore, it enables informed decisions on integrating auto-grading solutions effectively into Python programming education. Subsequent sections delve into the tools' deployment, outcomes, a comparative analysis, and the study's implications for future educational practices.

II. STUDY BACKGROUND

A. Categories of auto-graders

Auto-graders have revolutionized the assessment process in programming education by offering efficient and timely grading solutions (Matthews, Janicki, He, & Patterson, 2012). These tools employ diverse techniques to automatically evaluate students' code submissions, significantly reducing the burden on educators while providing valuable feedback to learners (Manzoor et al., 2020). Auto-graders can be classified into three main categories: Dynamic Analysis Auto-Graders, Static Analysis Auto-Graders, and Hybrid Approaches. Additionally, emerging technologies such as Machine Learning Auto-Graders are pushing the boundaries of automated assessment methods (Combéfis, 2022).

a) Static Analysis Auto-Graders: Static analysis auto-graders evaluate code without execution, using tools like compilers, interpreters, and analyzers (Messer, 2022). They assess various aspects, including syntax, code quality, and plagiarism. Metrics and measures compute complexity, maintainability, and design principles. Comparative analysis checks student submissions against model solutions. Similarity metrics, graphs, and regular expressions help to identify style and structural issues (Combéfis, 2022).

b) Dynamic Analysis Auto-Graders: Dynamic analysis auto-graders focus on program execution. They use unit tests to compare outputs or return values against expected results (Combéfis, 2022). These tools gauge the correctness, efficiency, and completeness of test suites. Instructors often design tests to train students in producing robust software. Advanced techniques analyze output semantics, enabling partial grading and distinguishing nearly correct answers from outright incorrect ones (Messer, Brown, Kölling, & Shi, 2023).

c) Hybrid Approaches: Hybrid approaches offer a comprehensive assessment by combining

dynamic and static methods (Combéfis, 2022). They are beneficial for code-generating output or assessing web applications. These approaches address challenges posed by non-compiling programs, enabling partial grading. Hybrid models attempt to repair non-compiling code before analysis, ensuring fair assessments (Haldeman et al., 2018).

In addition to these main categories, the landscape of auto-graders is evolving with the integration of Machine Learning Auto-Graders (Messer et al., 2023). These systems employ AI techniques to evaluate different aspects of code, such as grammar, design quality, and even robustness. Machine learning enables more nuanced grading and personalized feedback based on signature elements in the code.

In summary, categorizing auto-graders provides educators with a spectrum of tools to automate the assessment of programming assignments. These categories, encompassing dynamic, static, hybrid, and emerging AI-driven approaches, cater to diverse learning outcomes. By leveraging these technologies, educators can provide efficient, timely, and insightful feedback, enhancing the overall learning experience for programming students.

Table 1. Summary categories of auto-graders tools

Category	Description
Dynamic Analysis Auto-Graders	These auto-graders analyze running programs by evaluating their attributes during execution. They often utilize unit tests to check outputs or return values. Dynamic analysis assesses correctness, efficiency, and test suite completeness.
Static Analysis Auto-Graders	Static analysis techniques assess source code without execution. This category encompasses tools like compilers, interpreters, and static analyzers. It evaluates syntax, code quality, and even plagiarism. Metrics and property-based testing are also used.
Hybrid Approaches	Hybrid approaches combine both dynamic and static analyses. They provide holistic assessments by leveraging strengths from both categories. These methods are useful for grading code that generates output or for assessing web applications, ensuring comprehensive evaluations.

B. Auto-graders tools and platforms

There are several tools and platforms available that can support automatic grading for Python exercises. Educators and online learning platforms commonly use these tools to assess student assignments and exercises. Here are a few examples:

a) Web-CAT is a free tool that provides an independent platform for auto-grading programming assignments (Edwards & Perez-Quinones, 2008). It is known for its high level of customization and supports a range of programming languages. Its popularity is moderate, and educators have utilized it to automate grading processes.

b) Jupyter+nbgrader is a free tool that uses Jupyter Notebooks and the nbgrader extension for auto-grading coding assignments (Hamrick, 2016). It offers a high level of customization and is commonly used by educators to create interactive coding exercises. Its popularity is

moderate, especially in environments that use Jupyter for teaching.

c) Gradescope is a paid tool that provides an independent platform for auto-grading various assignments, including coding exercises (Bernius, Krusche, & Bruegge, 2021). It offers moderate customization and is popular among educators for its comprehensive feedback and reporting features.

d) Coding Rooms offers auto grading as a significant feature. It transforms grading scripts into automated processes, providing learners continuous feedback (Cazalas, Barlow, Cazalas, & Robinson, 2022). It offers high customization and is known for its ease of use. Details about its cost, community, and popularity are not provided.

Table 2. Comparison of procedure between grading exercises manually and using auto-grading tools

Tools	Cost	Deploy	Community & Support	Popularity
Web-CAT	Free	Hard	Moderate	Moderate
Jupyter+nbgrader	Free	Hard	Moderate	Moderate
Gradescope	Paid	Easy	Good	High
Coding Rooms	Paid	Easy	Good	High

Building upon the landscape of auto-grader tools, this study will strategically implement and assess the practical deployment of two distinctive tools: Codingrooms.com and nbgrader (Hackett et al., 2023; Hamrick, 2016). Through an in-depth analysis of these tools, the study aims to evaluate their functionality, usability, and effectiveness in auto-grading Python programming assignments across IT and non-IT majors. This investigation promises to contribute to the ongoing discourse on automated assessment methodologies and their integration into modern educational practices.

III. METHODOLOGY

In the traditional grading method, the instructors must manually grade the students' code exercise. While the auto-grading tools can help reduce a lot of time and effort of the lecturers. We create Table 3 as below to compare the differences of those methods.

Table 3. Comparison of procedure between grading exercises manually and using auto-grading tools

Steps	Grading exercises manually	Using auto-grading tools
1	Hand out the assignments	Hand out the assignments
2	Students submit answers	Students submit answers to the auto-grading system and get scores from the system.
3	Teachers give feedbacks	Students update answers
4	Students update answers	Teachers review the students' answers manually and give feedback
5	Teachers update scores	Students can update answers again
6		The teacher finalizes the scores.

As we can see in Table 3, the procedure of grading exercises manually consists of fewer steps than the procedure of using auto-grading tools. However, manual grading takes more time than auto-grading to finish grading and giving feedback. Meanwhile, the auto-grading method can help the students get the results immediately, so they have more time to improve their exercises, and the teachers will also have more time to give feedback on how the students can improve their programming skills (Combéfis, 2022).

The methodology employed in this study involves the utilization of Codingrooms.com and nbgrader for auto-grading purposes. Codingrooms.com, a subscription-based platform, is harnessed for assignment distribution and immediate result provision, enhancing interaction (Hackett et al., 2023). Similarly, nbgrader, an open-source extension integrated with Jupyter Notebook, facilitates coding exercises and automated grading (Hamrick, 2016). The deployment process entails course creation, student enrollment, exercise distribution, submission, real-time assessment, and feedback. This approach aims to streamline assessment, expedite feedback, and foster a more engaging learning environment, aligning with the study's purpose of efficient, automated grading and enhanced pedagogy. The deployment procedure for both tools shares similarities and encompasses the following steps:

a) Course Creation

The initial step involves creating a course within the chosen platform. Instructors establish the framework for the educational activities by defining the course structure, learning objectives, and grading criteria.

b) Student Enrollment

Students are added to the course roster, granting them access to the exercises and assignments. This step ensures that the right individuals participate and receive the necessary instructions.

c) Exercise Generation and Distribution

Instructors create coding exercises tailored to the course content and learning objectives. These exercises are then distributed to students through the platform. Students can engage with the exercises, complete coding tasks, and submit their solutions.

d) Submission and Immediate Results

Students submit their completed coding solutions through the platform. The auto-grading tools assess the submissions promptly, providing immediate feedback and results to the students. This real-time evaluation enables learners to gauge their performance immediately.

e) Review and Feedback

Instructors can access and review students' submitted answers and the corresponding auto-generated results. Instructors can analyze the assessments and offer personalized feedback to aid students in understanding their strengths and areas needing improvement.

IV. RESULTS AND DISCUSSION

A. Results

After finishing deployment, the user interface of those auto-grading tools is shown below in Fig. 1. Codingrooms.com is on the left, and nbgrader is on the right.

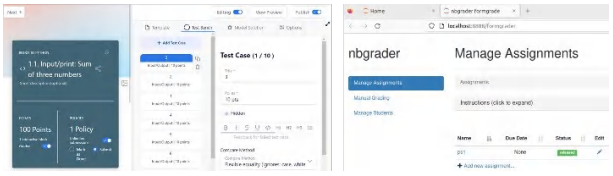

Figure 1. Assignment creating a page of auto-grading tools

a) Pilot Deployment of Codingrooms.com and nbgrader

The deployment process highlighted critical differences between the two tools. Codingrooms.com, a subscription-based platform, exhibited an intuitive and user-friendly interface, promoting ease of use for instructors and students. Conversely, nbgrader, an open-source tool integrated with Jupyter Notebooks, offered customization possibilities and potential for deployment on individual servers. This flexibility empowers educators to tailor assessments according to specific learning outcomes.

b) Strengths and Limitations of Codingrooms.com and nbgrader

Table 4. Strengths and limitations of tools

Strengths	Limitations
Consistency and Immediate Feedback: Both Codingrooms.com and nbgrader excelled in delivering prompt feedback to students upon submission. This immediate response empowers students to improve their coding skills without delay.	Subjective Aspects: While practical for objective assessments, both tools faced challenges in grading subjective code aspects requiring nuanced human judgment.
Efficiency and Workload Reduction: The auto-grading nature of these tools significantly reduces educators' grading workload, allowing them to dedicate more time to teaching and personalized mentorship.	Contextual Understanding: The tools' lack of contextual understanding could result in misinterpretation of complex assignment requirements.
Objective and Fair Assessment: The automated evaluation mitigates the potential for grading biases, ensuring an objective and fair assessment process.	Personalized Feedback: Although offering prompt feedback, the depth and personalization of feedback might not match the nuances of direct human interaction.
Scalability: Both tools efficiently managed assessment for a substantial number of students, making them well-suited for courses with large cohorts.	Quantitative Bias: The reliance on automated metrics might overshadow qualitative aspects critical to students' understanding.
Feedback Customization: Instructors could customize feedback based on the auto-grading tool's outputs, providing tailored guidance to students.	Technical Competence: Effective deployment required instructors to be well-versed in the tools' technicalities, potentially excluding educators less familiar with such technologies.

In conclusion, the pilot deployment of Codingrooms.com and nbgrader showcased their efficacy in automating the grading process for Python programming exercises. The strengths encompass efficiency, consistency, scalability, and immediate feedback, while

limitations revolve around subjective assessments and the need for personalized interactions. The subsequent section further explores a detailed comparison between the two tools, aiding in informed decisions for their adoption in Python programming education.

B. Discussion

User-Friendly Advantage: Codingrooms.com's user interface is designed with user-friendliness, providing a straightforward experience for instructors and students. This approach enhances engagement and simplifies tasks, which is particularly valuable for educators seeking efficiency (Hackett et al., 2023).

Codingrooms.com's Comprehensive Approach: Codingrooms.com's integration of assignment distribution, submission management, and instant result feedback creates a cohesive teaching environment. This approach simplifies instructor tasks and promotes a seamless learning journey.

Nbgrader's Customization and Performance: nbgrader's open-source nature empowers educators with customization options, aligning assessments precisely with learning outcomes. Furthermore, nbgrader's potential for deployment on individual servers offers enhanced performance control.

Balancing Needs: The choice between Codingrooms.com and nbgrader rests on prioritizing either user-friendliness or customization flexibility. Codingrooms.com suits those valuing simplicity and immediate access to results, while nbgrader offers adaptability for tailored pedagogical strategies.

Future Outlook: Both tools will likely evolve, potentially bridging their gaps. Codingrooms.com may expand customization, while nbgrader might enhance the user interface. Monitoring these developments can guide future tool selections.

V. CONCLUSION

This study delved into applying auto-grading tools in Python programming education, specifically benefiting non-IT majors. It illuminated the comparative advantages and limitations of Codingrooms.com and nbgrader, highlighting their potential to mitigate grading biases and provide timely feedback. Swift feedback empowers students to enhance their coding skills efficiently. Despite challenges like subjective assessments and personalized feedback, the tools offer transformative potential by catering to diverse programming proficiency levels.

Codingrooms.com's user-friendliness and nbgrader's open-source adaptability make them prime contenders for programming education enhancement. As these tools evolve, they are poised to bridge gaps further and enrich the educational experience. Notably, Eastern International University (EIU) stands to gain by embracing these tools for its Python courses. EIU could strategically develop tailored auto-grading solutions to empower instructors, streamline assessments, and foster an interactive learning environment. This strategic adoption aligns with global education trends, propelling EIU into a new era of pedagogical excellence.

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A MONITORING SYSTEM FOR CYBER SECURITY NETWORKS: AN OPEN-SOURCE APPROACH

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Abstract: In the rapidly increasing of digital threats and vulnerabilities, the need for robust and adaptive cyber security measures has become essential. This paper introduces an approach to tackle this challenge through the development of an open-source monitoring system designed for cyber networks. Built upon open-source technologies, this system offers a cost-effective solution that enables organizations to enhance the accessibility, adaptability and availability of their network. The paper details the system design, implementation, and key functionalities, with a focus on its real-time monitoring capabilities and integration of incident response. Through a combination of advanced plugins and techniques, the monitoring system facilitates the real-time identification and timely response. The potential impact of this open-source solution is significant, fostering collaboration, knowledge sharing, and providing training on cyber networks.

Keywords: *Monitoring system, cacti, plugin, open-source technology, SNMP, cyber networks*

I. INTRODUCTION

With the rapid increasing in digital threats and vulnerabilities, safeguarding the integrity and security of cyber networks plays as an imperative task. The need for better cybersecurity has led to new solutions, including the open-source approach, known for working together and being flexible. In this context, open-source network monitoring tools such as Nagios (Nagios Open Source, 2023), Zabbix (Zabbix, 2018), Cacti (Cacti, 2023), and LibreNMS (LibreNMS, 2023) have drawn attention for their capacity to provide collaborative solutions within the realm of security. Additionally, the integration of open-source Security Information and Event Management (SIEM) systems reinforces the capacity of open-source platforms to centralize log analysis and enable proactive security measures. Furthermore, the development of tools like Snort and Suricata enable the integration of intrusion detection and prevention mechanisms into open-source monitoring systems. This approach is further enhanced by the utilization of the open-source network security monitoring tool, (Zeek, 2023), which plays a role in analyzing network behavior (Khan & Khan, 2018).

This paper focuses on the design, characteristics, and deployment of an advanced monitoring system for cyber networks utilizing the open-source Cacti platform. The study presents a comprehensive, step-by-

step implementation of a specific network monitoring setup to highlight the effectiveness of Cacti as a strong open-source solution. This work can serve as a manual for individuals seeking to introduce an advanced network monitoring system in practical situations, or it can be employed for training and educational purposes.

II. METHODOLOGY

A. Open-source network monitoring system

Cacti is a network monitoring and graphing tool to monitor the performance and health of the network infrastructure. It enables users to collect, visualize, and analyze data from various devices, helping to identify issues, optimize performance, and make informed decisions about their network. Some key points about Cacti are as follows:

- Data Collection: Cacti gathers data from network devices using protocols like SNMP (Simple Network Management Protocol). This data can include information about bandwidth utilization, CPU usage, memory usage, network latency.
- Graphical Representation: Create visual graphs and charts based on the collected data. These graphs make it easier to understand trends, patterns, and anomalies in network performance.
- Thresholds and Alerts: Cacti supports setting thresholds for various metrics. When a metric exceeds or falls below a defined threshold, the system can generate alerts to notify administrators of potential issues.
- Historical Data: Cacti stores historical data, allowing users to review past network performance and identify trends over time. This data is crucial for capacity planning and troubleshooting.
- Plugins and Templates: Cacti can be extended using plugins and templates, which offer additional functionality and support for specific devices, services, or data sources.
- Web-Based Interface: Cacti provides a user-friendly web-based interface that allows administrators to configure devices, set up graphs, and manage the monitoring environment.
- Open Source: Cacti is an open-source software, which means it is freely available for use and can be modified to suit specific requirements.

Cacti collects data from network devices using SNMP, a standard protocol used to manage and monitor network devices, such as routers, switches, servers, and printers. The major techniques are used to gather data in Cacti are as follows:

- SNMP Protocol: A communication protocol that allows network management systems to retrieve information from SNMP-enabled devices. It operates on the UDP (User Datagram Protocol) and consists of managers (Cacti) and agents (devices to be monitored).
- OIDs (Object Identifiers): Network devices expose data through specific identifiers called Object Identifiers (OIDs). These OIDs correspond to various attributes and metrics of the device, such as CPU usage, memory utilization, interface status.
- Data Retrieval: Cacti uses SNMP queries to retrieve data from network devices. When

configuring data collection for a specific device, administrators specify the relevant OIDs that correspond to the metrics they want to monitor.

- Polling: Cacti periodically polls the network devices by sending SNMP queries. The devices respond with the requested data.
- Data Storage: The collected data is stored in a database managed by Cacti. This historical data is used to generate graphs and charts that visualize the network performance over time.
- RRDTool Integration: Cacti utilizes RRDTool (Round Robin Database Tool) for data storage. RRDTool stores data efficiently in round-robin databases, enabling the creation of graphs with multiple data points while managing database size.
- Graph Generation: Based on the collected data, Cacti generates graphs and charts. These visual representations provide insights into network performance, trends, and anomalies.

B. Simple Network Management Protocol (SNMP)

The application layer protocol known as SNMP uses the UDP protocol to control switches, hubs, and routers on an IP network (SNMP, 2023). A wide variety of operating systems, including Windows Server, Linux servers, and network equipment like routers and switches, support the widely used SNMP protocol. There are three components of SNMP architecture (Fig. 1):

- SNMP Manager: It is a centralized system for network surveillance. NMS, or Network Management Station, is another name for it.
- SNMP Agent: On a managed device, a software management module is present. Network devices like PCs, routers, switches, and servers can be worked as agent devices.
- Management Information Base (MIB): Information on resources that need to be controlled can be found in MIB. Hierarchical organization is used to arrange this data. It is made up of instances of objects, which are effectively variables.

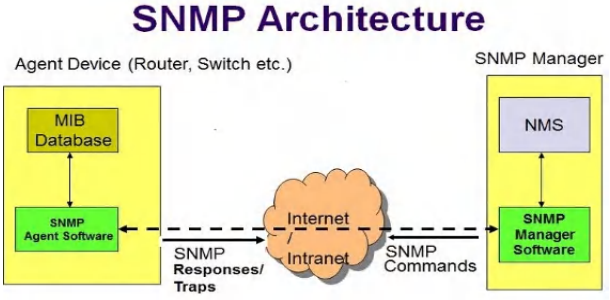

Figure 1. An example of SNMP architecture

SNMP defines several message types that facilitate communication between SNMP managers and SNMP agents. These message types provide the foundation for monitoring and managing network devices remotely, allowing administrators to gather data, configure devices, and receive notifications about critical events. The main SNMP message types are shown as in Table 1.

Table 1. SNMP message types

SNMP message	Functionality
GetRequest (Get)	To retrieve the value of one or more specified SNMP object identifiers (OIDs).
GetNextRequest (GetNext)	To request the next available OID in the MIB (Management Information Base).
GetBulkRequest (GetBulk)	To retrieve multiple sets of values from the agent in a single request.
SetRequest (Set)	To modify the value of a specific OID on an SNMP agent. This allows remote configuration of devices.
Trap (Trap and Inform)	To inform the manager about specific events or conditions, such as a link going down or a device reaching a threshold.
Inform (InformRequest)	To expect acknowledgment from the manager.
Response (Response)	The agent responds with a Response message containing the requested data.

There are three main versions of SNMP, each introducing enhancements and improvements over the previous version as shown in Table 2.

Table 2. Types of SNMP version

Version	Authentication	Data Protection	Features
SNMPv1	Community string	None	32-bit counters
SNMPv2c	Community string	None	Add bulk request and inform request messages types, 64-bit counters
SNMPv3	Username	Hash-based MAC, MD5, DES, 3DES, AES encryption	Add user authentication, data integrity, and encryption

C. Cacti installation

Apache, MySQL/MariaDB servers must be installed first before installing Cacti. The Cacti installation process is shown in Table 3.

Table 3. Cacti installation procedure

Steps	Operation
Step 1: Upgrade system packages	sudo apt update && sudo apt upgrade -y
Step 2: Setup PHP and necessary modules	sudo gedit /etc/php/*/ apache2/php.ini
Step 3: Configure the Apache Webserver	sudo gedit /etc/apache2/sites-available/cacti.conf
Step 4: Setup and configuration of MariaDB Server	sudo apt install mariadb-server -y
Step 5: Cacti database creation	sudo mysql -u root -p
Step 6: Install and configure SNMP	sudo apt install snmp snmpd snmp-mibs-downloader rrdtool
Step 7: Install Cacti	wget https://www.cacti.net/ downloads/cacti-latest.tar.gz

D. SNMP agent on windows client

Step 1: Install SNMP

- Click Programs and Features after selecting it from the Start Menu.
- Click Turn Windows features on or off on the left side.
- To install it, choose Simple Network Management Protocol (SNMP), and then click OK (Fig. 2).

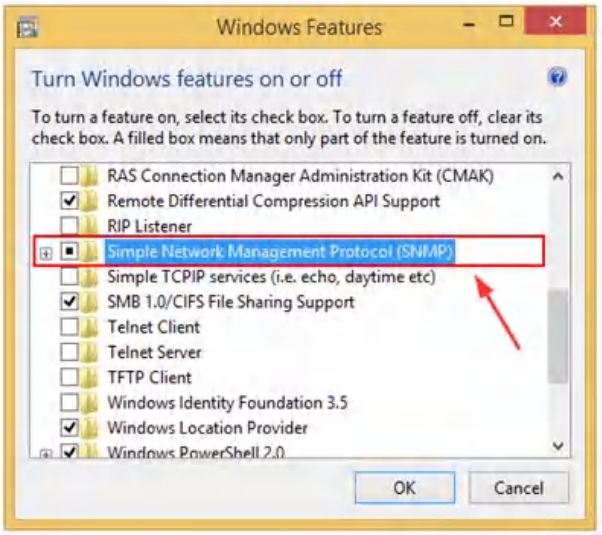

Figure 2. Enable SNMP on Windows

Step 2: Configure SNMP

- By typing "services.msc" into the Run command or searching for it, you can launch the Services applet.
- Navigate to SNMP Service, then choose Properties from the context menu.
- Select Automatic as the startup type under General to keep the service running even after restarting your computer (Fig. 3).

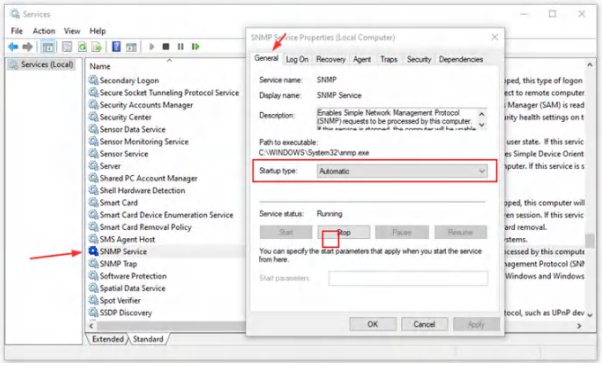

Figure 3. Configure some information in the General section

- Check the Agent tab to see if the SNMP values are enabled for each service mentioned there.

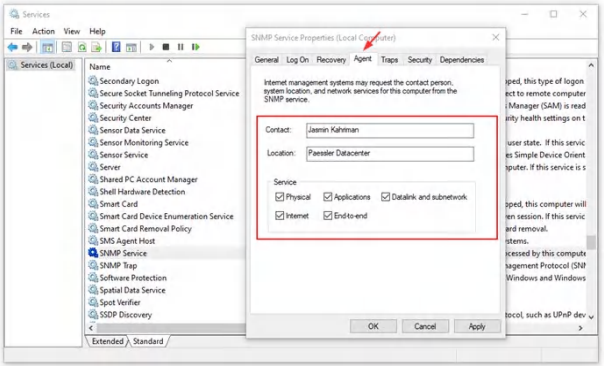

Figure 4. Configure in the agent section

- Go to the Security tab and set up the SNMP settings in accordance with your information. This includes the community string and the IP/host filter list (Fig. 4).

E. SNMP agent on Linux client

Step 1: Install SNMP Packages

Open your terminal and update the package list:

sudo apt update

Then, install the SNMP daemon (snmpd) and the SNMP utilities package:

sudo apt install snmpd snmp

Step 2: Configure SNMP

SNMP configuration is done in the /etc/snmp/snmpd.conf file.

sudo nano /etc/snmp/snmpd.conf

Modify the file according to your needs.

Listen for connections from localhost

agentAddress udp:127.0.0.1:161

Restrict SNMP access to localhost

rocommunity public 127.0.0.1

This example allows SNMP queries only from the localhost using the community string "public". Adjust the configuration to your security requirements.

Step 3: Restart SNMP

After modifying the configuration file, restart the SNMP service:

sudo systemctl restart snmpd

Step 4: Test SNMP

You can use the snmpwalk command to test SNMP. For example, to retrieve system information from the localhost:

snmpwalk -v 2c -c public localhost system

Replace "public" with your community string

Step 5: Allow External Access (Optional)

If you want to allow SNMP queries from other devices on your network, you'll need to modify the SNMP configuration to accept requests from your network's IP addresses. Edit /etc/snmp/snmpd.conf again:

sudo nano /etc/snmp/snmpd.conf

Add the following line to allow access from a specific IP address or network:

rocommunity public <IP_ADDRESS_OR_NETWORK>

Replace <IP_ADDRESS_OR_NETWORK> with the IP address or network you want to grant SNMP access to. Repeat this line for each allowed IP address or network.

Step 6. Restart SNMP

After making changes, restart SNMP again:

sudo systemctl restart snmpd

Now, SNMP is configured on your system. You can use SNMP monitoring tools such as Cacti to collect and analyze data from this device or configure other devices to query information from your Linux machine.

F. Configure SNMP on Network Devices

Configuring SNMP on a Cisco network device allows you to monitor and manage the device remotely. The configuration of SNMP on a Cisco router or switch is presented as follows:

Step 1: Access the Device

Connect to the Cisco device using a terminal emulator like PuTTY, Tera Term, or a similar program. Then log in to the device using your credentials with administrator or privileged access.

Step 2: Configure SNMP

a. Define the SNMP community string:

Define the community string, which acts as a password for SNMP access. Replace public with your desired community string and RO for read-only access or RW for read-write access:

snmp-server community public RO

b. Set SNMP version (optional):

By default, Cisco devices use SNMP version 2c. If you want to specify a different version (e.g., SNMPv3), use the following command and replace <version> with your preferred version:

snmp-server version <version> public

c. Set the SNMP system contact and location (optional):

You can provide contact and location information for the SNMP device. Replace <contact> and <location> with the appropriate details:

snmp-server contact <contact>

snmp-server location <location>

Step 3: Define SNMP Access Control (Optional)

Allow SNMP access from specific IP addresses: to restrict SNMP access to specific IP addresses, you can use access control lists (ACLs). Create an ACL and apply it to SNMP. Replace <acl-name> with your ACL name and <ip-address> with the allowed IP address:

access-list <acl-name> permit <ip-address>

snmp-server community public RO <acl-name>

Step 4: Verify SNMP Configuration

To verify your SNMP configuration, you can use the following command:

show running-config | include snmp

This command will display the SNMP-related configuration settings.

Step 5: Test SNMP Access

To test SNMP access to your Cisco device, you can use SNMP monitoring tools or SNMP commands from another device. For example, you can use the snmpwalk command on a Linux machine:

snmpwalk -v 2c -c public <device-ip> sysDescr

Replace <device-ip> with the IP address of your Cisco device.

You have successfully configured SNMP on your Cisco network device. Make sure to replace public with a strong community string and implement proper security measures to protect SNMP access.

III. RESULTS OF SYSTEM IMPLEMENTATION

A. Web-based Cacti interface

After successfully logging in, Cacti Dashboard will display as shown in Fig. 5.

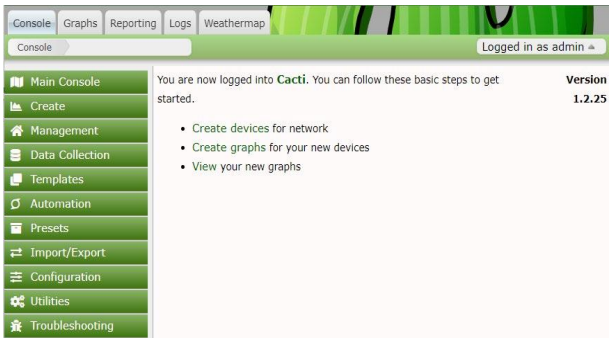

Figure 5. Cacti Dashboard

B. Monitor network device

Cacti can be used to monitor network devices, servers with their status, performance and other network information (Fig. 6).

Figure 6. Monitor network device

The information of each monitored device can be collected and visualized as shown in Fig. 7.

Figure 7. The information of monitored device in graphs

Cacti supports setting thresholds for various metrics. When a metric exceeds or falls below a defined threshold, the system can generate alerts to notify administrators of potential issues (Fig. 8)

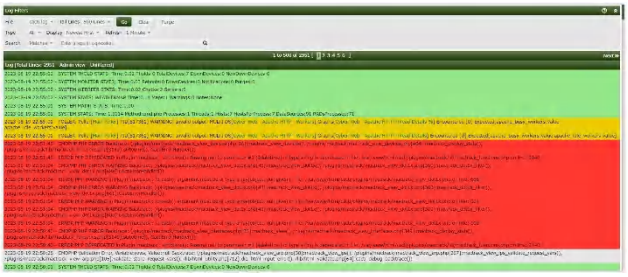

Figure 8. The logging system and alert message

C. Weathermap plugin

The Weathermap plugin is a popular and powerful feature that allows to create visual representations of network links and components. It is used to generate network weather maps, which are graphical representations of your network infrastructure showing the connectivity and status of various network elements. Here are some key features and aspects of the Weathermap plugin:

- Visual Network Mapping: Create dynamic, visual maps that represent network topology. It uses icons, lines, and colors to depict network devices, links, and their relationships.
- Link Status and Performance: Display real-time or historical data about link statuses and performance metrics. This could include data like link latency, bandwidth utilization, packet loss, and more.
- Customizable Design: Users can customize the appearance of the weather maps to match their preferences and requirements.
- Alerting and Highlighting: The plugin supports the ability to highlight links or devices that cross predefined thresholds. For example, if a link's latency exceeds a certain level, it could be displayed in a different color to draw attention.

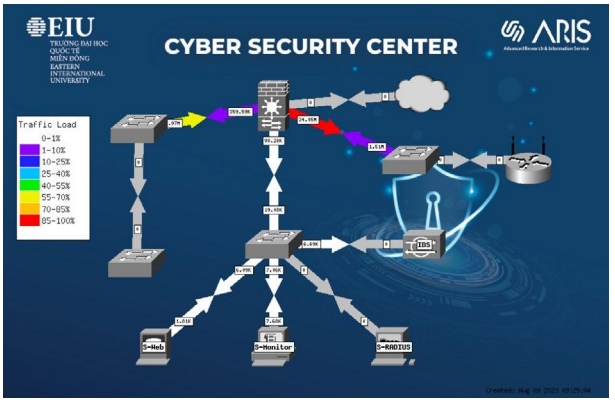

Figure 9. A network diagram with Weathermap

D. Monitor plugin

The monitor plugin refers to a feature or component within the Cacti network monitoring and graphing tool. The monitor plugin enhances Cacti capabilities by providing additional monitoring and alerting functionalities (Fig. 10).

- View Critical Hosts: The plugin provides a convenient way to view essential hosts within your network on a single dashboard or page, allowing you to quickly assess their status.
- Alerting: The plugin can be configured to generate audible alerts and send email notifications when a network device or multiple devices go offline or experience other defined issues. This is crucial for timely response to network problems.

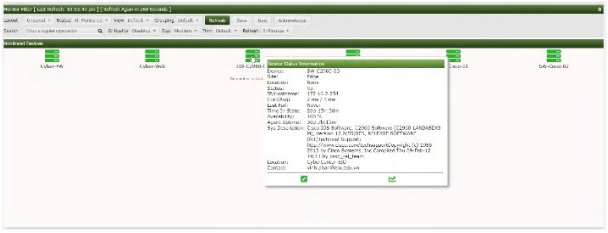

Figure 10. Monitor network device

Overall, the Monitor plugin in Cacti enhances the platform's ability to monitor, visualize, and respond to network performance issues. It provides users with a streamlined way to keep track of critical network components and receive alerts when problems arise.

E. Mactrack plugin

The MacTrack plugin has been developed with the purpose of scanning network switches, routers, and hubs to detect connected devices (Fig. 11). It then logs the location of these devices, which can be determined either by the port name or the alias of the switch or hub.

Figure 11. Network device tracking

Additionally, the plugin makes an effort to identify the IP address associated with the MAC address by referencing the MacTrack database. Another approach MacTrack employs is utilizing arpwatch to collect associations between IP and MAC addresses (Fig. 12).

Figure 12. Tracking the interface status and other information

Moreover, MacTrack possesses the capability to notify administrators or security personnel when the MAC address of a computer that has been reported missing or stolen reappears on the network. This notification mechanism can prove valuable in the process of recovering lost equipment. By utilizing MacTrack interface monitoring functionality, network administrators gain a comprehensive understanding of factors such as utilization, errors, and other critical metrics within their network infrastructure.

F. Routerconfigs plugin

The routerconfigs plugin functions in conjunction with the Cacti server's TFTP server to facilitate the reception of backups from router devices (Fig. 13).

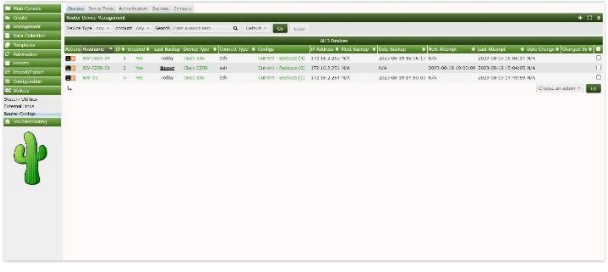

Figure 13. Network devices to backup configuration

In addition, it offers the capability to both view and compare the changes in router configurations as they evolve over time (Fig. 14). Although its main focus is on Cisco device types, there is a possibility that it can be used with other device types as well.

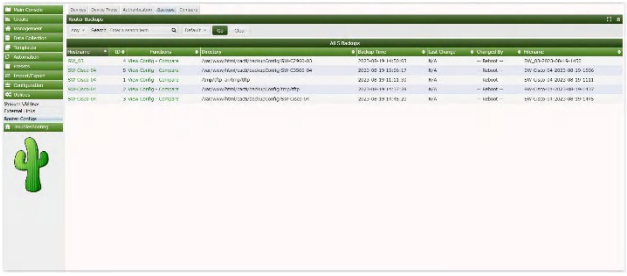

Figure 14. Configuration backup management

IV. CONCLUSION

This paper has presented the design, deployment, and main functions of an open-source monitoring system. Through a combination of advanced plugins and techniques, the monitoring system facilitates the real-time identification and timely response. The open-source solution has a big potential impact, encouraging teamwork, knowledge exchange, and providing training in cyber networks.

ACKNOWLEDGMENT

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A STUDENT MANAGEMENT SYSTEM BASED ON OBJECT DETECTION AND RECOGNITION

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Abstract: The purpose of this research work is to implement a student management system using the object detection and recognition technique based on the YOLO model for extracting information from EIU Student Cards. Additionally, the web application interface based on the Fast-API Framework is deployed to display the extracted data, facilitating student management. The findings indicate that this approach is highly valuable, dependable, and essential for implementing an automated attendance system within an educational environment. The successful outcomes of the testing demonstrate the significance of incorporating the object detection and recognition techniques into a student management system, providing a foundation for future deployment of an automatic attendance system.

Keywords: *computer vision, Fast-API, YOLO, student card, management system*

I. INTRODUCTION

Object detection and recognition is a well-established and popular task in the field of computer vision. It involves identifying and localizing specific regions of interest within an image while simultaneously classifying the objects contained in those regions, similar to a traditional image classifier. One notable challenge in object detection is the ability to handle images that contain multiple objects, making it a more complex challenge in contrast to conventional image model.

YOLO (You Only Look Once) is a highly popular object detection model known for its excellent balance of speed and accuracy. Developed by Joseph Redmon et al. in 2016, YOLO has been improved over time, with the latest version being YOLOv8, introduced in 2023. Its applications span across diverse fields in our daily lives, including face recognition, self-driving cars, speech detection, disease detection, card detection recognition, and much more.

In this project, we will employ YOLOv4 to extract information from EIU student cards and present the extracted data on a web application interface. Additionally, this application is designed to streamline and automate the process of EIU student management, making it more efficient and user-friendly.

II. METHODOLOGY

A. Application programming interface

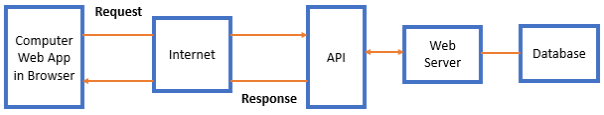

Figure 1. A Fast-API framework

APIs (Application Programming Interfaces) serve as the foundation of modern software architecture by enabling seamless communication between various applications. They facilitate data sharing, collaboration, and streamlined processes, leading to significant time and resource savings. APIs allows developers to create applications quickly, and they simplify the maintenance and updates of these apps.

In Python, there are several frameworks available for constructing APIs, each with its own strengths. Some popular options include Django, Flask, and FastAPI (Ali, 2022). These frameworks provide developers with a range of tools and functionalities to build robust and efficient APIs that supports the project requirements.

The API acts as an intermediary between an application and a server, facilitating communication between the two. When an application sends a request to the API, this request is relayed to the web server for handling. The server proceeds to process the request, formulating a response that contains the necessary information. Subsequently, this response is transmitted back to the application through the API, as shown in Fig. 1. Subsequently, the application interprets the received data and presents it in a user-friendly format for the end-user. In this way, APIs play a vital role in enabling seamless interaction and data exchange between applications and servers.

B. YOLO algorithm

YOLO introduces a novel concept by employing a single deep convolutional network that simultaneously predicts bounding boxes and class probabilities. This distinguishes it from earlier object detection techniques that repurposed classifiers for this task. All predictions in YOLO are consolidated through a single fully connected layer (Patel, 2020). The YOLO algorithm process is shown in Fig. 2:

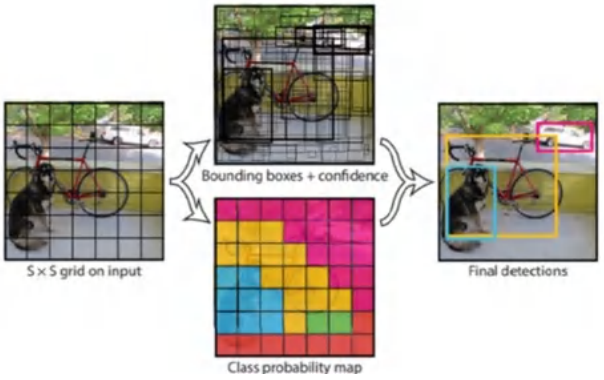

Figure 2. YOLO algorithm process

YOLO partitions an input image into a grid of dimensions S x S. When the center of an object falls within a grid cell, that cell takes on the responsibility of detecting that particular object. Within each grid cell, predictions are made for bounding boxes, along with associated confidence scores. These confidence scores indicate the model level of certainty regarding the presence of an object in the box and the accuracy of its prediction. When combined with the class probability map of the image, these predictions yield the definitive bounding boxes, selecting the ones with the highest Intersection over Union (IOU).

- **YOLOv4 Architecture**

The architecture of YOLOv4 (Solawetz, 2022) is described in Fig. 3.

Backbone

The CSPDarknet53 network is an extension of the Darknet 53 network, incorporating CSPNet (Cross Stage Partial Network) principles. CSPNet enhances the CNN's learning capacity while concurrently reducing computational and memory overhead. It integrates Darknet53 to maintain network depth while effectively mitigating the vanishing gradient issue. The output of this stage is the feature maps of objects.

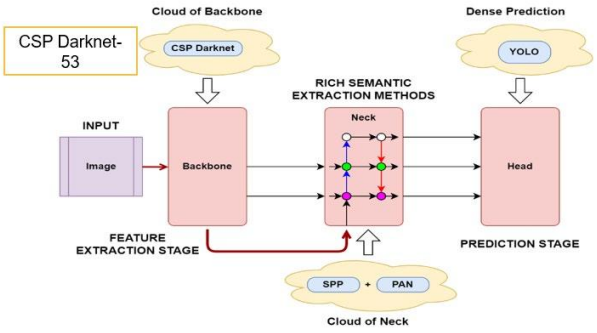

Figure 3. YOLOv4 Architecture

Neck

By employing two networks, specifically the SPP (Spatial Pyramid Pooling) and PANet (Path Aggregation Network), we achieve certain advantages. The SPP network is used to expand the receptive field, aiding in the differentiation of features. Meanwhile, PANet serves to streamline the connection between low-level and high-level information pathways, thus facilitating the convergence of parameters across various levels.

Head

Head predicts the bounding box of the object, and outputs the center coordinates (Bx, By, Bh, Bw). This helps to predict the object.

- **YOLOv4 -tiny**

The reason why we choose using **YOLOv4-tiny** is because it prioritizes faster real-time object detection and reduce training time but trade off the accuracy of detection as shown in Fig. 4 (Saponara et al., 2022).

YOLOv4's backbone is CPSDarknet-53 using Mish function for learning the dataset its RAM occupancy rate is extremely high but YOLOv4-tiny's is **CPSDarknet53-tiny** using **Leaky_Relu** function which is take the benefits of both Mish and ReLU activations, ensuring that information from the negative axis is preserved. This effectively resolves the issue encountered by the ReLU function when trying to learn from negative values.

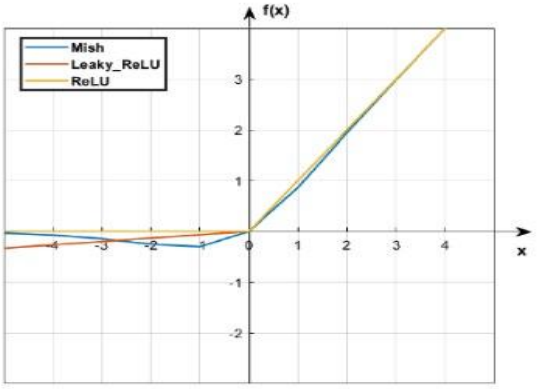

Figure 4. The comparison of YOLOv4 components

C. Project implementation

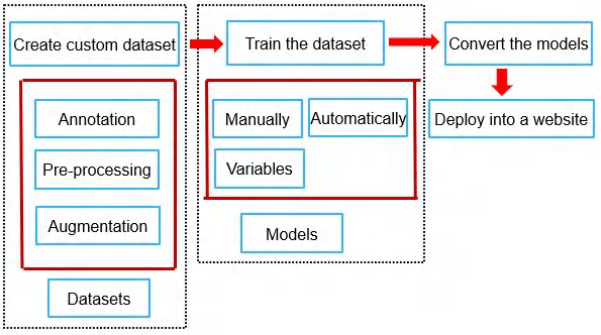

Figure 5. Project implementation process

The implementation of our project is divided into three phases: creating a custom dataset, training the dataset, converting and deploying it into a web application (Fig. 5).

- ***Phase 1: Creating the custom dataset***

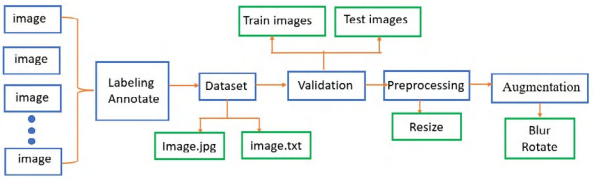

Figure 6. The procedure of creating the customize dataset

In preparation for the training dataset, we gathered over one hundred images of EIU student cards (as shown in Fig. 6). When using Darknet to train models, the input image's size is not a concern, and you can retain the original dimensions. However, the crucial aspect is the input resolution, as it determines the number of pixels that the model will use for learning and predictions. A higher resolution can enhance accuracy by aiding the model in detecting smaller objects, but it may lead to slower training and inference times as a trade-off.

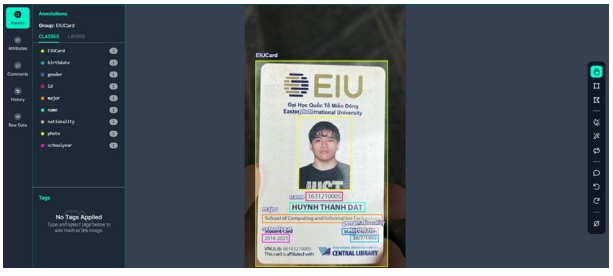

Figure 7. Roboflow annotation

We utilize the Roboflow Annotation application to label the pertinent objects in the custom dataset (Fig. 7). Subsequently, the input dataset is divided into the train set and test set. A crucial step in this stage involves applying pre-processing and augmentation to our labeled images. This process serves two main purposes: reducing training time and enhancing performance. Pre-processing involves applying image transformations to all images, while augmentation generates new training examples for the model to learn from. Pre-processing Step usually includes:

- Resizing: Images are often resized to a consistent resolution to ensure that they all have the same dimensions. This is necessary because many deep learning models require a fixed input size.
- Normalization: Pixel values in images are usually scaled to a standard range, often between 0 and 1 or -1 and 1. Normalization helps stabilize training by ensuring that all input features have similar scales.
- Data Augmentation: Although data augmentation is often discussed separately, some augmentation techniques can be considered as part of pre-processing. These include random cropping, rotation, flipping, and color adjustments applied to the training images to increase the diversity of the dataset.

1) Pre-processing

Because of the input image sizes usually bigger or smaller than the **yolov4-tiny** standard (416 × 416), so in this stage we need to pass these labeled images though pre-processing stage by transforming all the images in this dataset to help to fix the standard size as well as it helps to decrease training time and increase performance.

The missing part of the image, if it is smaller than the standard, will be black because it helps focus more on the color image. If it's

too big, we just need to downsize it but need to keep its ratio (Fig. 8).

Figure 8. Applying the pre-processing

2) Augmentation

Augmentation is a very important stage for our dataset if you want to boost the number of new training examples. It helps to generate augmented versions of each image in our training images so that our detector model can learn more unqualified cases of images. There are two main fields such as apply for the image itself and for its bounding boxes. It is good for the model if you have the huge of labeled images, the more augmentations applied, the more complicated model can learn and detect (Fig. 9).

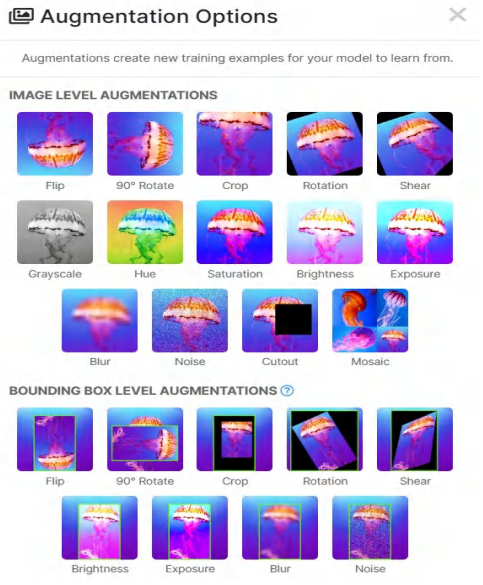

Figure 9. Augmentation options

However, because our dataset is quite small, so we only apply some of them which will increase our result.

- Crop: (0 – 12%) Add variability to positioning and size to help your model be more resilient to subject translations and camera position (Fig. 10).

Figure 10. Crop augmentation

- Brightness: (-12% - +12%) Add variability to the image brightness to help your model be more resilient to lighting and camera setting changes (Fig. 11).

Figure 11. Brightness augmentation

- Blur: (2px) Add random Gaussian blur to help your model be more resilient to camera focus (Fig. 12).

Figure 12. Blur augmentation

- Noise: (2%) Add noise to help your model be more resilient to camera artifacts (Fig. 13).

Figure 13. Noise augmentation

After applying needed augmentation to all dataset, we will get the training images as shown in Fig. 14.

Figure 14. Result of augmentation stage

Finally, we can generate more versions of the dataset by locking selective pre-processing and augmentation for reproducibility. For example, we have 43 training images, 12 validation images, 6 testing images (total is 61 images). If we generate "x3" images with selected augmentation, we will get 129 training images which we only have 43 before.

- ***Phase 2: Training the custom dataset***

Once the initial phase is completed, we proceed to train the model using the custom dataset on Collab. This platform is chosen because it offers the advantage of convenient model saving and loading, making the process smoother and less time-consuming. It is important to note that this stage of training might take some time before producing the desired result, which is the weights model.

The important steps in training our own dataset can be described as follows:

- *Step 1*: Make sure we are training on GPU.
- *Step 2*: Find the type of GPU we are using on Collab.
- *Step 3*: Clone the Darknet Repository in Github into the Collab.
- *Step 4*: Enable OpenCV on Makefile of Darket folder.
- *Step 5*: Verify the CUDA version (important).
- *Step 6*: Run the Makefile.
- *Step 7*: Download the newly released YOLOv4-tiny weights.
- *Step 8*: Import the custom created dataset (from Roboflow API).
- *Step 9*: Set up the file directories to contain the custom dataset and where we save the trained file when the training finished.
- *Step 10*: Build a dynamically config based on our number of annotated classes.
- *Step 11*: Train our custom dataset with YOLOv4-tiny model.
- *Step 12*: Wait a while to get the final trained file. At the end of this stage, we will get some weights trained file that stored in backup directory.
- *Step 13*: Download our own trained file for the next stage.

The detail of training custom dataset with YOLOv4-tiny can be accessed here (Mukhtar, 2020).

- ***Phase 3: Converting and deploying the trained model into the website***

The outcome of training the custom dataset is a trained model in the Darknet weight format. However, for easier deployment, we must convert it into other formats such as PyTorch, tflite, and TensorFlow. These alternative formats facilitate seamless integration and deployment of the model in different environments and frameworks.

In the final step, we take the trained model in TensorFlow format and deploy it within a web application. This web application is designed to extract relevant information from the EIU student card. The extracted information serves a valuable purpose in the student management system, particularly when adding new students to the student list. By utilizing this system, the process of managing student data becomes more efficient and streamlined.

III. RESULTS OF PROJECT IMPLEMENTATION

A. The web application interface

The images displayed below depict the front-end of the website. As a fundamental component, the website features a login page (Fig. 15). This login page serves as the entry point for users to access the website functionalities.

Figure 15. The login page

Upon accessing the Homepage (Fig. 16), users are presented with two options:

EIU Card Extractor: This option allows users to test the project and perform card extraction.

View Result: By selecting this option, users can view the extracted data that has been processed and obtained from the EIU student cards.

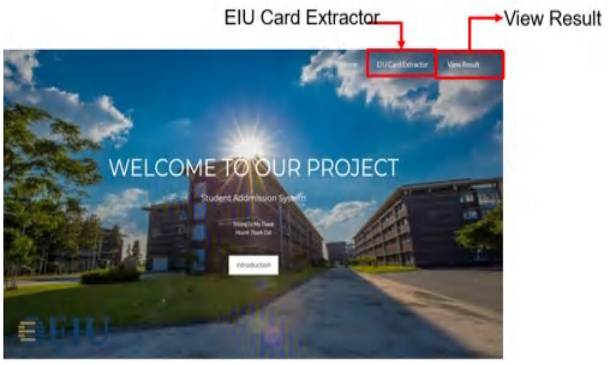

Figure 16. The home page

B. EIU student card extraction

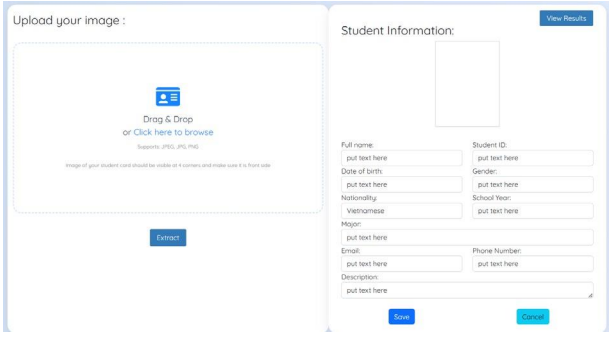

Figure 17. An example of student card extraction interface

- *Step 1*: To initiate data extraction, simply drag the EIU Card image to the left side of the interface.
- *Step 2*: Click the *Extract* button to start the extraction process.
- *Step 3*: Allow some time for the extractor to process the information, and the results

will be presented once the extraction is complete. Please be patient during this process.

C. The result of EIU student card extraction

The result of EIU student card extraction is illustrated in Fig. 18.

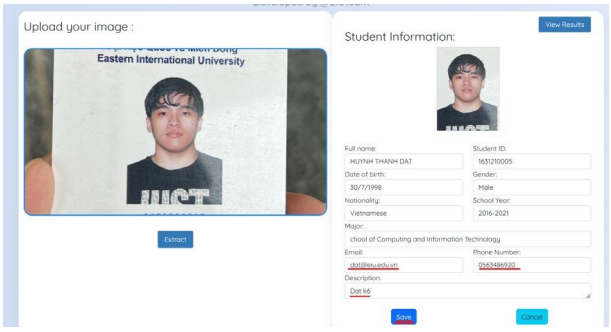

Figure 18. The result of sutdent card extraction

Figure 19. List of student entries

Fig. 19 shows the list of students whose information is extracted using card detection method.

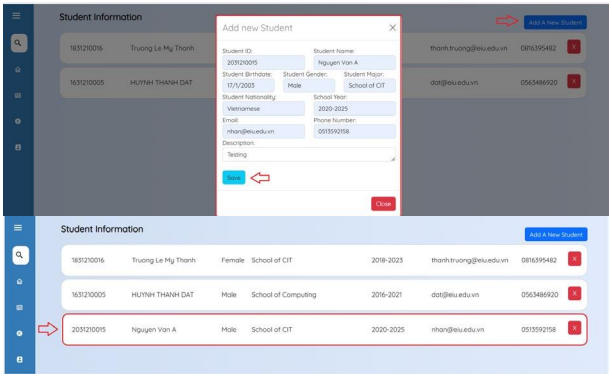

Figure 20. Adding a student entry manually

However, the student information can be modified manually as shown in Fig. 20.

Figure 21. Deleting the student entry from the list

The admin can modify or delete the student entry from the list as shown in Fig. 21. The information detail of each student is displayed as in Fig. 22.

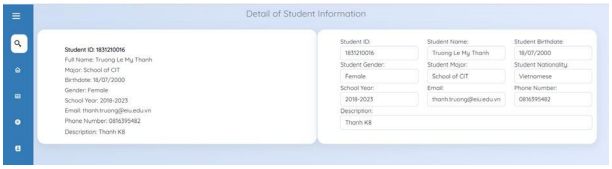

Figure 22. Viewing the information of each student

D. The implementation result disscusion

The EIU student card contains numerous valuable pieces of information that can be extracted, including student ID, student name, birthdate, major, student photo, school year, and nationality. However, it is important to carefully determine which specific information needs to be extracted, as it can significantly impact the overall performance. Obtaining more information from the EIU student card can lead to slower inference times and potentially reduced accuracy. Therefore, striking a balance between the required information and performance considerations is essential.

- ***Case study 1: Extracting 9 classes***

In this scenario, the input EIU student cards are categorized into 9 classes, which

comprise EIUCard, birthdate, gender, id, major, name, photo, school year, and nationality. However, upon training, we have observed that the overall performance for the dataset with 9 classes is not satisfactory, particularly with the *nationality* label achieving only 50.46% accuracy, as depicted in Table 1.

Table 1. Result of the labeled student cards with 9 classes

Class ID	Accuracy
EIUCard	100.00%
birthdate	73.15%
gender	83.33%
id	100.00%
major	91.67%
name	100.00%
nationality	50.46%
photo	100.00%
schoolyear	100.00%

The reason behind this can be attributed to the spatial proximity of the *nationality* field and the *birthdate* field on the EIU student card. Due to their close proximity, it becomes challenging to precisely detect both fields during the inference phase if they are labeled together. The close proximity of these fields creates ambiguity and makes it difficult for the model to distinguish between them accurately. As a result, the model performance in detecting both the *nationality* and *birthdate* fields simultaneously is affected, leading to the observed decrease in accuracy for the *nationality* label during training.

- ***Case study 2: Extracting 8 classes***

Table 2. Result of the labeled student cards with 8 classes

Class ID	Accuracy
EIUCard	100.00%
birthdate	100.00%
gender	83.33%
id	100.00%
major	90.97%
name	100.00%
photo	100.00%
schoolyear	100.00%

In this study, we have made a modification by labeling the EIU student cards with only 8 classes, and specifically, we have removed the *nationality* field from the training data. The outcomes of the trained model are illustrated in Table 2.

After conducting further analysis, we discovered a significant improvement in the extractor's accuracy when training with only 8 classes, excluding the nationality field. In the previous training with 9 classes, only 4 values achieved 100% accuracy, while both *birthdate* and *nationality* labels performed poorly, especially *nationality* with only 50.46% accuracy.

Upon closer examination, we realized that the *nationality* value was consistently Vietnamese since the majority of EIU students are Vietnamese, and very few are foreigners. As a result, by removing the *nationality* field, the accuracy of the *birthdate* field dramatically increased to 100% (previously at 73.15%). This led us to decide to deploy the model with 8 classes, excluding the *nationality* field.

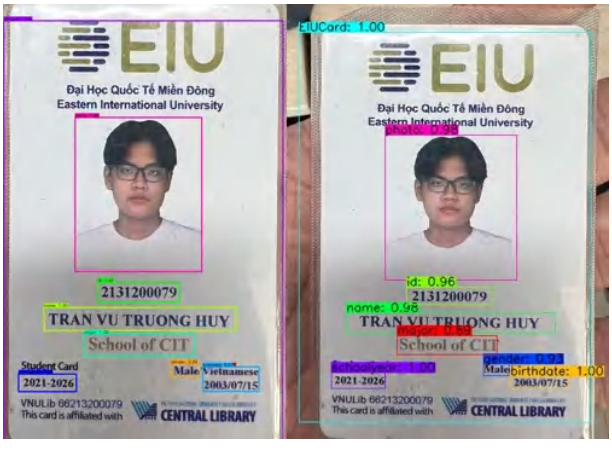

Figure 23. The result of student card detection using two different classes

Fig. 23 demonstrates the performance between the two models in inferencing and

further validates our decision to use the model with 8 classes for deployment.

IV. CONCLUSION

In this research paper, we have presented our approach, which focuses on customizing a trained model for detecting and recognizing EIU Student Cards. Furthermore, we have successfully deployed the project as a web application to streamline the process of extracting information from EIU student cards. The extracted data from these student cards is stored in a MySQL database, and it is conveniently displayed on the web page, ensuring a user-friendly experience and seamless integration with the student management system. In the future, it will be essential to incorporate additional object detection and recognition algorithms in order to train our gathered student dataset more comprehensively. This will enable a more robust evaluation and, consequently, enhance the overall performance of the system.

ACKNOWLEDGMENT

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A STUDY OF IMAGE RESTORATION USING CNN AND ESRGAN

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Abstract: A fundamental computer vision task, image restoration has been the subject of intensive research for many years. Deep learning-based methods have recently produced cutting-edge outcomes for a variety of image restoration tasks, including denoising, deblurring, super-resolution, and others. The mapping between the degraded input images and their corresponding clean versions is learned using these approaches, which rely on extensive training data. However, the quality and quantity of training data, which may be scarce in some applications, is a key factor in how well these methods work. In this research, we study a novel deep learning methods for picture restoration that attempts to boost the effectiveness of current approaches by utilizing the potential of transfer learning. This paper explores the use of deep learning techniques for image restoration, focusing on recent advances in the field and their practical applications. Specifically, we will discuss the challenges of image restoration, the current state-of-the-art methods using deep learning, and future directions for research in this area.

Keywords: *deep learning, image restoration, transfer learning*

I. INTRODUCTION

The main purpose of image restoration is to recover a damaged image to a state that is closest to it original form or of higher quality than the corrupted one, in other words an inverse problem. The damage to an image can be due to many causes but is typically divided into internal causes (e.g., camera blur, file corruption, low quality photo materials) and external causes (e.g., mishandling of the image, environmental factors like storage temperature and humidity). Normally image restoration often rely on advanced mathematics and probability models to calculate the priors of an image and then use them to solve the inverse problems like noise reduction, super-resolution, and in-painting. In recent years the computer vision saw an increase in methods utilizing deep learning which brings many improvement to the image restoration field. For example: greater boost to performance compared to conventional techniques, calculation of estimations that cannot be modeled mathematically, the usage of graphic processing units (GPUs) which yield higher efficiency than CPUs. Nonetheless, these new techniques are without flaws. Since deep learning use neural networks as the core these methods require a large number of training data of suitable quality for the networks to output

desirable results. Thus the aim of this paper is to introduce a learning method called Transfer Learning to assist in image restoration that will have lesser data requirement versus other deep learning techniques and therefor will improve efficiency of the training process along with lower hardware requirements. The format for the remain of this paper is:

- Section 2: Summary of the proposed method

- Section 3: Detailed explanation of the proposed method

- Section 4: Experimental results

- Section 5: Conclusion

II. RELATED WORK

Image restoration is an essential computer vision task that has been extensively researched. Traditional approaches, such denoising filters and deblurring algorithms, frequently rely on manually created features and mathematical models to infer the underlying image structure. However, these techniques frequently can not deal with intricate deterioration patterns and are not resistant to noise and other distortions. Deep learning-based techniques have demonstrated promising results in a number of image restoration tasks in recent years, including denoising, deblurring, super-resolution, and others. These techniques successfully capture the underlying picture priors and produce high-quality outputs by learning the mapping between the degraded input images and their corresponding clean versions using deep neural networks. Convolutional neural networks (CNNs), generative adversarial networks (GANs), Discriminative Transfer Learning are some of the most well-known deep learning-based methods for picture restoration.

A. Convolutional Neural Networks (CNN) (Jain et al., 2009)

Convolutional neural networks (CNNs), a subclass of deep neural networks, have demonstrated outstanding performance in image restoration challenges. When it comes to image restoration, CNNs are trained to map a degraded input image to a corresponding clean or restored image. Convolutional layers, which apply a collection of filters to the input image and produce feature maps that reflect important image features, are used in the architecture of CNNs to capture local patterns and structures in images.

In order to train CNNs for image restoration, pairs of corrupted and uncorrupted images are commonly used. These pairs make up a training set that is used to optimize the network's parameters using supervised learning. Given a fresh contaminated image during inference, the trained CNN can create a restored image that keeps crucial details and eliminates noise or artifacts. Super-resolution, denoising, and inpainting are just a few of the picture restoration tasks for which CNN-based approaches have demonstrated improved performance.

Even while CNNs have done an amazing job at image restoration, there is still room for improvement. Challenges like managing various types of deterioration simultaneously and enhancing the effectiveness and generalizability of these networks are the focus of current research. Overall, CNNs are still a useful tool for image restoration applications and are a hot topic of computer vision research.

B. Generative Adversarial Networks (GAN) (Baumgartner et al., 2018)

Generative adversarial networks (GANs) have shown great promise in image restoration

tasks such as denoising, super-resolution, and inpainting. In this approach, two neural networks are trained simultaneously - a generator network that produces restored images from degraded inputs, and a discriminator network that tries to distinguish between the restored images and the ground truth clean images.

The GAN training process is typically divided into two stages: a pre-training stage where the generator is trained using traditional loss functions such as mean squared error, and a fine-tuning stage where the adversarial loss is introduced to improve the visual quality of the restored images. By training the generator through this adversarial process, it learns to create realistic-looking images that are visually similar to the ground truth.

Several variations of GANs have been proposed for image restoration, such as conditional GANs (cGANs) which take additional information such as class labels or image masks as input to guide the restoration process. Additionally, deep convolutional neural networks (DCNNs)(Roy et al., 2016) are often used as the backbone of both the generator and discriminator networks to capture more complex image features.

Overall, GANs have shown impressive results in image restoration tasks, especially in scenarios where traditional methods struggle to produce high-quality results. However, challenges such as instability during training and artifacts in the generated images still exist, and further research is needed to address these issues and improve the effectiveness of GANs for image restoration

III. PROPOSED METHOD

A. Prepare data

To get data for training our model and for testing, we apply Gaussian blur on the image to lower its resolution. Gaussian blur is a common technique used to reduce image resolution. This method involves convolving the image with a Gaussian filter (Fig. 1), which effectively smooths out the image and reduces its level of detail. The amount of blur applied can be controlled by adjusting the size of the kernel used in the convolution process. Gaussian blur is often used in image processing applications such as edge detection, noise reduction, and image compression

Next, we will cover the 2 method deep learning method we use to deblur image.

B. Convolutional Neural Networks (CNN) (Jain et al., 2009)

A Convolutional Neural Network (CNN) is a type of deep learning algorithm that is primarily designed for image recognition and computer vision tasks. It is composed of multiple layers, each performing a specific function in the image processing pipeline. The core idea behind CNNs is to learn hierarchical representations of visual data by convolving small filters over the input image, followed by pooling operations that downsample the feature maps to reduce their size.

CNNs have shown great promise in the field of image restoration. Image restoration is the process of removing noise and corruption from damaged or degraded images, with the goal of enhancing their quality and making them more visually appealing.

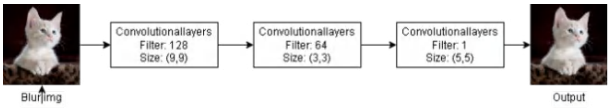

Figure 1. The flow chart of the proposed system

We have defined a model named SRCNN (Super-Resolution Convolutional Neural Network) (Dong et al., 2016) using the Sequential class provided by the Keras library. The SRCNN model aims to improve the resolution of low-quality images by learning the mapping between low-resolution and high-resolution image patches.

The Super-Resolution Convolutional Neural Network (SRCNN) is a classical technique used for single image super resolution (SR) in computer vision. It aims to enhance the quality of a larger image based on a small image. The SRCNN technique was introduced in 2014 and has been widely adopted in the field of deep learning and convolutional neural networks.

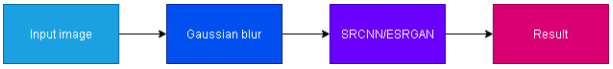

Figure 2. SRCNN mode (Dong et al., 2016)

The first convolutional layer conv1 has 128 filter and a kernel size of 9x9, with padding of 2 pixels on each side. This layer is designed to extract high-level features from the input image.

The second convolutional layer conv2 has 64 filter and a kernel size of 3x3, with padding of 2 pixels on each side. This layer works as a bottleneck for the network, reducing the number of parameters and computational complexity of the model.

The third convolutional layer conv3 has 1filter and a kernel size of 5x5, with padding of 2 pixels on each side. This layer is responsible for mapping the extracted features back to the original image space.

Each convolutional layer is applied to the input data sequentially, followed by a ReLU activation function in the case of the first two layers. Finally, the output is returned as the predicted output image.

Overall, the proposed method defines a deep CNN model which takes low-resolution images as input and outputs high-resolution images after learning the mapping between them. It uses three convolutional layers with different filter sizes to extract features from the input image and generate high-quality output images.

C. Generative Adversarial Networks (GAN) (Baumgartner et al., 2018)

GANs are a type of generative model that consist of two neural networks: a generator network and a discriminator network. In the context of image restoration, the generator network is trained to generate a restored image based on a degraded input image, while the discriminator network is trained to differentiate between real and generated images. GANs have the advantage of being able to generate visually realistic images with complex details and textures, which can be difficult for CNNs to achieve. However, GANs are more complex and difficult to implement and train than CNNs, and can be prone to generating unrealistic or distorted images if not properly trained.

The proposed method in the ESRGAN (Enhanced Super-Resolution Generative Adversarial Networks) (Sanchez et al., 2023) is an approach for enhancing the resolution and visual quality of low-resolution images. The ESRGAN (Enhanced Super-Resolution Generative Adversarial Networks) architecture uses a variant of the Residual in Residual Dense Block (RRDB((Li et al., 2021) as its main

building block. The RRDB is a modification of the original DenseNet architecture, which was originally proposed for image classification.

The main idea behind the DenseNet architecture is to connect all layers in a feed-forward fashion so that each layer receives the feature maps of all preceding layers as input. This approach encourages feature reuse and reduces the number of parameters needed to model the network. However, the original DenseNet architecture is not well suited for super-resolution tasks because it uses too many pooling layers, which can limit the resolution of the output.

The RRDB modifies the DenseNet architecture by replacing the pooling layers with convolutional layers and residual connections. The residual connections allow the network to learn from the input features at different scales, while the dense connections promote feature reuse and simplify the training process.

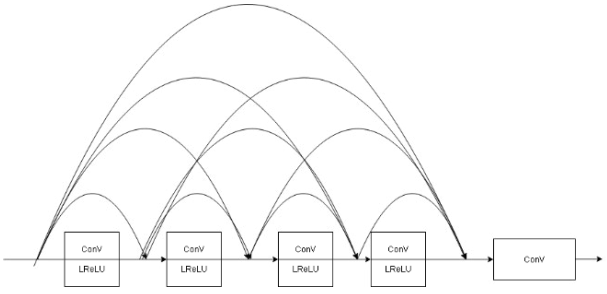

Figure 3. Dense Block

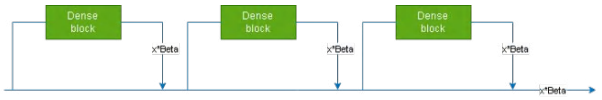

Figure 4. ESRGAN RRDB architectur (Li et al., 2021)

The ESRGAN model consists of two main components: a generator network and a discriminator network.

The generator network is responsible for generating super-resolved images from low-resolution inputs. It utilizes a deep residual network architecture with skip connections to better preserve image details during the upscaling process. Additionally, the generator network incorporates a perceptual loss function that is based on high-level features extracted from a pre-trained VGG network. This loss function encourages the generated images to have similar content and style as the corresponding high-resolution images.

The discriminator network is used to distinguish between real high-resolution images and generated super-resolved images. It also provides feedback to the generator network by providing an adversarial loss signal that encourages the generator to produce more realistic images. The discriminator network is designed to be lightweight and efficient, using a patch-based architecture that allows for faster training and inference times.

To further improve the performance of the ESRGAN model, several techniques are employed. One such technique is called progressive resizing, where the generator is trained to progressively increase the resolution of images during training. Another technique is called feature fusion, where intermediate features from multiple layers of the generator network are combined to create a more detailed and visually appealing output.

ESRGAN stabilizes the training process by adding a regularization term to the generator loss function. This term encourages the generator to produce images that are close to the real data distribution, reducing the likelihood of mode collapse and improving the stability of the training process.

ESRGAN can be trained efficiently using off-the-shelf optimization algorithms, without requiring extensive hyperparameter tuning or specialized hardware. But SRGAN relies on the discriminator to provide feedback to the generator, which can limit the level of control over the generated images. The generator may not always produce the desired images, especially when the discriminator is strong.

IV. EXPERIMENTAL RESULTS

A. Convolutional Neural Networks (CNN) (Jain et al., 2009)

Dataset: We use T91 data set combine with Set14 and Set5 dataset to train with 2500 epoche.

T91 data set contain 91 images classically used to train neural networks for super resolution. Most of the images are cropped images of flowers.

The Set14 and Set5 dataset is a commonly used benchmark dataset for image denoising tasks in computer vision research. The images depict natural scenes such as buildings, landscapes, and people.

We use the resize method to lower the picture resolution and the original image as images reference. We train the model using the T91 dataset and evaluate the model on the Set5 and Set14 datasets on Google Colab and it took more than 24 hour.

Here the result:

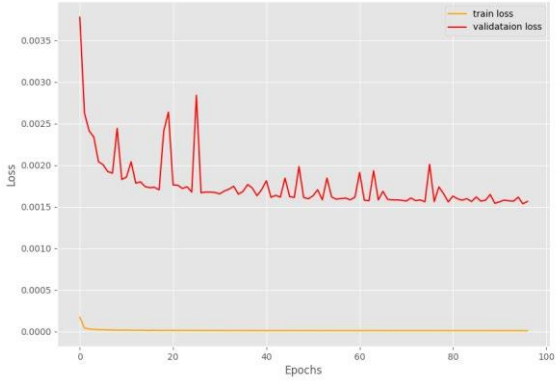

Figure 5. Loss in the first few hour

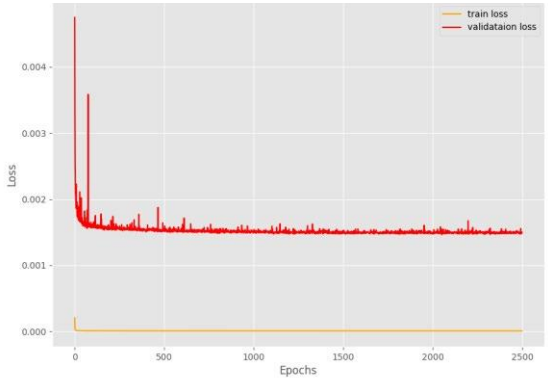

Figure 6. Loss when finish

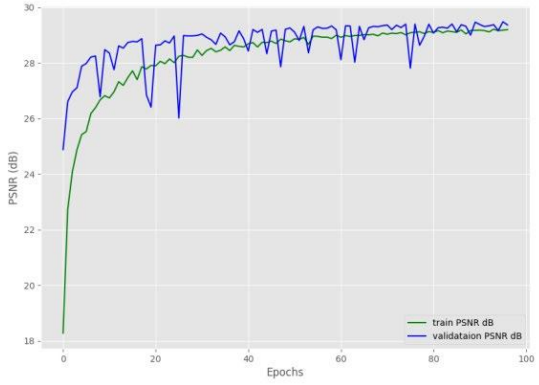

Figure 7. PSNR graph in the first few hour

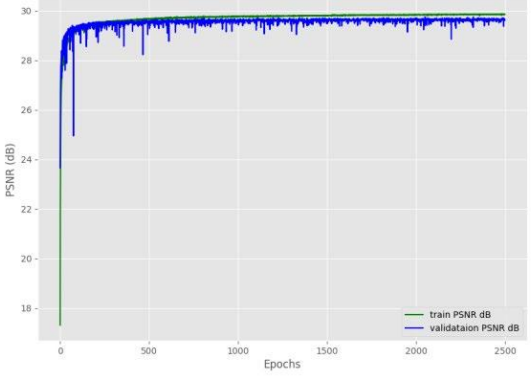

Figure 8. PSNR graph when finishing

Figure 9. CNN result 1

Figure 10. CNN result 2

Figure 11. CNN result 3

Figure 12. CNN result 4 at EIU

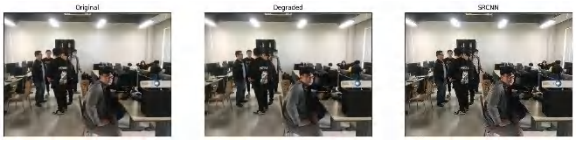

Figure 13. CNN result 5 at EIU

Although this method is better than bicubic method, the result is not perfect. SR-CNNs require a large amount of training data to learn the mapping between low-resolution and high-resolution images. Collecting and labeling such data can be challenging and time-consuming. Although SR-CNNs are generally faster than traditional image processing methods, they still require significant computational resources, especially when processing large images. This can limit their use in resource-constrained environments.

B. Generative Adversarial Networks (GAN) (Baumgartner et al., 2018)

We train the ESRGAN model using the DIV2K dataset, which contains 800 high-resolution images, and then evaluate the model on the Set5 and Set14 datasets, which contain 5 and 14 images, respectively.

Here the result:

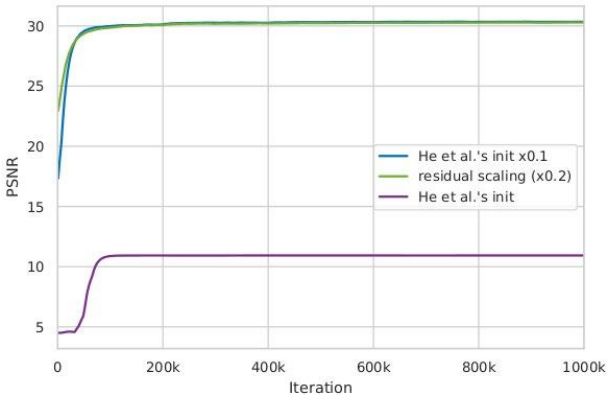

Figure 14. PSNR ESRGAN

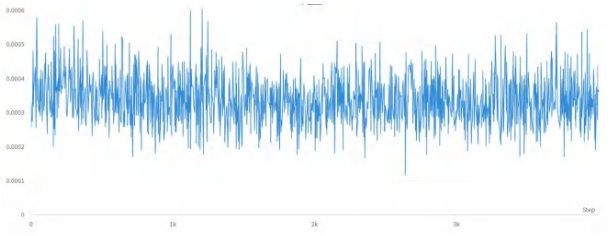

Figure 15. ESRGAN Loss graph

Figure 16. ESRGAN res 1

Figure 17. ESRGAN res 2

Figure 18. ESRGAN res 3

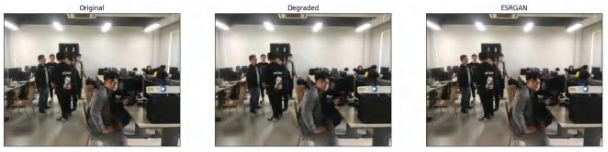

Figure 19. ESRGAN res 4 at EIU

Figure 20. ESRGAN res 5 at EIU

Our visual comparisons illustrate that ESRGAN generates more realistic textures and sharper edges than the bicubic method and other state-of-the-art super-resolution methods. This is particularly evident in complex textures, such as fabrics and foliage, where ESRGAN produces more natural-looking images with finer details.

V. CONCLUSION

After our research on image restoration, we have implemented the Convolutional neural networks (CNN) (Jain et al., 2009) and Generative adversarial networks (GAN) method (Baumgartner et al., 2018) into our project to achieve the best result possible. Our system has shown positive results in restoring and even enhancing the image's resolution. SRCNN is slightly inferior to ESRGAN when using the same amount of resources. Also ESRGAN has more potential to develop, the evidence is it have been extend into Real-ESRGAN which is a really effective for image restoration.

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A STUDY OF OBJECTS DETECTION USING BILATERAL FILTER AND YOLOV4

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Abstract: This project focuses on the development of a robust and efficient vehicle detection system using Deep Neural Networks (DNN) with the YOLO (You Only Look Once) v4 architecture. The ability to detect and track vehicles in real-time video streams has significant applications in areas such as traffic management, surveillance systems, and autonomous driving. The proposed system leverages the power of YOLO v4, a state-of-the-art object detection algorithm, which employs a single network to predict bounding boxes and class probabilities directly from input images. This architecture is particularly suitable for real-time applications due to its speed and accuracy.

Keywords: *DNN, YOLO*

I. INTRODUCTION

The twenty-first century has seen the emergence of a revolutionary period of technological innovation, with the convergence of artificial intelligence, computer vision, and deep learning reshaping the landscape of numerous sectors. Object identification and tracking, particularly the detection and monitoring of moving objects in real-time video streams, is one of the key sectors benefiting from these improvements. Vehicles take a key place among these moving items due to their pervasive presence in our everyday lives.

The detection and tracking of moving objects, particularly vehicles, in real-time video streams have become increasingly important in various domains, ranging from traffic management to surveillance systems and autonomous driving. Accurate and efficient vehicle detection systems are essential for applications that require monitoring and analysis of vehicle movements in dynamic environments.

Traditional approaches to vehicle detection often rely on handcrafted features and heuristic-based algorithms, which are time-consuming to develop and may lack the necessary robustness and scalability. In recent years, with the advancements in deep learning, particularly Deep Neural Networks (DNNs), vehicle detection has witnessed significant improvements in accuracy and efficiency (Danelljan et al., 2015).

This project focuses on developing a vehicle detection system utilizing the YOLO v4 architecture (Redmon et al., 2018), which is a

popular DNN-based object detection algorithm known for its speed and accuracy. YOLO v4 employs a single neural network to directly predict bounding boxes and class probabilities of objects in input images, making it particularly suitable for real-time applications.

The primary objective of this project is to design a system that can accurately detect and track vehicles in real-time video streams. By leveraging the power of YOLO v4, the system aims to achieve high detection accuracy and real-time performance, making it an ideal choice for various practical applications.

II. RELATED WORK

Aside from YOLO, there have been many methods used for object detection, these methods are mainly used for counting people, estimating the size of the crowd, detecting moving individuals on screen for security purposes, and vehicle detection. In addition, there are also have a lot research for object detection by using popular deep learning model, such as faster R-CNN, Region-based Convolutional Neural Network.

The field of computer vision has witnessed remarkable advancements in recent years, and object detection is a crucial aspect of this domain. Among the various object detection algorithms, You Only Look Once (YOLO) has gained significant popularity due to its real-time processing capabilities and remarkable accuracy.

Object detection is a computer vision task that involves identifying and localizing objects within an image or video. Traditional approaches often employ region proposal-based methods, such as the Faster R-CNN algorithm, which requires multiple passes over an image. YOLO, on the other hand, follows a different paradigm by framing object detection as a regression problem.

The YOLO algorithm operates by dividing an image into a grid and predicting bounding boxes and class probabilities for each grid cell. The key components of the YOLO architecture include:

a. Input Division: The input image is divided into an S × S grid.

b. Anchor Boxes: Anchor boxes of different sizes are predefined to accommodate objects with varying aspect ratios.

c. Convolutional Neural Network (CNN): A CNN processes the image to extract features and generate feature maps.

d. Predictions: Each grid cell predicts B bounding boxes, each defined by coordinates (x, y, w, h) and associated class probabilities.

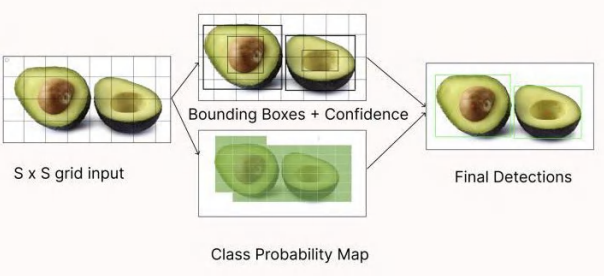

Figure 1. YOLO Grid Detection

YOLO training involves two main stages: pretraining and fine-tuning.

a. Pretraining: A CNN is pre-trained on a large dataset such as ImageNet, enabling it to learn general features.

b. Fine-tuning: The pre-trained CNN is combined with additional layers responsible for predicting bounding boxes and class

probabilities. The network is then fine-tuned on an object detection dataset, optimizing for localization accuracy and object classification.

YOLO offers several advantages over traditional object detection algorithms:

a. Real-time Processing: YOLO's unified architecture enables it to detect objects in real-time, making it suitable for applications requiring low latency.

b. Single-pass Approach: YOLO processes the entire image at once, eliminating the need for multiple passes, resulting in faster inference times.

c. High Accuracy: YOLO achieves remarkable accuracy, even for small objects, due to its ability to capture context and global information from the entire image.

d. Flexibility: YOLO can be applied to various object detection tasks, such as pedestrian detection, face recognition, and self-driving cars.

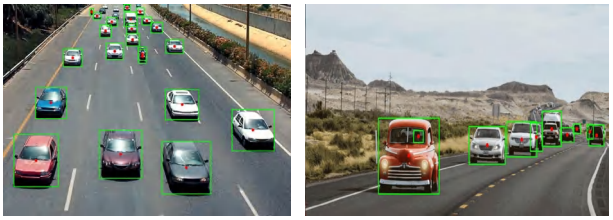

Figure 2. YOLO Driving Detection

YOLO has found extensive applications in numerous domains, including:

a. Autonomous Vehicles: YOLO helps in real-time object detection for autonomous vehicles, enabling them to perceive and react to their surroundings effectively.

b. Surveillance Systems: YOLO facilitates real-time monitoring by detecting and tracking objects of interest in surveillance videos.

c. Robotics: YOLO enables robots to detect and interact with objects in their environment, enabling tasks such as pick-and-place operations.

d. Augmented Reality: YOLO can be utilized to detect and track objects in real-time, enhancing augmented reality experiences.

YOLO has emerged as a powerful object detection algorithm, offering real-time processing capabilities and high accuracy. Its unique single-pass approach and flexibility make it suitable for a wide range of applications. As developers with basic knowledge of image processing, understanding the underlying principles and applications of YOLO can open up exciting possibilities for leveraging computer vision in various domains.

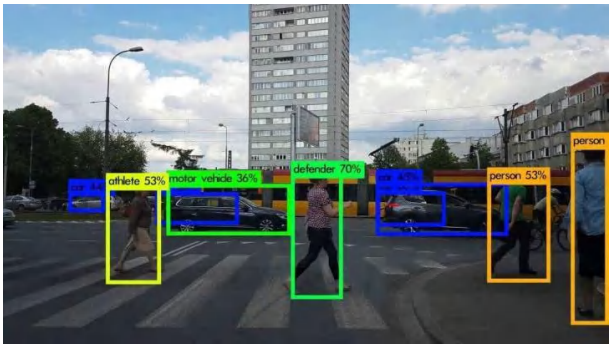

Figure 3. YOLO objects detection (on the road)

Let's compare YOLO (You Only Look Once) to some other popular object detection algorithms, namely Faster R-CNN (Region-based Convolutional Neural Network) and SSD (Single Shot MultiBox Detector). These three approaches have been influential in the field of computer vision, and each has its own strengths and weaknesses.

YOLO (You Only Look Once):

Single-Pass Efficiency: YOLO stands out for its single-pass approach, which allows it to

detect objects in a single forward pass through the neural network. This makes it incredibly fast and suitable for real-time applications, such as video analysis and robotics.

Flexibility: YOLO is highly flexible and can be trained to detect a wide range of objects and classes. Its adaptability makes it versatile and well-suited to various tasks and domains.

Accuracy vs. Speed Balance: YOLO strikes a balance between speed and accuracy. While it may not be the absolute best in terms of accuracy compared to some other methods, its speed is a significant advantage for many real-world applications.

Open-Source Community: YOLO has a strong open-source community that actively contributes to its development. This collaborative environment has led to continuous improvements and innovations.

Faster R-CNN (Region-based Convolutional Neural Network):

Two-Stage Approach: Faster R-CNN follows a two-stage approach, where it first proposes regions of interest using a Region Proposal Network (RPN) and then classifies those regions. This approach can yield high accuracy but is computationally more intensive than YOLO's single-pass method.

State-of-the-Art Accuracy: Faster R-CNN has often been the benchmark for accuracy in object detection tasks. It excels in scenarios where precision is paramount, such as medical image analysis or fine-grained object recognition.

Complexity: The two-stage architecture can make Faster R-CNN more complex to implement and train, requiring more computational resources.

SSD (Single Shot MultiBox Detector)

Balanced Approach: SSD takes a middle ground between YOLO and Faster R-CNN. It uses multiple scales of feature maps to predict bounding boxes and class scores, providing a balance between accuracy and speed.

Efficiency: SSD is efficient and can process images in real time. Its architecture is simpler than Faster R-CNN, making it easier to implement and train.

Versatility Like YOLO, SSD is versatile and can be adapted to various object detection tasks. It's suitable for scenarios where a compromise between speed and accuracy is needed.

Accuracy While SSD offers good accuracy, it might not match the top-tier performance of Faster R-CNN in tasks that demand the highest precision.

The choice between YOLO, Faster R-CNN, and SSD depends on the specific requirements of the object detection task at hand:

- Use YOLO for real-time applications where speed is crucial and a good balance between speed and accuracy is acceptable.

- Opt for Faster R-CNN when the highest accuracy is required, and computational resources are not a significant constraint.

- Consider SSD when you need a balanced approach, suitable for a wide range of applications that demand reasonable accuracy without sacrificing too much speed.

YOLO (You Only Look Once) is often used for vehicle detection due to its unique characteristics and advantages that make it well-suited for this specific task:

One of the primary reasons YOLO is preferred for vehicle detection is its ability to

process images and video streams in real time. This is crucial for applications like autonomous driving, traffic monitoring, and surveillance, where timely detection of vehicles is essential for safety and decision-making.

YOLO's single-pass approach and efficient neural network architecture make it computationally efficient. This efficiency is especially valuable in resource-constrained environments, such as embedded systems in vehicles, drones, or traffic cameras.

YOLO is capable of detecting multiple classes of objects simultaneously. In the context of vehicle detection, this means it can not only identify vehicles but also differentiate between different types of vehicles like cars, trucks, motorcycles, and buses.

YOLO is highly adaptable and can be trained to detect vehicles under various conditions, including different lighting, weather, and road conditions. This adaptability is crucial for real-world applications where environmental factors can change rapidly.

YOLO can be combined with object-tracking algorithms to track vehicles over time. This is essential in traffic management, where monitoring the movement and behavior of vehicles is vital for optimizing traffic flow and ensuring safety.

YOLO benefits from an active open-source community, which means that developers and researchers worldwide contribute to its development and share pre-trained models and datasets. This collaborative ecosystem accelerates advancements in vehicle detection capabilities.

YOLO's speed, accuracy, and real-time processing capabilities make it a valuable component in autonomous vehicle systems. It can assist self-driving cars in identifying and avoiding obstacles, improving road safety.

In summary, YOLO's ability to process images in real-time, its efficiency, multi-class detection capabilities, adaptability, and strong community support make it a compelling choice for vehicle detection applications, contributing to advancements in transportation, safety, and autonomous driving technologies.

YOLO (You Only Look Once) has proven to be an effective solution in various other applications and scenarios beyond vehicle detection. Here are some additional contexts where YOLO shines:

Object Tracking in Surveillance: YOLO can be utilized for real-time object tracking in surveillance systems. It excels at tracking multiple objects simultaneously, making it valuable for tracking people, animals, and objects in security and monitoring applications.

Pedestrian Detection: YOLO is not limited to vehicles; it can effectively detect pedestrians in urban environments, sidewalks, and crosswalks. This is vital for pedestrian safety systems and urban planning.

Industrial Automation: YOLO can be employed in manufacturing and industrial settings to detect and track objects on assembly lines. It ensures quality control by identifying defects or irregularities in products and helps with inventory management.

Agriculture: In precision agriculture, YOLO can be used for crop monitoring, plant disease detection, and even counting livestock. It assists farmers in making data-driven decisions to optimize yields and minimize resource usage.

Retail and Inventory Management: YOLO can aid in retail applications by tracking products on store shelves and monitoring inventory levels. This helps retailers maintain stock levels, prevent theft, and improve the shopping experience.

Medical Image Analysis: YOLO has applications in medical imaging, where it can detect and classify anomalies in X-rays, CT scans, and MRIs. It aids radiologists in early disease diagnosis and treatment planning.

Wildlife Conservation: YOLO has been used in wildlife conservation efforts to monitor and track animals in their natural habitats. It assists researchers in studying animal behavior, population dynamics, and poaching prevention.

Geospatial Analysis: YOLO can contribute to geospatial analysis by detecting objects in satellite or aerial imagery. This is valuable for urban planning, disaster response, and environmental monitoring.

Sports Analytics: YOLO can track players and objects in sports events, providing valuable data for coaches, analysts, and broadcasters. It enhances the viewer experience and aids in player performance analysis.

Food Quality Control: In the food industry, YOLO can be used to inspect food products for quality control, identify defects or contamination, ensure food safety, and maintain product consistency.

III. PROPOSED METHOD

The first problem that must be solved is the rapid identification of the target item when the detection target's backdrop is diverse and there is a broad diversity of things present in the image. YOLOv4 has a powerful real-time detection capability. It uses a single neural network to directly predict bounding boxes and class probabilities from input photos. Because of its speed and precision, this architecture is well-suited for real-time applications. The CSPDarkNet53 neural network serves as the backbone of YOLOv4 (Redmon et al., 2018). The YOLO structure of vehicle detection is shown in Fig. 4.

Backbone Architecture: YOLOv4 employs the CSPDarknet53 backbone, which combines the benefits of CSPNet and Darknet53, enhancing feature extraction and information flow.

Detection Head: The detection head of YOLOv4 utilizes PANet, a feature pyramid network, to capture multi-scale features efficiently, leading to improved accuracy in detecting objects of various sizes.

Bag of Freebies (BoF) and Bag of Specials (BoS): YOLOv4 incorporates BoF and BoS techniques, which include data augmentation, label smoothing, CIoU loss, and more. These techniques collectively enhance model training and object detection performance.

Use of Anchor Boxes: Anchor boxes are crucial for improving detection accuracy. YOLOv4 adopts a technique called anchor box clustering to determine the optimal anchor boxes for specific datasets, leading to better localization.

Efficient Post-processing: The model utilizes non-maximum suppression (NMS) and dynamic anchor assignment, which improve post-processing efficiency while maintaining detection quality.

Training Strategies: YOLOv4 introduces training strategies like mosaic data augmentation, CIOU loss, and the use of the cosine annealing scheduler, which helps the model generalize better and achieve higher accuracy.

Speed and Parallelism: YOLOv4 maintains real-time detection capabilities while achieving remarkable accuracy. It also supports model parallelism and multi-GPU training for even faster convergence.

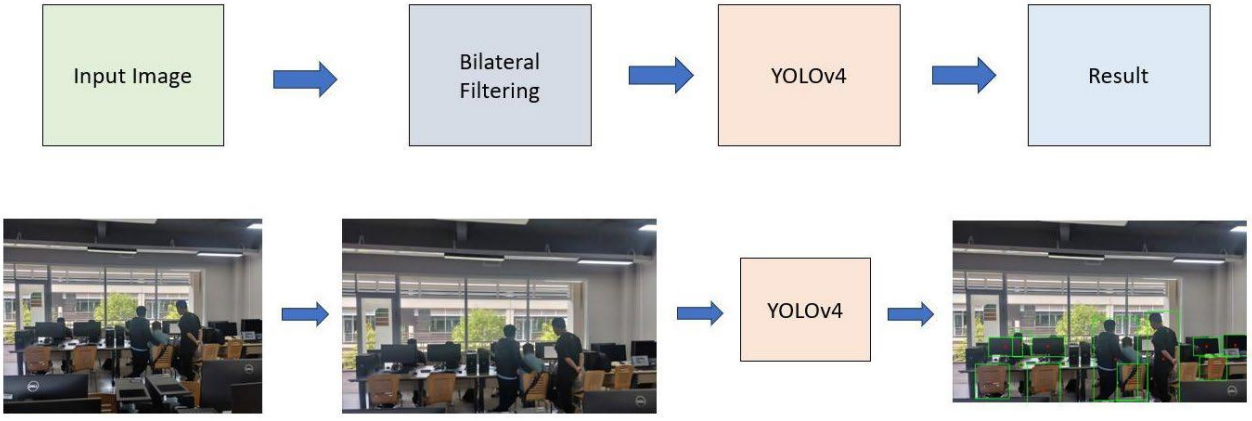

Figure 4. YOLOv4 detecting process

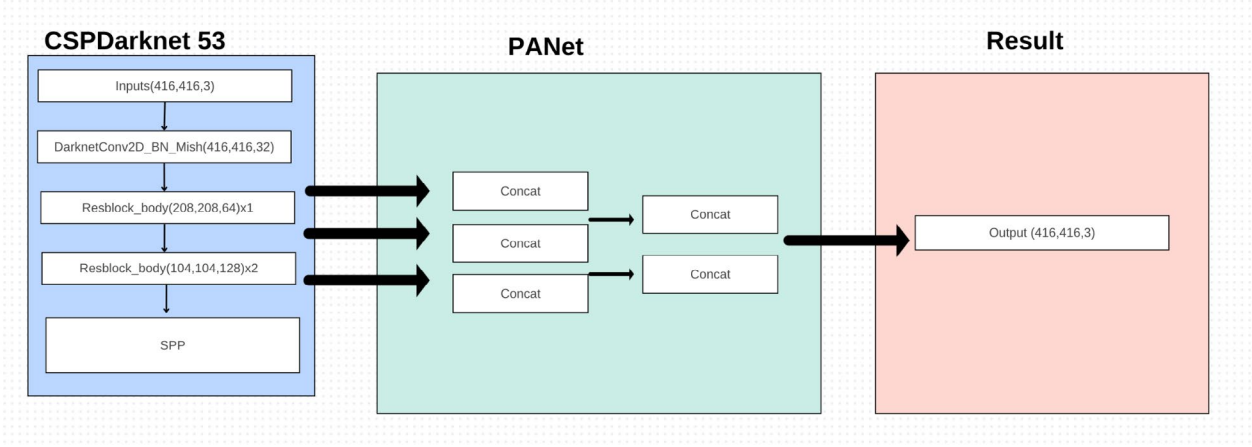

Figure 5. The proposed deep learning system of YOLOv4

IV. EXPERIMENTAL RESULTS

We have been testing videos with traffic jam which has shown some positive result as below. Our trials included a variety of settings, including urban and rural areas, varying lighting conditions, and a wide range of vehicle types, including automobiles, trucks, motorbikes, and buses. The variety of scenarios was designed to measure the system's flexibility and generalization skills. One of the primary experimental situations was assessing the performance of our technology in the midst of traffic congestion. For efficient traffic management, traffic jams are dynamic and complex settings that need precise and real-time vehicle recognition. Fig. 6 depicts the findings acquired in a traffic jam scenario, demonstrating the system's capacity to recognize and track cars accurately even under crowded traffic situations.

Figure 6. Result with traffic jam

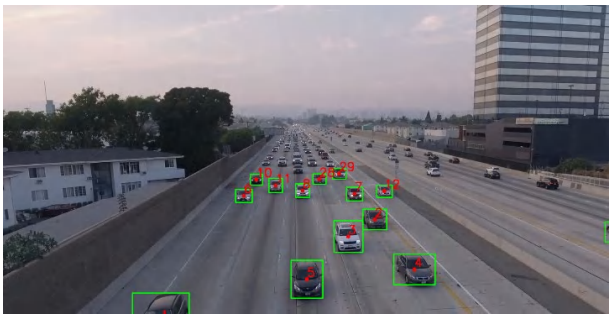

Figure 7. Result with non-traffic jam

YOLOv4 is used to evaluate the performance of our system by using the prepared dataset. Figs 5 and 6 show the train and validation loss and precision of YOLOv4, respectively. Our system got better results than YOLOv4 when considering two metrics: precision and recall. We further evaluate the performance of our system and YOLOv4 on testing images as shown in Fig. 7 and Fig. 8. The proposed method accurately detects and classifies human and non-human.

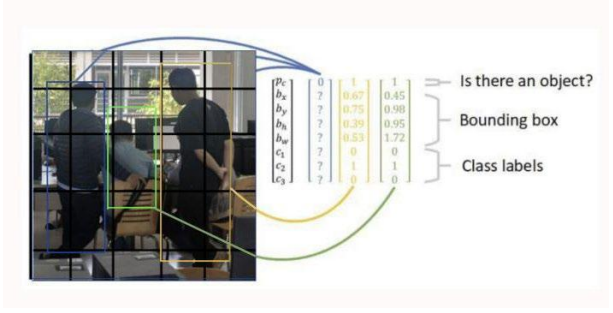

Figure 8. Detection analysis

V. CONCLUSION

This study introduced a vehicle detection system that uses the advanced YOLO v4 deep neural network object detection algorithm. The system can accurately detect and track vehicles in real-time video streams, making it useful for various applications such as traffic management, surveillance, and autonomous driving. The system's design maximizes the power of YOLO v4 to achieve high detection accuracy and real-time performance, making it suitable for real-world situations. The experimental results indicated that the proposed system performed better than YOLOv4 in terms of precision and recall. Overall, this project showcases the potential of deep learning-based object detection algorithms in solving practical problems.

ACKNOWLEDGEMENT

We would like to express our heartfelt appreciation and gratitude to Eastern International University for their crucial assistance in funding, supporting, and allowing the installation and deployment of our cutting-edge vehicle detection technology. Their continuous dedication to developing science and technology has been critical to the project's success.

Furthermore, we would like to convey our profound gratitude to the committed members of our research team who have relentlessly donated their knowledge, time, and effort. Their unwavering pursuit of innovation and perfection has been the driving factor behind the creation and refining of our system.

Finally, this initiative would not have been feasible without the joint efforts, support, and

participation of all those indicated above. We are appreciative of their efforts and look forward to additional developments and breakthroughs in the field of vehicle identification and computer vision.

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EASTERN INTERNATIONAL UNIVERSITY
SCIENTIFIC CONFERENCE 2023 (EIUSC 2023)
PROCEEDINGS

A STUDY OF USING CNN AND HISTOGRAM EQUALIZATION TO SOLVE SUDOKU PROBLEMS

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Abstract: Sudoku is a famous game and suitable for almost all ages. Not only simple and decent to solve, but at the same time it also requires players to understand how to think to find the most appropriate explanation. Sudoku is both a game and an effective way to train the mind. In the past, solving Sudoku has been a popular hobby for old folk since the 18th century and it continues to attract younger generations to join in the fun like a great way to let time pass. Despite the simple rules, there can be over six trillion combinations of just basic difficulty in a 9x9 sized Sudoku, some of which are extremely difficult to solve. At the same time, although players can apply logical thinking and some rules to find the appropriate answer for each cell in the table, there are always cases where simple logical thinking is difficult to solve and there is no other way but to perform trial and error. Besides, even though it's just a small game, in theory its difficulty can be increased as much as you want if you increase the size of the board and the number of elements it can have. The size of the state space makes this an interesting and challenging constraint satisfaction problem. Clearly the search algorithm has to be more intelligent than just searching the entire space until it gets to a puzzle that matches the initial values. There are several search strategies that are effective for this problem and we will be using backtracking search.

Keywords: *backtracking search, image processing, characters recognition*

I. INTRODUCTION

Applying technology and scientific methods to find solutions to life's problems, thereby continuing to discover other hidden problems, the nature of things, as well as the principles of operation of them, then using the knowledge gained from that process to solve more complex problems is never a wrong direction. Sudoku is just a small game and does not have too many practical applications in real life. However, the knowledge gained during the process of exploring and researching it can be used for other purposes later such as in industrial problems, computer science, or some real-life applications.

In this study, in addition to presenting an optimal algorithm for finding solutions to the Sudoku problem, we also learn more about how computers recognize and process images and extract necessary data documents in photos for later work. That way the computer will be able to read and solve Sudoku directly through the camera, without needing to manually enter data from the keyboard.

Recently, along with the rapid development of artificial intelligence, more and more applications with the integration of artificial intelligence technology appear in daily life. In which the ability to extract and process data in the form of images is always a direction that attracts the attention and interest of many. Thanks to the advancement in Deep Learning technology, recognizing an object in an image through Object Detection algorithms such as YOLO, Vision Transformer... becomes easy and accurate. Through that, the data that computers can extract from an image is also increasingly rich, diverse, and accurate, creating the foundation for other applications to develop later based on processing extracted data from the image, in which, the recognition, extraction, and processing of data with an object that is a piece of text or a character can be said to be one of the most common tasks. At the same time, that is also one of the main goals of this research. By using Deep Learning algorithms, the computer can quickly identify a Sudoku board appearing in an image, and extract the data contained in the Sudoku board.

In general, to recognize and extract text from an image, people often use Optical Character Recognition (OCR) technology, the computer will scan the image containing the text to be processed and compare the images of the characters with the available form one by one. Due to the diversity and richness of the script, it was difficult and inefficient in the early days to use OCR to recognize and extract characters in a handwritten letter, then the emergence of Intelligent Character Recognition. (ICR) an extension of OCR using Machine Learning algorithms has contributed to solving this problem. Through the application of Deep Learning algorithms such as Convolutional Neural Networks (CNN), computers can recognize handwritten characters by comparing and finding similarities in the strokes of the characters. Recently, in 2020 Mayur Bhargab Bora and his colleagues proposed combining CNN technology with Error Correcting Output Code (ECOC) to increase the accuracy of the algorithm. After being able to extract and process raw data from images through the Camera, the next job that needs to be done is to find an appropriate algorithm to be able to process the collected data and solve the problem. Sudoku. To solve a complex problem, there is not always only one method to solve it. The same is true in solving a Sudoku problem. There are many methods and algorithms that can be used to find the solution to a Sudoku table such as Backtracking, Stochastic search (optimization methods), Constraint programming, Exact cover, Relations and residuals. Among them, Backtracking is the most popular method.

II. RELATED WORKS

According to Rusell and Norvig reports on several methods, backtracking search with implementation of Forward Checking, Constraint Propagation, Minimum Remaining Values, Hill Climbing and Random Restart has proven itself to be the most consistent search algorithm for solving Sudoku puzzle, by choosing a square and check other square in the same row and column and assigning one to it, if it conflicts with other value it will change to two. If a square has no possible value, then return to the previous position and change the value. Doing this will guarantee us to find a solution if the puzzle is possible to solve.

Backtracking is basically a brute force search algorithm, or more precisely, depth-first search. In which we assign any value in the appropriate range to the cell we want to search and then assign the value to the next cell. If we cannot find an appropriate value to assign,

we go back and change the value assigned to a previous cell and continue to repeat the process until we have completed the task of assigning values to all the cells we need to search, and it is also the solution to the Sudoku problem.

As mentioned above, Sudoku can be solved using different algorithms. In a study published in 2008 by Meir Perez and Tshilidzi Marwala, titled "Stochastic Optimization Approaches for Solving Sudoku", the study showed the feasibility of using Stochastic search (optimization methods) to solve the problem.

In another recently published study (May 22, 2023) by Leo Hall, titled "Efficiently Solving the Exact Cover Problem In OPENMP", an example of solving a Sudoku problem through the use of Use Knuth's Algorithm X. This is an algorithm for solving the exact cover problem. It is a straightforward recursive, nondeterministic, depth-first, backtracking algorithm to demonstrate an efficient implementation called DLX, which uses the dancing links technique. The exact cover problem is represented in Algorithm X by a matrix consisting of 0 and 1. The goal is to select a subset of the rows such that the digit 1 appears in each column for only one time. In a Sudoku puzzle, the Sudoku puzzle is converted into a matrix of 1s and 0s. Each row in that matrix represents a value from 1 to 9. According to Leo Hall, the author of the report, this new matrix will have up to 729 rows.

Compared to the other two methods mentioned above, Backtracking appears weak because it needs to consume a large amount of computer resources, leading to very slow execution time and requiring a strong enough computer configuration. to be able to solve highly complex problems. However, due to its convenience and simple implementation, Backtracking is also a widely used algorithm to solve Sudoku problems.

Although during application testing, it was found that the process was slow because both CNN and Backtracking algorithms require consuming a large amount of computer computing resources. In addition, some external environmental factors also affect the accuracy of information collected from cameras, causing the output results to not be as expected.

In summary, the field of Sudoku puzzle-solving is rich with diverse approaches, ranging from heuristic-driven backtracking to stochastic optimization and algorithmic transformations like Algorithm X. Each method has its strengths and limitations, and the choice of approach depends on factors such as puzzle complexity and available computational resources. Furthermore, real-world applications may introduce additional challenges that impact algorithm performance.

III. PROPOSED METHODS

In the context of this project, our methodology combines the power of a Convolutional Neural Network (CNN) with the precision of the Backtracking algorithm to provide a comprehensive Sudoku-solving solution. The implementation of this dual approach allows us to seamlessly transition from the physical puzzle paper to a digital platform, thereby enhancing the user experience. The utilization of the CNN technology enables us to capture and interpret the Sudoku puzzle from the physical paper, translating it into a format that can be processed digitally. This initial step is crucial for accurately understanding the puzzle's layout and initial values.

Subsequently, once the puzzle is successfully digitized and interpreted, we leverage the Backtracking algorithm to undertake the solving process. Backtracking, as previously mentioned, serves as the workhorse

of our Sudoku-solving strategy, systematically exploring possible solutions and backtracking when necessary to arrive at the correct puzzle configuration. The combination of CNN and Backtracking ensures a comprehensive and reliable approach to solving Sudoku puzzles of varying complexity.

Upon completing the solving phase, the generated solution is seamlessly integrated back onto the physical puzzle using the webcam. This integration bridges the physical and digital realms, providing users with a holistic and interactive Sudoku-solving experience. By projecting the solution onto the physical puzzle, we create a seamless transition from the traditional paper-and-pencil Sudoku solving method to a modern, technology-enhanced approach, offering users the best of both worlds.

In summary, our project's methodology, which leverages CNN and Backtracking, not only facilitates the digitization and solving of Sudoku puzzles but also enhances the user's interaction with the physical puzzle. This multi-faceted approach reflects our commitment to providing a versatile and engaging Sudoku-solving solution that caters to diverse user preferences and scenarios.

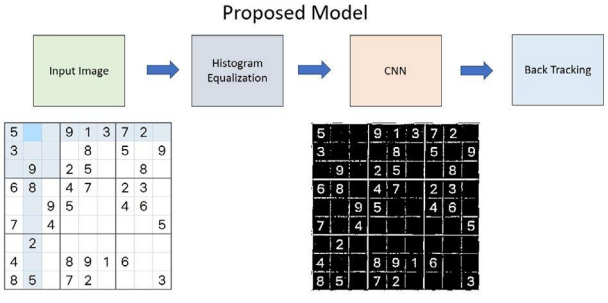

Figure 1. Project proposed model

A. Convolutional Neural Network (Chernyshova et al., 2020)

Convolutional Neural Network (CNN) is an artificial neural network designed mainly for feature extraction from a mesh matrix dataset. In reality, the colorful digital photos we see every day are actually made up of matrices, including an infinite number of pixels, each pixel includes 3 indexes with values ranging from 0 - 255 representing the three primary color classes, so CNNs can operate and extract data from them.

Through the artificial neural network, the computer can recognize objects in the image, such as cars, people or a character.

After receiving the input image, the CNN network extracts feature from the input image by scanning the kernel, the square matrix, over each pixel in the image and calculating the dot product between the kernel and patch weights corresponding to the input image. After completing the kernel scan through the image, we will receive a new feature layer with a smaller size, in which each feature on the new layer is the result of a set of features on the previous layer. Thus, by changing the weight of the kernel and surrounding features, we can extract important features of the object in the image. These features will then be further processed for classification and regression and during this processing the number of features will also be reduced until they match the output data model.

To make it easier to imagine, when the computer receives an input image and transfers it to the CNN network, the artificial neural

network will in turn extract the characteristics of the image in order of each network layer such as raw pixel > edges > shapes > facial > high-level features. In particular, the last layer will be used to distinguish objects in the image

B. Solving Sudoku puzzle with backtracking (Singh et al., 2014)

For each empty cell, there will be a limited number of possible cases that can be filled in, among which there may be correct and incorrect cases. The task of the solution is to find the correct case among all possible cases or to indicate that the Sudoku matrix does not have a valid case that satisfies all conditions. In this case, the backtracking technique will help eliminate all incorrect cases.

In terms of detailed algorithm, the solving function takes the Sudoku matrix as input, performs preprocessing on the matrix, including checking for value repetitions in rows, columns, and 3x3 blocks, and then saves all the empty cells (represented by the value 0).

After obtaining the list of empty cells, it proceeds to iterate through each cell. For each cell, it retrieves the set of possible values in the range [1, 9]. If the set is not empty, it assigns the first element of the set as the value for the empty cell, removes that element from the set, moves the pointer to the next empty cell, and performs similar steps. In the case where the set of possible values is empty, it means that there is no valid value for that cell. It needs to change the value of the previous cell, and the pointer will return to the previous empty cell to update the new value. The algorithm ends when there are no more empty cells, and it returns the Sudoku matrix with the empty cells filled with valid values. That is the solution to the Sudoku matrix problem.

The algorithm culminates when there are no more empty cells to fill. At this point, it returns the completed Sudoku matrix, with all empty cells now populated with valid values. This final configuration represents the successful solution to the Sudoku matrix problem.

IV. EXPERIMENTAL RESULTS

A. System configuration

During the development phase, our Sudoku-solving project primarily relied on laptops equipped with modest graphics capabilities, featuring VRAM ranging from 2GB to 4GB. These computing resources allowed us to run the program effectively, although the performance was noticeably influenced by the available VRAM. The duration of the Sudoku puzzle-solving process typically spanned around twenty seconds on average, although this timeframe was subject to variation based on the steadiness of the user's hands while holding the puzzle paper in front of the webcam.

One of the prominent challenges we encountered during the development was related to real-time image capture and processing. To address this issue, our program was designed to capture a frame of the puzzle as soon as it recognized the distinctive pattern of the table and then perform analysis based on this captured image. However, this approach occasionally backfired as it introduced a degree of instability into the program's operation.

Specifically, the process of capturing frames, while essential for image recognition and puzzle interpretation, had the unintended consequence of occasionally freezing the program. This freezing, although transient, disrupted the user experience and caused frustration. It was observed that the freezing

occurred as a result of the computational load associated with capturing and processing high-resolution images in real time.

In response to these challenges, we recognize the need for further optimization of the image capture and processing pipeline. Strategies to reduce computational overhead and enhance the program's stability are currently under consideration. These optimizations aim to minimize the freeze periods and create a smoother and more seamless user experience when using our Sudoku-solving program.

Our ongoing commitment to refining and enhancing the program is driven by our dedication to delivering a reliable and efficient Sudoku-solving tool that can accommodate various real-world scenarios and user preferences. As we continue to fine-tune our algorithms and improve the program's performance, we anticipate a significant reduction in freeze occurrences, ultimately resulting in a more user-friendly and dependable solution for Sudoku enthusiasts.

B. Results and discussion

With all the methods working out, we successfully create our Sudoku solver using Python with the help of Backtracking Search and CNN. Fig. 1 shows the Sudoku table post processing the image in real-time, and Fig. 2 shows the answer filled in the image.

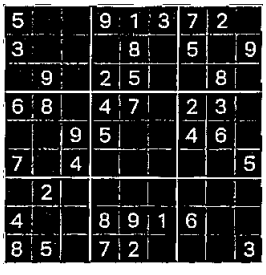

Figure 2. Sudoku table from the image

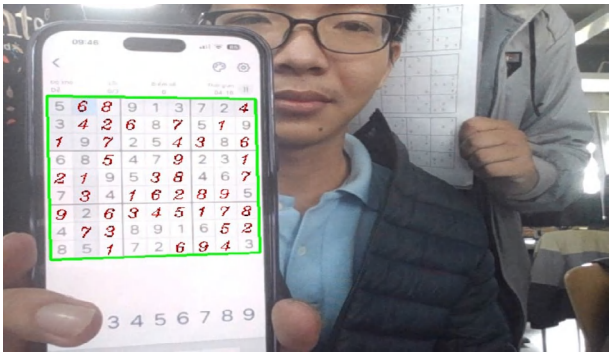

Figure 3. Answer output directly on paper

V. CONCLUSION

In conclusion, the development and implementation of our Sudoku-solving program have yielded valuable insights into the realm of computational puzzle-solving. Sudoku, a classic and challenging puzzle, has been a suitable testbed for exploring various algorithmic approaches, each with its strengths and limitations.

Our program predominantly relied on the backtracking search algorithm, enhanced with techniques such as Forward Checking, Constraint Propagation, Minimum Remaining Values, and heuristic-based strategies like Hill Climbing and Random Restart. This combination of methods allowed us to consistently and efficiently tackle a wide range of Sudoku puzzles.

Moreover, we examined alternative approaches to Sudoku problem-solving, including stochastic optimization techniques and Algorithms based on the exact cover problem. These approaches provided valuable perspectives on puzzle-solving, offering different avenues for exploration.

Despite its reliability and versatility, we acknowledge that the backtracking algorithm, while effective, can be computationally

demanding for highly complex Sudoku puzzles, necessitating substantial computing resources. Furthermore, real-world applications may introduce challenges such as environmental factors affecting input accuracy, as observed during testing.

In the future, further enhancements to our program could include optimizations to reduce computational resource requirements and the integration of more advanced techniques to handle real-world variations of Sudoku puzzles.

Overall, our program serves as a foundation for continued research and development in Sudoku puzzle-solving, offering valuable insights into the algorithms, strategies, and challenges associated with this captivating endeavor. As we advance in our pursuit of efficient puzzle-solving techniques, we anticipate the continued evolution of Sudoku-solving programs, making them even more accessible and effective for enthusiasts and practitioners alike.

ACKNOWLEDGEMENT

We would like to thank Eastern International University for sponsoring the project.

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AN IMPLEMENTATION OF A NEXT-GENERATION FIREWALL BASED ON OPEN-SOURCE TECHNOLOGY

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Abstract: The rapid evolution of network threats and the increasing complexity of modern network environments have driven the need for advanced security solutions. This paper presents the design and implementation of a next-generation firewall (NGFW) using open-source technology for network detection and prevention systems. The results demonstrate that the deployed firewall is capable of effectively addressing the challenges presented by contemporary cyber security threats, making it applicable to real-world scenarios.

Keywords: *Next-generation firewall, pfSense, open-source, intrusion detection and prevention, VPN*

I. INTRODUCTION

A next-gen firewall represents the third generation of firewall technology (VMware Glossary, 2023), devised to combat advanced security threats occurring at the application level through intelligent security functions that consider contextual information. This new generation firewall integrates conventional firewall features such as packet filtering and stateful inspection with additional capabilities to enhance its decision-making process regarding traffic flow. The next-gen firewall has the capacity to evaluate packets based on the applications they belong to and to deeply analyze the data they carry, besides the information of IP headers. Moreover, NGFW operates at up to the OSI model's layer 7 (the application layer), whereas the traditional firewall operated up to layer 4 (the transport layer). As attacks targeting layers 4 to 7 of the OSI model continue to rise, this ability emerges as a critical aspect. Within the domain of NGFWs, pfSense presents as an open-source software developed on the FreeBSD platform, demonstrating the capacity to effectively addressing the diverse challenges from modern threats. The pfSense not only enables the management of Quality of Service (QoS), Virtual Private Networks (VPNs), and network traffic shaping, but also integrates an intrusion detection and prevention system (IDS/IPS).

This paper focus on the architecture, features, and deployment of a Next-Generation Firewall based on the open-source framework pfSense. The detailed implementation process is outlined to demonstrate the effectiveness of pfSense as a robust and adaptable NGFW solution. This paper can be utilized as a manual for individuals seeking to implement advanced firewalls within real-world contexts, and it also holds potential value in cyber security programs for training and education.

II. METHODOLOGY

A. Next-generation firewall

Next-generation firewalls (NGFWs) offer a range of advanced features that go beyond the capabilities of traditional firewalls. These features are designed to provide more comprehensive and effective security in modern network environments. Some of the key features of next-generation firewalls include:

- Application Awareness and Control: NGFWs can identify and categorize applications within network traffic. This enables better control over application usage and helps prevent unauthorized or risky applications from accessing the network.
- Intrusion Prevention System (IPS): NGFWs incorporate intrusion prevention capabilities to detect and prevent a wide range of attacks. They analyze network traffic for suspicious patterns and behaviors, blocking or alerting on potential threats in real-time.
- Deep Packet Inspection (DPI): NGFWs perform deep packet inspection, analyzing the detailed content of network packets. This allows them to detect threats, malware, and anomalies that might be hidden within the packet payloads.
- Content Filtering: NGFWs can inspect and filter content based on predefined rules, preventing the transmission of sensitive or inappropriate information. This feature is essential for maintaining compliance and preventing data leaks.
- Malware and Threat Detection: NGFWs can identify and block malicious files and URLs through integration with threat intelligence feeds and malware databases.
- Virtual Private Network (VPN) Support: Many NGFWs offer built-in VPN capabilities, allowing secure remote access to the network while maintaining encryption and authentication.
- Quality of Service Management: NGFWs have the ability to give priority and distribute resources for all network services, guaranteeing that essential applications get the required bandwidth and minimal delay, thus improving the overall performance of the network.

Within the domain of NGFWs, pfSense stands out in terms of performance and is commonly used in practical scenarios (Fig. 1). It can run on almost hardware and platforms.

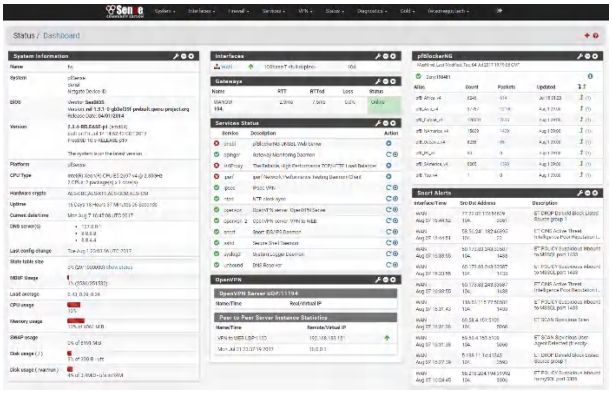

Figure 1. The pfSense Web interface

B. Firewall implementation procedure

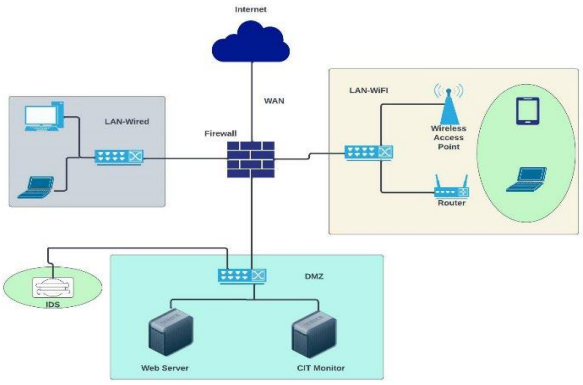

Figure 2. The implementation network for NGFW

The NGFWs implementation contains three parts: deploying pfSense on VMware, performing the initial configuration, configuring pfSense features using a web interface. In this implementation, the network topology is used as shown in Fig. 2.

1. Deploying pfSense on VMware

Before starting the installation, we download the pfSense media (pfSense Documentation, 2023). We use the pfSense ISO Image to mount to the virtual machine to begin the installation. pfSense configuration requires at least two interfaces, one for the WAN, one for the DMZ, one for the WIFI and the other for the LAN. The WAN interface demands internet access, the LAN will act as a gateway for the LAN users while the DMZ is used for web server and the WIFI for WiFi access. We will configure these four interfaces on the VMware workstation first (Fig. 3).

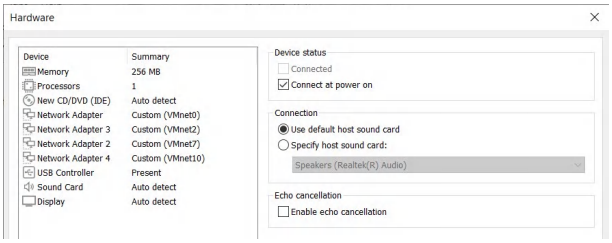

Figure 3. Setting up network interfaces in virtual machine

2. Performing the initial configuration of pfSense

Figure 4. The pfSense console interface

After assigning IP addresses to all interfaces via the console interface (Fig. 4), we should be able to access the pfSense web GUI via the pfSense login interface (Fig. 5).

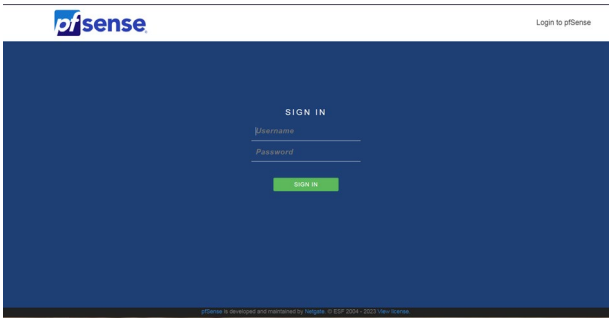

Figure 5. The pfSense login interface

The pfSense interfaces allow a wide range of option combinations. They can also handle several networks and protocols on a single interface, or they can join many interfaces to create a virtual interface with more capacity or redundancy (Fig. 6). Any connection or role may be defined for any interface.

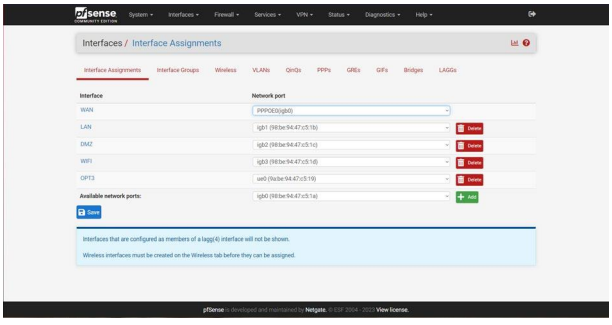

Figure 6. The pfSense dashboard interface

At this point, we begin creating firewall and NAT rules for our environment to start filtering network traffic (B., & B., 2022).

3. Configuring functionalities and features of pfSense

- *Setting the rules and policies*

The important steps in creating our firewall rules can be described as follows:

- Step 1: Go to the interface where you intend to create the rule and click on "Add."
- Step 2: Choose the desired action in the Action tab, whether to permit (pass), block, or reject the traffic.
- Step 3: If needed, update the interface, and then select the address family as IPv4, IPv6, or both IPv4 and IPv6.
- Step 4: Under the protocol section, pick the appropriate protocol; various options will appear depending on your selection.
- Step 5: In source section, select category.
- Step 6: In the destination section, choose the appropriate option (matching the source section).
- Step 7: Optionally, provide a description for the rule and save it.

Once pfSense is set up and its configuration begins, the firewall assumes a critical role, determining whether traffic should be permitted or denied (Fig. 7). Without firewall rules, every connection is automatically denied by default, it's necessary to set allow rules for traffic that should be allowed.

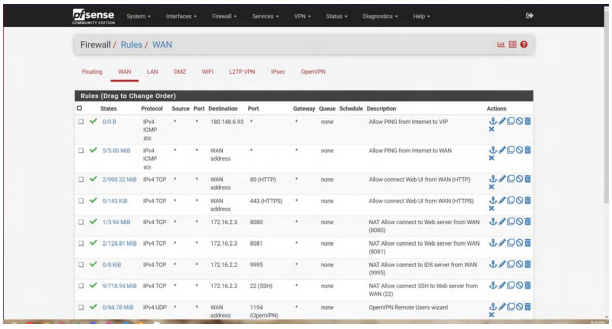

Figure 7. Creating the firewall rules in pfSense

- *Configuring the captive portal feature*

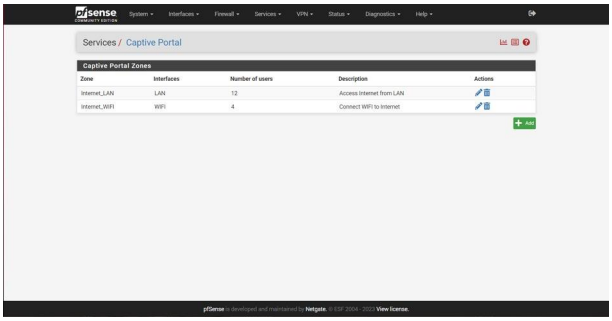

Figure 8. Configuring the Captive Portal Zones in pfSense

The captive portal is a useful feature that individuals using a internet network must first view and engage with before gaining access to the external network (Fig. 8). For certain captive portals, a login and password are required. Users who have been verified may receive username or password from a company. This gives the business control over who uses its Wi-Fi hotspot. They are also protected from potential legal liability by the terms of service page. Moreover, we have to implement network segmentation in the infrastructure by separating the guest network from private LAN in order to provide the organization's guests with free Internet access.

• *Configuring Virtual Private Networks (VPN)*

There exist three supported VPN types within the pfSense framework: OpenVPN, IPSec VPN, and L2TP VPN (What Is VPN, 2023).

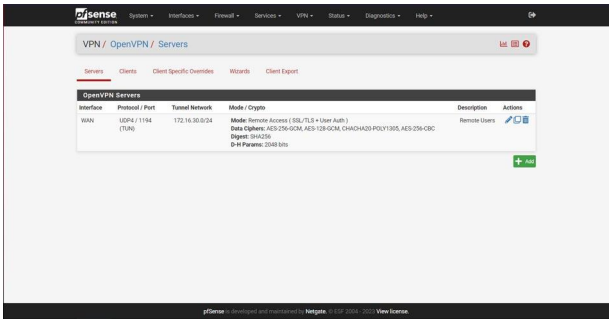

Figure 9. The installation of OpenVPN in pfSense

❖ Configure OpenVPN

OpenVPN is an application that helps with secure online communications. It is an open-source VPN solution designed to create secure point-to-point or site-to-site connections. In order to hide the user's data and location, it encrypts the user's internet traffic and routes it through a server.

Prior to configuring the Open VPN service, we need to select an authentication method. Both OpenVPN and pfSense offer support for authentication based on passwords, certificates, or a combination of both (Fig. 9). To perform the installation, perform the following steps:

- Step 1: Generate the Certificate Authority (CA).
- Step 2: Generate the certification of server.
- Step 3: Create the OpenVPN user and user certificate.
- Step 4: Establish the OpenVPN service.
- Step 5: Setup the OpenVPN Client Export Utility and modify the OpenVPN client parameters.

Particularly when using public Wi-Fi networks, OpenVPN adds an additional layer of protection and anonymity online. When an organization operates a VPN service within its network, employees can securely connect to their home network.

❖ Configure IPSec VPN

Configuring an IPSec VPN in Mobile Client mode on pfSense allows individual devices (e.g., laptops, smartphones) to connect to the pfSense firewall using VPN client software. To set up an IPSec Mobile Client VPN on pfSense, follow these steps:

- Step 1: To access the pfSense Web Interface, launch a web browser, input the IP address of your pfSense firewall, and authenticate using your administrator credentials.
- Step 2: Navigate to VPN Configuration:

  In the pfSense web interface, go to "VPN" and select "IPsec".
- Step 3: Enable the IPsec Service:

  If IPsec is not already enabled, click the "Enable IPsec" button.
- Step 4: Configure Phase 1

  Key Exchange Version: Typically, use "IKEv2"

  Internet Protocol: Choose "IPv4"

  Interface: Select the WAN interface.

  Description: Add a meaningful name for this Phase 1 configuration.

  Authentication Method: Choose "EAP-RADIUS" or another method depending on your setup.

  My Identifier: Set to "My IP Address."

  Peer Identifier: Set to "Any."

  Pre-Shared Key: Enter a strong shared secret.

Encryption Algorithm: Select the desired encryption algorithm (e.g., AES-256).

Hash Algorithm: Choose the hash algorithm (e.g., SHA256).

DH Group: Set the Diffie-Hellman group (e.g., Group 14).

- Step 5: Configure Phase 2

  Mode: Select "Tunnel."

  Local Network: Define your local network (LAN) subnet.

  NAT/BINAT Translation: Leave this as "None" unless you have specific NAT requirements.

  Description: Add a meaningful name for this Phase 2 configuration.

  Protocol: Typically, select "ESP" (Encapsulating Security Payload).

  Encryption Algorithms: Choose the encryption algorithm(s) that match the VPN client's settings.

  Hash Algorithms: Select the hash algorithm(s) that match the VPN client's settings.

  PFS Key Group: Set to the same Diffie-Hellman group as in Phase 1.

  Click "Save" to save the Phase 2 configuration.

- Step 6: Configure User Authentication:

  Go to "VPN" > "IPsec" > "Pre-Shared Keys."

  Click the "Add Preshared Key" button.

  Input a username and create a robust password for each VPN user.

- Step 7: Configure Firewall Rules

  Ensure that you have firewall rules that allow VPN traffic between the WAN and LAN interfaces and vice versa.

- Step 8: Configure VPN Clients

  Configure the VPN client software on each device with the appropriate settings:

  Server IP/Hostname: The public IP address or hostname of your pfSense firewall.

  Username and Password: The credentials you set up in step 6.

  Shared Secret: The pre-shared key you configured in Phase 1.

  Encryption and Authentication settings: Match the settings from Phase 1 and Phase 2.

- Step 9: Connect VPN Clients

  Use the VPN client software to initiate a connection to the pfSense firewall.

- Step 10: Monitor and Test

  Go to "Status" > "IPsec" in the pfSense web interface to monitor VPN connections.

  Test the VPN connections to ensure they are working as expected.

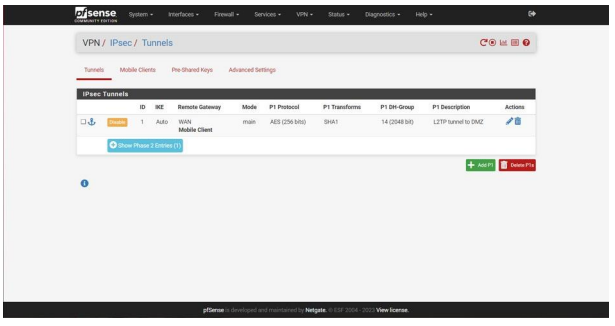

Figure 10. The installation of IPSec in pfSense

The result of IPSec VPN Mobile Client mode is presented in Fig. 10. This allows mobile client connect to local network in a secure manner.

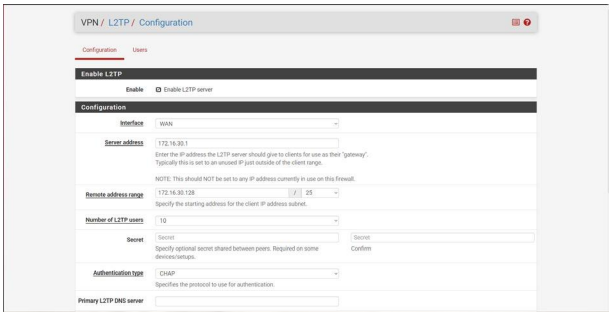

Figure 11. The installation of L2TP in pfSense

Firewall pfSense utilizes the Layer Two Tunneling Protocol (L2TP), which is an extension of the Point-to-Point Tunneling Protocol (PPTP), for facilitating virtual private networks (VPNs). L2TP mandates the use of an encryption protocol for communication within the tunnel to uphold security and privacy (Fig. 11). Due to the fact that L2TP is only a tunneling protocol and does not provide encryption on its own, it is often used in conjunction with another encryption method, such as IPsec.

- *Configuring the open-source tool - Snort*

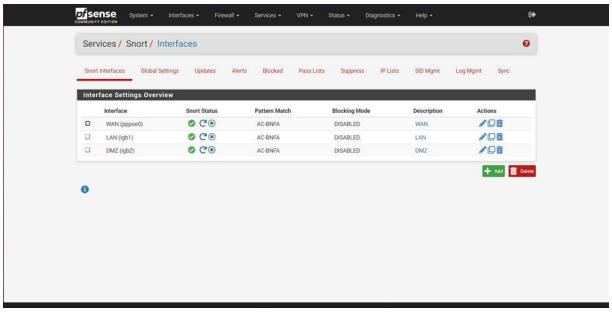

Figure 12. The pfSense dashboard interface

Snort, an open-source Intrusion Detection System (IDS), can be conveniently installed on a pfSense firewall to serve as an intrusion detection and prevention system, safeguarding both home and corporate networks from unauthorized access, as illustrated in Fig. 12. Additionally, Snort allows it to be configured to operate as an intrusion prevention system (IPS). Network administrators can use Snort to monitor incoming packets comprehensively and identify those posing potential threats to the system. It relies on a library packet capture tool and offers straightforward rule creation and implementation, making it suitable for deployment across various operating systems and network environments (Packages — IDS / IPS — Configuring the Snort Package, 2023). Follow these steps to complete the installation:

- Step 1: Search Snort package to get the install link.
- Step 2: Setup the Snort in the package manager on pfSense.
- Step 3: Configure the important parameters for Snort.
- Step 4: Add Snort to an interface.
- Step 5: Starting Snort on an interface.
- Step 6: Select which types of signatures will protect the network.
- Step 7: Define servers to protect and improve performance.

- *Configuring the plugin pfBlockerNG*

The pfBlockerNG plugin is a powerful package that can be added to the pfSense firewall system. It enhances the firewall's capabilities by providing advanced filtering, blocking, and monitoring of network traffic based on a wide range of criteria, including IP addresses, domains, URLs (Fig. 13). This plugin is specifically designed to help manage and control network traffic using various lists and rules to improve security, privacy, and performance.

Key features and functionalities of the pfBlockerNG plugin include:

- DNSBL (DNS Block List): The plugin can integrate with various DNS-based

block lists to prevent access to malicious or unwanted domains and websites. This is commonly used to block ads, tracking services, and known malicious sites.

- IP Block Lists: pfBlockerNG allows to import and manage lists of IP addresses or ranges associated with malicious or undesirable activities, such as known attackers, spammers, or sources of malware.
- GeoIP Filtering: Block traffic based on geographic regions, preventing or allowing access from specific countries based on your organization's policies or security requirements.
- Whitelisting and Custom Lists: The plugin enables you to create custom whitelists and block lists, giving you fine-grained control over which IPs, domains, or URLs are allowed or blocked.

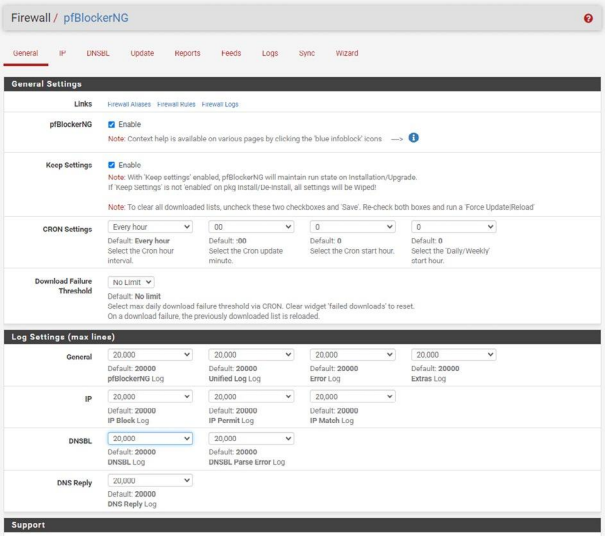

Figure 13. The interface of pfBlockerNG plugin

III. RESULTS OF IMPLEMENTATION

A. Network traffic filtering feature

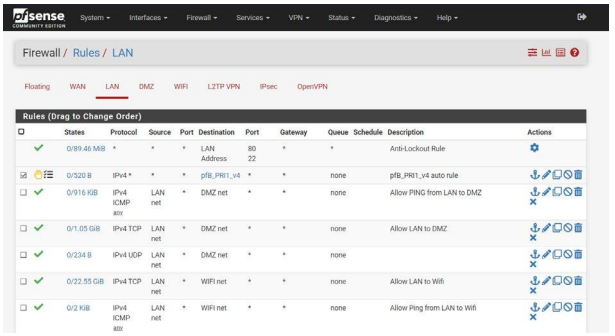

Figure 14. An example of setting rules to block traffic from LAN

The image displayed below depicts the result of blocking access to www.google.com (Fig. 14). This rule prevents traffic originating from the guest network from accessing the LAN network. Conversely, on the LAN network interface, a rule can be established to restrict traffic from the LAN network from reaching the guest network, depending on how administrator wants any traffic passing from the LAN and guest networks (Fig. 15).

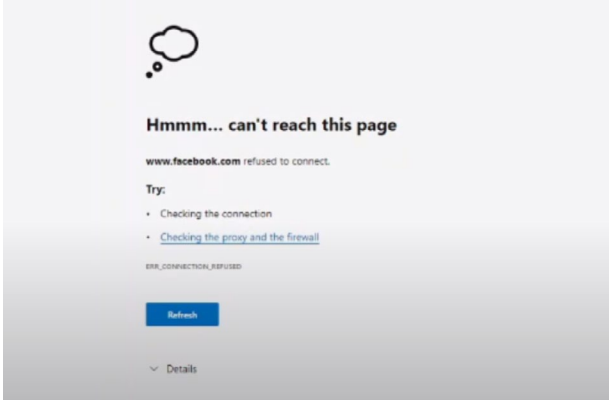

Figure 15. An example of blocked accessing to a specific website

On the other hand, users can ping from clients in the LAN network to the DMZ network

by allowing ICMP to pass through the firewall in order to debug a network or test the target host's response.

B. Captive portal (WiFi access)

Once completed configuring Captive Portal on pfSense, people who wants to have internet access must use their account to verify their activities (Fig. 16).

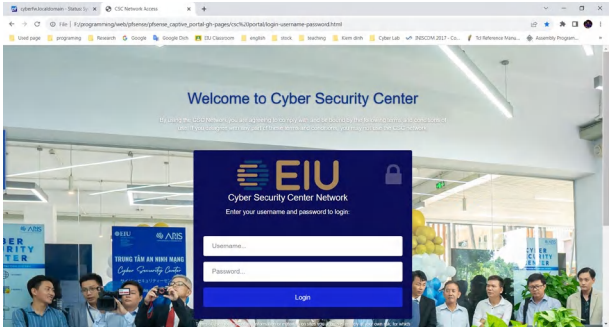

Figure 16. An example of captive portal for Wifi service

C. Virtual private networks (VPN) service

Using a VPN helps to share files securely, without worrying that the content will be exposed or compromised. Additionally, clients can access the internet anonymously and protect their identity (Fig. 17).

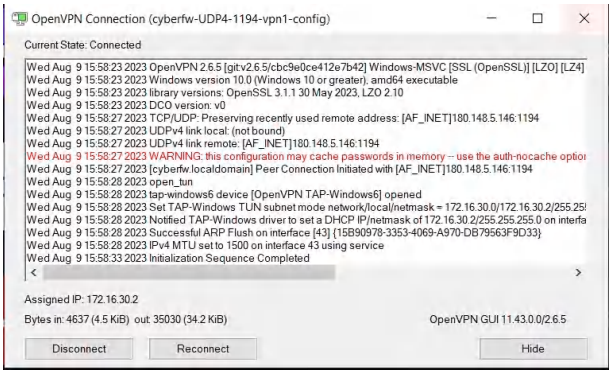

Figure 17. An example of VPN service

D. Intrusion detection/Prevention system

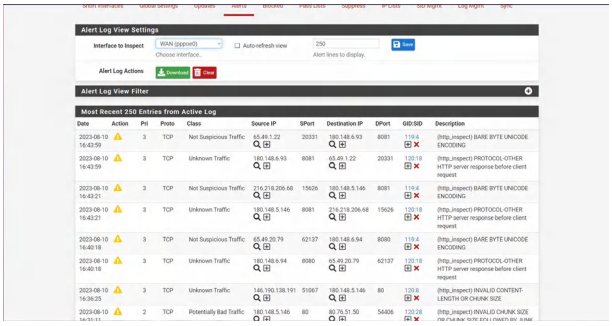

Figure 18. An example of Snort deployment

Adding Snort to PfSense is a great way to increase network safety. By examining traffic and selecting the appropriate configuration, an IDS added to the network will support the firewall's setup (Fig. 18). PfSense is a great network management tool for both residential and business networks. Both PfSense and Snort are well supported by the community. They provide outstanding security and network administration for organizations and optional commercial assistance, making it simple for all customers to utilize them.

E. Control network traffic with pfBlockerNG

Configuring the DNSBL (DNS Block List) feature in the pfBlockerNG plugin for pfSense involves a few steps (Zoltan & Zoltan, 2023). DNSBL allows to block access to domains and websites that are known to be malicious, unwanted, or associated with ads and tracking (Fig. 19).

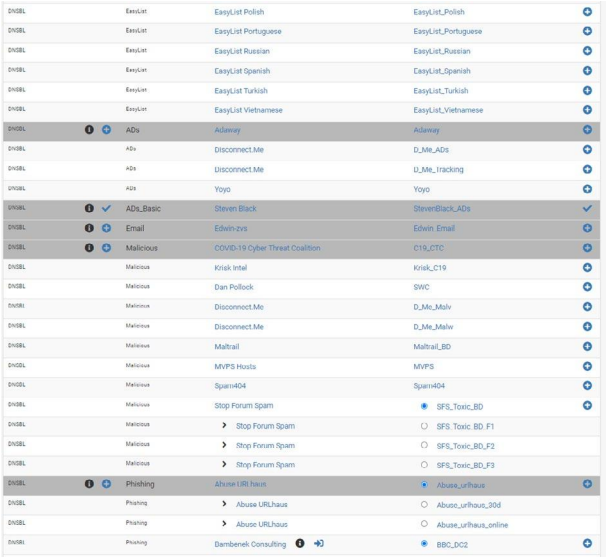

Figure 19. An example of DNS block list configuration

By using pfBlockerNG, which includes DNS blackholing functionality, can stop adverts and some harmful websites like gambling, porn, and malware. The DNS queries made against a list of recognized ad networks and trackers will be banned at the DNS level on your network when the DNSBL functionality on your pfBlockerNG is enabled. Moreover, pfBlockerNG can be used to enforce SafeSearch and YouTube restrictions by blocking or redirecting traffic to ensure safer and more controlled browsing experiences (Fig. 20).

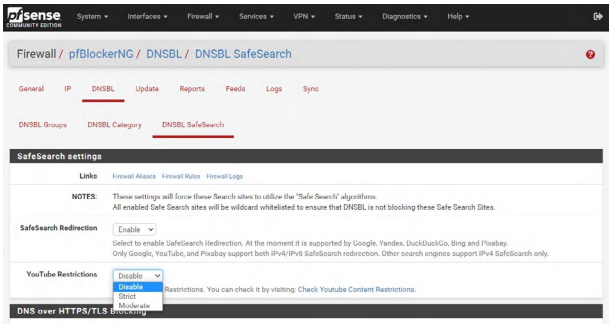

Figure 20. An example of SafeSearch feature configuration

IV. CONCLUSION

In this study, the implementation of an open-source technology next-generation firewall highlights the importance of adaptable network security solutions. The integration of advanced NGFW capabilities and the utilization of open-source tools, as demonstrated through the implemented application of pfSense, has proved the capacity to effectively strengthen contemporary network environments against cyber security threats.

ACKNOWLEDGMENT

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DESIGN AND IMPLEMENTATION OF A CYBER SECURITY TESTBED FOR NETWORK INTRUSION DETECTION

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Abstract: A cyber security testbed is an effective method for hands-on learning in the field of information security. Designing and setting up such a testbed is a challenging endeavor as it has to satisfy the requirements in training and exercises related to cyber security for different target groups like students, IT professionals, and engineers. They cover diverse domains such as malware analysis, cyber security, IoT, and Industry 4.0. Moreover, these testbeds often demand significant maintenance and resources, making them less accessible to non-expert communities. In this study, we explore how to design an educational cyber security testbed and implementing a typical testbed design for network intrusion detection based on open source technology. This paper can provide the valuable guidance to institutions looking to structure cybersecurity programs for educational objectives.

Keywords: *cyber security, testbed, training, practice, open source*

I. INTRODUCTION

The rapid evolution of digital technology has led to an increasingly potential for cyber threats, leading to the critical need for effective cyber security measures. In response to this growing challenge, the design of cyber security testing environment has emerged as essential tools for evaluating, refining, and enhancing security strategies. These testbeds provide controlled environments that simulate real-world scenarios, enabling researchers, practitioners, and students to comprehensively study various attack vectors, vulnerabilities, and defense mechanisms. Furthermore, these testbeds enable to address the variety of network intrusion detection challenges, assessing the efficiency of detection systems, and enhancing incident response strategies. These platforms serve as a bridge to remove the gap between theory and practice by facilitating hands-on exploration of attack scenarios within a secure and controlled environment.

Several studies have focused on the design cyber security testbeds, particularly in the context of network intrusion detection. One notable related work is the research by Furtuna et al. (Furtună, Patriciu, & Bica, 2010), which presents a methodical execution of a cybersecurity system, encompassing design considerations for every phase in a structured manner. This paper can function as a manual for individuals interested in arranging cybersecurity exercises for educational objectives. Another study by Frank et al.

(Frank, Leitner, & Pahi, 2017) presents about design considerations for cyber security testbed aimed at education, employing open source technology. The authors also introduced a model to guide the creation and implementation of such testing environment. The study in (Sahu et al., 2021) presents four case studies focused on cyber attack and defense scenarios utilizing RESLab. In these cases, the authors demonstrate the manipulation of false data and command injection through the application of Man-in-the-Middle and Denial of Service attacks. Another approach is to use the virtual lab technology in practical projects with real-world applications, which can yield positive outcomes (Luse & Rursch, 2021). It positively affects participants' perceptions of networking concepts and boosts their confidence in applying the technology. Additionally, the study demonstrates that these practical projects encourage students to engage in advanced cognitive thinking. These works contribute to the development of comprehensive and realistic testing environments that aim at evaluating the effectiveness of intrusion detection systems and enhancing cyber defense strategies (Kummerow et al., 2023).

This paper introduces the core processes for designing and implementing a cyber security testbed, with a specific focus on network intrusion detection. It explores the considerations, objectives, and methodologies that contribute to the creation of a robust testbed. We focus on the design of an educational cyber security testbed and the implementation of typical testbed configurations utilizing open-source technology. This paper can serve as a valuable guideline for individuals aiming to establish cyber security programs for educational purposes.

II. METHODOLOGY

A. Design consideration for cyber security testbeds

Designing and implementing a cyber security testbed is a time-consuming task that requires in-depth planning and significant resource investment. This is due to the diverse forms and distinct characteristics of cyber security threats. Some common design factors for security testbeds are as follows:

- Objectives: Clearly define the objectives of the testbed, including the specific skills or knowledge you aim to develop or assess.
- Realism: Strive for a realistic environment that mirrors actual cyber threats and scenarios. This ensures that participants encounter challenges and scenarios that closely resemble real-world situations.
- Flexibility and Scalability: Design the testbed to be adaptable and modifiable. This allows for future updates, changes in numbers of participants, scenarios, and resources. It should be flexible enough to scale up or down as needed.
- Diversity of Scenarios: Incorporate a diverse range of scenarios, encompassing different types of attacks, vulnerabilities, and defensive strategies.
- Technological Variety: Reflect a wide array of technologies, software, and hardware commonly used in the field. This exposes participants to a realistic technological landscape.
- Learning Outcomes: Align the design with specific learning outcomes. Clearly define what participants should be able to accomplish or understand after completing the exercise.

- Security and Privacy: Ensure the security and privacy of a testbed. Participants should have a controlled environment that does not compromise actual systems or sensitive data.
- Resource Management: Consider resource allocation and utilization. Ensure that the testbed operates efficiently without overwhelming participants or systems.
- Accessibility: Make the testbed accessible to a wide range of participants. Consider issues of physical accessibility and also ensure that the technology used is compatible with various devices and platforms.
- Ethical Considerations: Address ethical considerations and potential consequences of the exercise. Ensure that participants understand the boundaries and adhere to ethical standards.

Taking these considerations into account when designing cyber security testbeds can enhance the overall learning experience, preparing participants for real-world challenges in the field of cyber security.

B. Design objectives and approach

Defining the design objectives is a crucial initial step in the cyber security testbed design. All subsequent design phases must derive from the selected objectives and are shaped by them. Several key objectives should be taken into account when designing cyber security testbeds:

- Skill Development: The testbed should aim to develop specific technical skills and competencies related to cyber security, such as threat detection, incident response, vulnerability assessment, and penetration testing.
- Practical Experience: Participants should gain hands-on experience in dealing with real-world cyber security scenarios, which can enhance their problem-solving abilities and decision-making skills.
- Understanding Threats: The testbed should deepen participants' understanding of various cyber threats, attack vectors, and tactics employed by malicious actors.
- Defensive Strategies: The exercise should enable participants to develop effective defensive strategies, including system hardening, network monitoring, and incident mitigation.
- Adaptability: The testbed should teach participants how to adapt their strategies in response to evolving cyber threats and changing circumstances.
- Incident Response: Train participants in handling security incidents effectively, from initial detection to containment, eradication, and recovery.
- Security Awareness: Instill a heightened sense of security awareness among participants, promoting a proactive mindset in identifying and mitigating threats.
- Hands-On Technical Skills: Provide opportunities for participants to practice technical skills, such as configuring firewalls, analyzing malware, and using security tools.
- Critical Thinking: Foster critical thinking skills by presenting participants with complex scenarios that require logical analysis and problem-solving.
- Compliance and Regulations: Familiarize participants with relevant industry regulations, standards, and compliance requirements.

By aligning the design of cyber security testbeds with these objectives, we can ensure that participants acquire a comprehensive skill set and knowledge base that prepares them to effectively navigate the complex landscape of cyber security.

When designing cyber security testbeds, a variety of methods can be considered to create effective and impactful learning experiences. Some typical approaches are presented in the Table 1:

Table 1. Cyber security testbed design approach

Approach	Objective
Scenario-Based Approach	Design the testbed around realistic and engaging scenarios that replicate actual cyber security challenges. Participants navigate through these scenarios, applying their skills to address threats, vulnerabilities, and incidents.
Simulation-Based Approach	Utilize realistic simulations of networks, systems, and applications to immerse participants in virtual environments. This approach allows participants to practice skills without real-world consequences.
Hands-On Labs	Create interactive labs that guide participants through exercises to perform specific tasks, such as malware analysis, penetration testing, or network monitoring.
Capture The Flag (CTF) Style	Implement a gamified approach where participants solve challenges, uncover clues, and progress through levels to achieve predefined goals. This approach encourages competitiveness and active problem-solving.
Red Team vs. Blue Team	Structure the testbed as a simulated conflict between offensive "Red Teams" (attackers) and defensive "Blue Teams" (defenders). This approach mirrors real-world cyber battles and emphasizes collaboration and strategy.
Threat Emulation	Emulate specific threats, attack scenarios, or malware samples to expose participants to realistic cyber security incidents.
Industry-Specific Scenarios	Tailor scenarios to specific industries, such as finance, healthcare, or critical infrastructure, to provide contextually relevant learning experiences.

The approach chosen should align with the learning objectives, available resources, and the desired level of complexity. Ultimately, the selected approach should create an engaging and educational environment that enhances participants' cyber security skills and knowledge.

C. Technical specifications

Technical specifications in the designing and implementation of cyber security testbeds refer to the detailed requirements and configurations that define the technical aspects of the testbed environment. These specifications provide a baseline for setting up the infrastructure, hardware, software, networking components, and other technical elements necessary to create a functional and realistic testing environment (as shown in Table 2).

Table 2. Technical specification of a cyber security testbed

Content	Detail
Hardware Requirements	Define the hardware components needed for the testbed, such as servers, workstations, routers, switches, firewalls, and other networking devices. Specify hardware specifications like processing power, memory, storage capacity, and network interfaces.
Software Configuration	Specify the operating systems, security software, and applications that will be installed on the testbed's systems. This may include virtualization software, security tools, monitoring applications, and other relevant software.
Networking Topology	Outline the network architecture, including the arrangement of systems, subnets, IP addresses, and network connections. Define how systems communicate, simulate internet connectivity, and replicate network segments.
Security Mechanisms	Describe the security measures to be implemented within the testbed environment, such as firewalls, intrusion detection systems, encryption protocols, and access control mechanisms.
Virtualization and Emulation	Determine whether virtualization or emulation technologies will be used to replicate different components of the testbed. Specify virtualization platforms, hypervisors, or emulation tools.
Configuration Management	Establish how systems will be configured, patched, and maintained over time to ensure consistency and relevancy of the testbed environment.
Resource Allocation	Define how system resources will be allocated among different exercises or scenarios. Address issues related to scalability, load balancing, and resource contention.
Network Segmentation	Determine how the network will be segmented to simulate different zones within an organization's infrastructure, such as DMZs, internal networks, and isolated environments.
Data Privacy and Protection	Specify measures to safeguard sensitive or confidential data used within the testbed. Ensure compliance with data protection regulations and ethical considerations.

III. TESTBED IMPLEMENTATION AND RESULT

A. Testbed implementation process

Implementing cyber security testbeds is a sequenced procedure to create a realistic environment for participants to practice and enhance their cyber security skills. The summary of implementing our cyber security testbed for network intrusion detection testbed is shown in Table 3.

Table 3. Security testbed implementation process

Procedure	Detail
Define Objectives and Scope	*Objective*: Develop participants' skills in detecting and mitigating network-based cyber threats using an intrusion detection systems (IDS). *Scope*: Simulate various types of network attacks (Reconnaissance, denial-of-service attack, Web application attack).
Select Tools and Technologies	*VMW* for virtualization to create multiple virtual machines (VMs). *Open-source* technology for major Testbed components: Snort (an open-source IDS) and CloudCoffer (software-based IDS) to monitor network traffic and detect suspicious activities; pfSense (free and open-source firewall), cacti (monitoring system)

Procedure	Detail
Install Software and Systems	Install the desired operating systems (e.g., Ubuntu Server) on each hardware server or VM and then install Snort, pfSense, Cacti, KALI on the target systems.
Develop Educational Case Study (CS)	*CS 1:* Simulate a port scanning attack on the client network segment. *CS 2:* Launch a denial-of-service (DoS) attack on the web server. *CS 3:* Perform SQL Injection Attack.
Security Measures	Setup firewalls to isolate different network segments and control traffic flow. Configure IDS rules to detect patterns indicative of port scanning and DoS attacks.
Test and Refine	Test the network setup by running the attack scenarios and monitoring IDS detection capabilities. Refine IDS rules and network configurations as needed based on testing outcomes.

C. The results of testbed implementation

This section illustrates the implementation of a Testbed for network intrusion detection, including the network topology, software and system setup, and the evaluation procedure.

1. Cyber security network topology

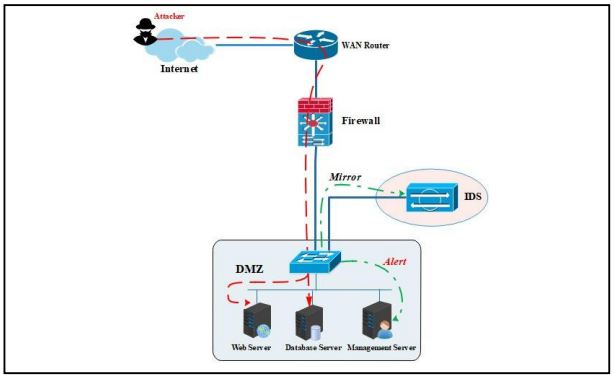

Figure 1. The network topology for cyber security testbed

The network topology of our cyber security testbed is designed to simulate a real-world network environment with distinct segments and subnets for specific functions (as shown in Fig. 1), including: DMZ (Demilitarized Zone), Internal Network (LAN), Penetration Network (Pen-NET).

2. Web server setup and configuration

Figure 2. An example of the Web application configuration

For the configuration of a web server, it is essential to install web server software like Apache, Nginx, or Microsoft IIS. In our testbed, Nginx was selected due to its capability for high-performance processing and handling multiple threats, while MariaDB was chosen for database storage. These components are operational on a dedicated hardware server running the Ubuntu Server version 22.04 platform (Fig. 2).

3. Open-source firewall deployment

A firewall plays is a key role within a security testbed by managing the movement of

network traffic. In this testbed, pfSense has been selected as the preferred firewall since it is an open-source solution with a friendly web-based interface for configuration and management (Fig. 3). Additionally, pfSense offers a wide range of features, including Network Address Translation (NAT), Intrusion Detection and Prevention Systems (IDS/IPS), and support for Virtual Private Networks (VPNs). There exist three supported VPN types within the pfSense framework: OpenVPN, IPSec VPN, and L2TP VPN. Configuring an VPN in Mobile Client mode on pfSense allows individual devices (e.g., laptops, smartphones) to connect to the pfSense firewall using VPN client software. Firewall rule configuration is illustrated in Fig. 4.

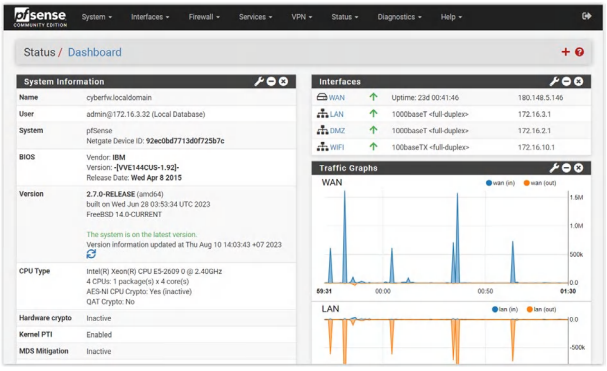

Figure 3. An example of the Dashboard firewall

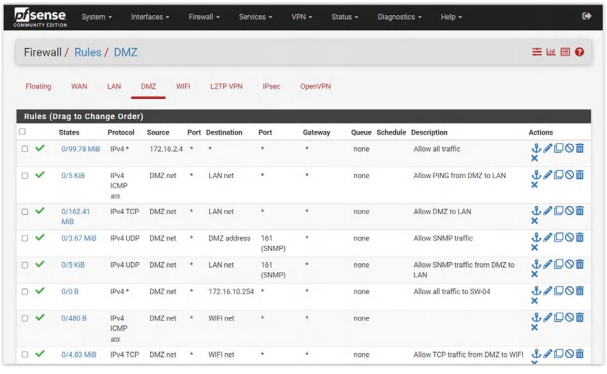

Figure 4. An example of the firewall rule configuration

4. Intrusion detection system deployment

To simulate intrusion detection capabilities, Snort, an open-source IDS, was deployed to monitor incoming and outgoing traffic across all network segments. Snort rules were carefully crafted to detect specific attack patterns and signatures, including port scanning attempts, denial-of-service attacks, and suspicious traffic patterns. Custom rules were designed to align with the learning objectives and scenarios defined earlier (Fig. 5).

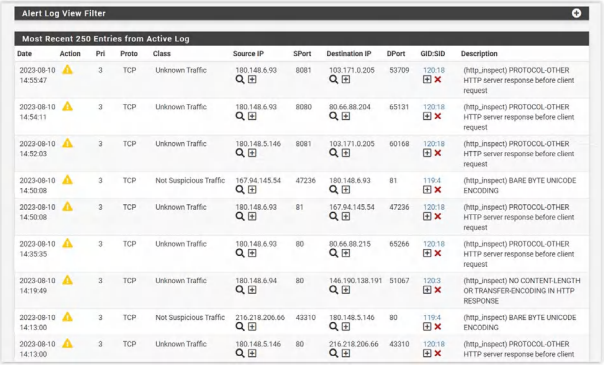

Figure 5. An example of alert logging in Snort

Furthermore, we deploy CloudCoffer, a Linux-based IDS/IPS solution that combines advanced threat detection capabilities with real-time response mechanisms. This enables us to proactively identify and mitigate potential security breaches (Fig. 6).

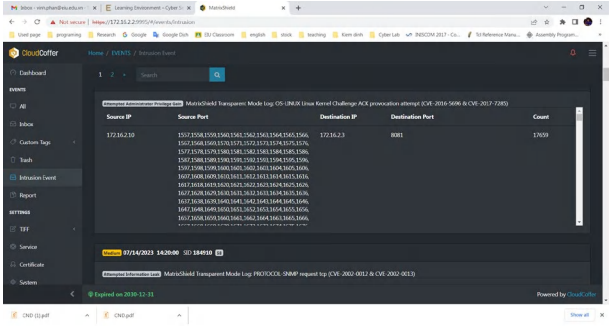

Figure 6. An example of the notification message in CloudCoffer

5. Network monitoring and alert system

In a modern network, a reliable network monitoring tool becomes essential to maintain network operations and proactively address potential issues. Cacti, an open-source tool, is used to monitor and optimize the network infrastructure (Fig. 7). Cacti can track network performance, visualize traffic patterns, and monitor device health in real-time (Fig. 8).

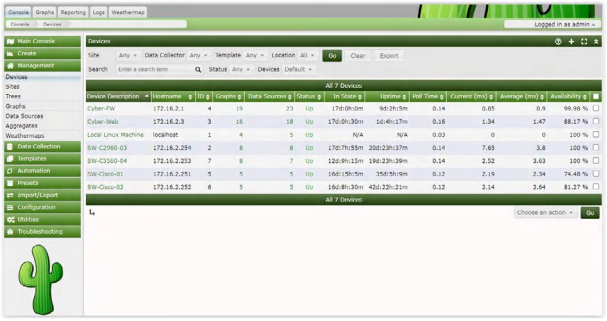

Figure 7. An example of the network device monitoring and configuration

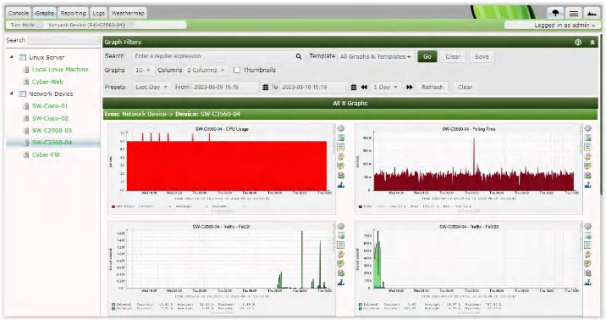

Figure 8. An illustration of the network topology monitoring

Additionally, Cacti can serve as an alerting system to notify the critical events or deviations from preset thresholds (Fig. 9).

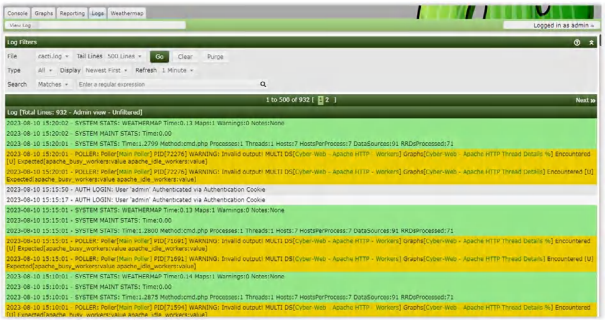

Figure 9. An example of the alert logging message system

C. Attack scenario execution

Participants were challenged with simulating network attacks targeting the web server, the database server and the management server within the DMZ. The attacker system is used to initiate the attacks while the IDS monitored network traffic. Network and attack tools are illustrated in the Table 4.

Table 4. Tools and attack method

Tools	Method
Wireshark	Capture and analyze network traffic in real-time.
Tcpdump	A command-line packet analyzer that captures and displays network traffic.
Nmap	A powerful open-source network scanning tool. It can be used to discover hosts, services, and potential vulnerabilities on a network.
Hping	Hping is a versatile and powerful command-line tool used for network packet crafting, scanning, and testing.
KALI and Metasploit	A penetration testing framework that includes various tools and exploits to simulate different types of attacks.
SQLMap	SQLMap is an open-source penetration testing tool that specializes in detecting and exploiting SQL injection vulnerabilities.

These tools are just a starting point, and the choice of tools depends on the specific goals of your network attack study. Keep in mind that using these tools for studying network attacks should be done in a controlled and ethical environment to avoid any unintended consequences (Fig. 10-12).

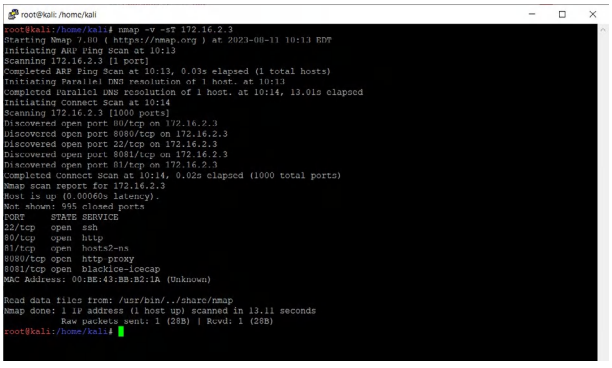

Figure 10. An example of port scanning attack

Figure 11. An example of the DoS attack

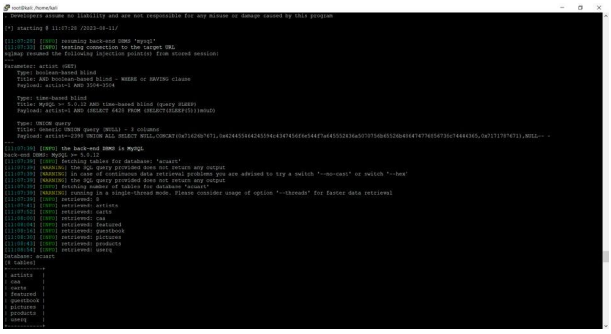

Figure 12. An example of the SQL injection attack

IV. CONCLUSION

In this paper, we have presented our approach, which focuses on the design and implementation of a functional cyber security testbed for network intrusion detection. By following the defined scenarios, participants gained hands-on experience in detecting and mitigating network-based threats, enhancing their practical skills in a controlled and secure environment. This testbed served as a valuable training resource for developing expertise in network intrusion detection and response.

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PEOPLE COUNTER IN REAL-TIME USING GAUSSIAN BLUR AND SSD ALGORITHM

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Abstract: Accurate people counting in various environments is essential for resource allocation, public safety, and operational efficiency. This project presents a Python-based people counter that utilizes computer vision techniques to track individuals in real-time. By leveraging Python and its libraries, such as OpenCV and NumPy, we develop a reliable and cost-effective solution that can be easily deployed and scaled for different applications. The system analyzes video streams or images, employing image processing algorithms and advanced computer vision techniques to accurately count the number of people entering and exiting a defined area of interest. This report discusses the system's components, algorithms, implementation details, challenges faced, and potential future enhancements. The goal is to contribute to the field of computer vision and provide a practical tool for accurate people counting, enhancing decision-making processes and operational efficiency.

Keywords: *computer vision, people counting, real-time tracking, image processing*

I. INTRODUCTION

The accurate counting of people in various environments has become increasingly important for resource allocation, public safety, and operational efficiency in numerous real-world applications.

One such application is in retail analytics. Imagine a bustling shopping mall where store owners want to understand footfall patterns and customer behavior to optimize staffing levels and improve store layouts. By implementing a Python-based people counter utilizing computer vision techniques, the mall management can accurately track the number of customers entering and exiting different stores. This data provides invaluable insights into customer flow, popular shopping periods, and conversion rates, empowering store owners to make data-driven decisions regarding sales strategies, staff deployment, and store designs.

Public transportation systems also benefit from people counting systems. Take a busy metropolitan subway station, for example. By deploying a people counter that leverages computer vision technology, transportation authorities can accurately monitor passenger volume in real-time. This information plays a pivotal role in optimizing schedules, ensuring adequate train frequency, and allocating resources efficiently. Furthermore, it contributes to enhancing public safety by preventing overcrowding and allowing authorities to promptly respond to emergencies.

In the realm of crowd control at events, accurately counting attendees becomes crucial for organizers, whether it is a music festival, sports event, or conference. A Python-based people counter, powered by computer vision algorithms, provides a practical tool for monitoring the number of people entering and exiting specific areas. Armed with this data, event organizers can proactively manage crowd density, control entry to restricted zones, arrange adequate facilities, and ensure visitor safety.

The applications of people counting systems are not confined to retail, public transportation, and events alone. They extend to managing workplace and facility occupancy, optimizing museum and exhibition layouts, monitoring pedestrian traffic at busy intersections, and much more. The proposed Python-based people counting system, with its foundation in computer vision techniques and Python libraries like OpenCV and NumPy, aims to provide a reliable, scalable, and cost-effective solution applicable across diverse domains. It analyzes video streams or images, employing advanced image processing algorithms and computer vision techniques to accurately count individuals in a defined area of interest.

This paper delves into the system's components, algorithms, implementation details, challenges faced, and potential future enhancements, contributing to the field of computer vision. Ultimately, the goal is to equip decision-makers with a practical tool for accurate people counting, amplifying operational efficiency, enhancing public safety, and facilitating informed resource allocation in various real-world contexts.

II. RELATED WORK

Extensive research has been conducted to explore various approaches and technologies in the field of people counting systems. These studies delve into the analysis of different methodologies, including employing diverse technologies and techniques for accurate and efficient people counting. By rigorously examining the strengths and limitations of various approaches, researchers aim to enhance the accuracy, reliability, and scalability of people counting systems across various contexts and environments. Through the amalgamation of cutting-edge technologies and innovative methodologies, these studies contribute significantly to the development and advancement of the field, ultimately paving the way for more sophisticated and robust people counting systems.

The cloud-based people counter system is implemented using Raspberry Pi, OpenCV, and Python. This innovative combination of technologies allows for efficient and accurate counting of individuals. By leveraging the power of cloud computing, the Raspberry Pi device can process and analyze video footage captured by a camera, with the help of OpenCV and Python. This setup eliminates the need for extensive local computing resources and provides the flexibility of accessing and managing the system remotely. The utilization of Raspberry Pi, OpenCV, and Python together creates a robust and cost-effective solution for accurately monitoring and counting people. (Abd et al., 2020).

The PIR sensor-based system is designed to detect infrared radiation emitted by human bodies, enabling the counting of individuals.

However, it is important to acknowledge the limitations of this system, particularly those related to perspective distortion. Perspective distortion occurs when objects are viewed from different angles, leading to inaccuracies in the counting process. Therefore, it is crucial to account for and mitigate these distortions to ensure reliable results. Despite this limitation, the PIR sensor-based system remains an effective and affordable solution for people counting, offering valuable insights for various applications (Sruthi et al., 2019).

The RGB-D camera-based people counting method incorporates several key components to enhance accuracy and address common challenges. Firstly, image calibration is applied to ensure precise measurements by accounting for any distortion or irregularities in the camera's imaging system. This prepares the input data for subsequent processing stages. Next, the system employs foreground detection, which allows for the extraction of people from the background, enabling focused analysis. Additionally, the method includes robust tracking capabilities that can handle challenges such as occlusions (when people are partially or temporarily blocked from view) and changes in direction or stationary positions. By incorporating these techniques, the RGB-D camera-based method offers a comprehensive and reliable solution for accurately counting people in various environments (Wahyu et al., 2021).

A system incorporates foreground extraction, dilated motion search, and flow analysis procedures to ensure accurate counting. With these advanced techniques, the system improved the precision of object detection and tracking in real-world surveillance scenarios. Additionally, these procedures enabled us to address challenges such as varying backgrounds, occlusions, and complex motion patterns. By utilizing foreground extraction, dilated motion search, and flow analysis, the system could provide reliable and accurate counting results.

APL-based background modeling and MAP-based dilated motion search, improving the efficiency and precision of video analysis. The Array Programming Language (APL) could accurately identify complex scene backgrounds and distinguish foreground objects with high accuracy. Additionally, MAP-based dilated motion search technique refined motion estimation, enhancing detection accuracy and reducing processing time. Compared to benchmark methods, this approach offers superior performance, providing exceptional accuracy and faster results.

The people counter implemented in Python combines the strengths and features of different approaches, resulting in a powerful and versatile system. By leveraging computer vision algorithms, Raspberry Pi, and OpenCV, the counter achieves real-time accuracy in people counting tasks. This Python-based implementation stands out for its ability to handle complex operations efficiently, ensuring accurate and timely results. By integrating the strengths of various technologies and frameworks, including Raspberry Pi's computational capabilities and OpenCV's robust image processing functions, the system offers a flexible and cost-effective solution for real-time people counting applications (Sung et al., 2018).

III. PROPOSED METHOD

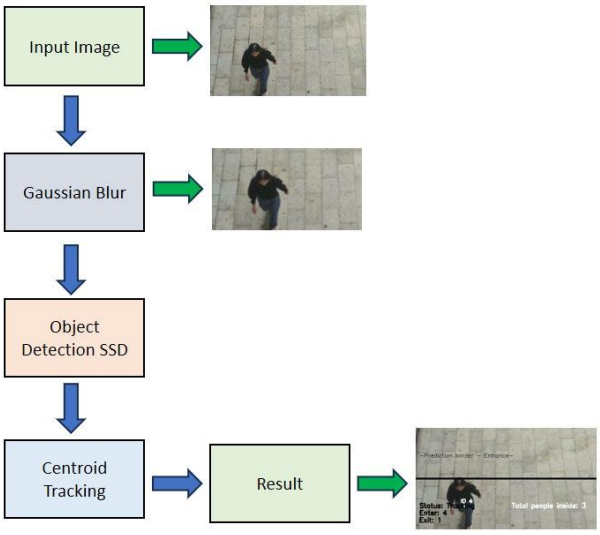

Figure 1. Proposed model

The proposed method introduces an advanced approach for object detection and tracking in real-world surveillance systems. It takes advantage of a deep learning-based algorithm that relies on the highly efficient Single-Shot Detection architecture. Additionally, to ensure precise people counting, the system also utilizes the Centroid Tracker algorithm. The primary goal of our system is to enhance the precision of object detection and tracking, which are crucial for reliable people counting systems.

To further enhance the image quality, this method incorporates Gaussian Blur. This technique effectively reduces noise and improves the overall clarity of the captured visuals. By combining these sophisticated algorithms and image processing techniques, our system aims to deliver accurate and high-quality results in the challenging domain of real-world surveillance.

A. The Gaussian Blur

Gaussian Blur is a commonly used technique in video pre-processing, offering several benefits to enhance the quality and appearance of video footage. Similar to its application in image processing, Gaussian blur in pre-processing can effectively reduce noise, smooth out minor details, and create visually pleasing results.

In video pre-processing, Gaussian blur is applied to each frame of the video by convolving it with a Gaussian kernel. This blurring operation can significantly reduce the impact of noise, such as random variations in pixel values, resulting in a cleaner and more visually appealing video.

One of the primary advantages of Gaussian blur in video pre-processing is its ability to provide temporal coherence. By blurring neighboring frames in a consistent manner, Gaussian blur can help reduce flickering or abrupt changes between frames, creating a smoother and more continuous visual experience.

The level of blur can be adjusted by controlling the size and standard deviation of the Gaussian filter. A larger filter size will result in a more pronounced blur, while a smaller filter size will yield a more subtle effect. The standard deviation determines the spread of the Gaussian distribution, influencing the intensity and sharpness of the blurred areas in the video.

Gaussian blur in video pre-processing finds wide-ranging applications. It is often utilized in video denoising, where it helps minimize the impact of noise and improves overall visual quality. Additionally, Gaussian blur can be employed to soften sharp or jagged edges in videos, providing a more aesthetically pleasing and polished appearance.

Furthermore, Gaussian blur can be utilized for privacy protection or content

anonymization in videos. By blurring specific regions or faces, it helps to conceal identities or sensitive information while preserving the overall content.

Overall, Gaussian blur is a valuable tool in video pre-processing that can enhance the visual quality, reduce noise, improve temporal coherence, and provide aesthetic improvements. Its flexibility and effectiveness make it a popular choice for a wide range of video processing applications, from professional video editing to video surveillance systems.

B. The Proposed Single-Shot Detection (Adrian et al., 2021)

The SSD method has gained widespread adoption in object detection tasks due to its efficiency in accurately detecting objects using a single pass through a convolutional neural network (CNN). A key aspect of SSD is the generation of fixed anchor boxes at different scales and aspect ratios, serving as reference bounding boxes for predicting class probabilities and offsets.

SSD comes in different versions, such as SSD300 and SSD512, each tailored for specific image resolutions. SSD300 employs a network architecture with convolutional layers followed by additional layers of decreasing spatial dimensions, optimized for 300x300 pixel images. In contrast, SSD512 is designed to handle higher-resolution images with a 512x512 pixel resolution, utilizing a deeper network structure.

Furthermore, SSD incorporates popular CNN architectures like MobileNet, ResNet, and EfficientNet. MobileNet-SSD combines MobileNet with SSD for a computationally efficient model suitable for resource-constrained devices. ResNet-SSD leverages the accuracy of the ResNet architecture to enhance object detection performance, while EfficientNet-SSD strikes a balance between accuracy and computational efficiency through the use of EfficientNet's design principles and neural architecture search.

The SSD loss function plays a vital role in training the model by combining classification and regression losses to measure the disparity between predicted and ground-truth values for class probabilities and bounding box offsets. This facilitates the model's learning and improvement in object detection.

Thus, with SSD versions like SSD300, SSD512, MobileNet-SSD, ResNet-SSD, and EfficientNet-SSD, object detection tasks are equipped with a range of options that cater to different image resolutions and computational resources.

C. The Proposed Centroid Tracker (Adrian et al., 2021)

After detecting the people, the Centroid Tracker algorithm comes into play. This algorithm plays a crucial role in assigning unique identification numbers (IDs) to each detected person. It tracks their movements across consecutive video frames by relying on their specific locations within the frame. To achieve accurate tracking, the Centroid Tracker algorithm calculates the Euclidean distance between the centroids of two objects. By continuously updating and comparing these distances, it ensures precise and reliable tracking of individuals over time. This approach enables the system to maintain an accurate record of each person's movement throughout the video sequence.

Finally, the Centroid Tracker algorithm generates a total count of unique IDs, which represents the final number of people detected. This counting method is accurate and efficient, making it a valuable solution for people counting in real-world surveillance systems. The application of this approach extends to various domains, including pedestrian traffic monitoring, crowd control, and retail analysis. By accurately tracking and counting individuals, it becomes possible to gather valuable insights and make informed decisions in these areas. Whether it is managing footfall in public spaces, ensuring crowd safety, or optimizing retail operations, the Centroid Tracker algorithm provides a reliable tool for addressing these challenges.

D. Detail implementation of our system (Adrian et al., 2021)

To establish a robust and accurate people counting system through the utilization of Single-Shot Detection and Centroid Tracker in PyCharm, it is essential to take a systematic approach. This includes the initial installation of requisite libraries such as OpenCV, NumPy, and TensorFlow/PyTorch. After that, we downloaded and loaded the pre-trained SSD model into the project directory before capturing the video feed from the camera. Following this, individuals in the frames could be detected by passing them through the SSD model and applying non-maximum suppression to eliminate overlaps. Object tracking across frames could be achieved via the Centroid algorithm, while the number of individuals moving in and out of the area could be counted based on the tracked objects. Finally, displaying the real-time outcomes on the screen or saving them in a file using OpenCV is needed for further analysis.

During the deployment process of establishing a robust and accurate people counting system using Single-Shot Detection (SSD) and Centroid Tracker in PyCharm, a number of challenges could arise. Firstly, ensuring the proper installation and compatibility of the required libraries, including OpenCV, NumPy, and TensorFlow/PyTorch, was a time-consuming task. We had to double-check that we had installed the required libraries correctly, with the correct versions compatible with our PyCharm environment. Besides, we also verified that the dependencies are satisfied, and considered reinstalling or updating the libraries if necessary. Additionally, downloading and loading the pre-trained SSD model into the project directory correctly is crucial for accurate detection. Capturing a video feed from the camera and processing each frame using the SSD model might lead to performance issues, especially when dealing with real-time video streams. Dealing with overlaps and eliminating false detections through non-maximum suppression requires careful parameter tuning to achieve accurate results. Object tracking across frames using the Centroid algorithm can be challenging, especially in complex scenarios where individuals may occlude each other or exhibit rapid movements. Finally, displaying real-time outcomes on the screen or saving them for further analysis adds another layer of complexity, requiring meticulous coding and integration with libraries such as OpenCV. To overcome this challenge, we validated that the real-time display or saving of results functions as intended, then checked the code implementation for any errors, ensured the correct use of OpenCV functions, and verified that the output format matches your requirements. Despite these challenges, with proper implementation and troubleshooting,

a robust and accurate people counting system can be achieved, enabling valuable insights in various applications.

IV. EXPERIMENTAL RESULTS

A. Configuration specifications

The proposed method was evaluated on laptop HP ProBook 440 G8 Notebook PC with 11th Gen Intel(R) Core(TM) i7-1165G7 @ 2.80GHz (8 CPUs), ~2.8GHz, 16GB and card Intel(R) Iris(R) Xe Graphics.

B. Results and discussion

Our proposed method utilizing SSD and Centroid Tracker provides an accurate and efficient solution for object detection, tracking, and people counting in surveillance systems. Additionally, we improved the accuracy of the system by using the Gaussian Blur technique. The Fig.2 and Fig.3 show the results of this people counting system.

Figure 2. Testing result of the system using proposed methods (SSD and Centroid Tracker) from a video

Figure 3. Experimental result of the system using proposed methods (SSD and Centroid Tracker) at Eastern International University

While our proposed method utilizing SSD and Centroid Tracker showcases promising results for object detection, tracking, and people counting in surveillance systems, there are certain limitations that should be taken into consideration. Firstly, the accuracy and efficiency of the system heavily rely on the quality and resolution of the input video data. Noisy or low-resolution videos may lead to reduced detection and tracking performance. Secondly, the proposed method may face challenges when dealing with occluded or overlapping objects, as it heavily relies on centroid tracking. In such scenarios, the accuracy of object detection and tracking may decrease. Additionally, the integration of the Gaussian Blur technique, while enhancing the system's accuracy, may also introduce blurriness or artifacts that could potentially affect object recognition and tracking in certain situations. Future developments should focus on addressing these limitations and adapting the proposed method to be more robust in handling challenging surveillance scenarios.

V. CONCLUSION

Our research made significant strides in enhancing the accuracy of current people counting systems. Through the implementation of the Gaussian Blur technique, our innovative system effectively enhances the performance of both the SSD and the Centroid Tracker. However, it is important to acknowledge that our proposed system still has room for improvement and faces certain limitations that warrant future enhancements. Firstly, we observed that the accuracy of our system tends to decrease under noisy scenarios, such as videos with background noise or low-resolution footage. This indicates the need for further refinement to ensure optimal performance in such situations. Secondly, it is worth noting that our system may encounter challenges when dealing with fast-paced movements, potentially leading to reduced accuracy in counting. Addressing this limitation can enhance the system's overall robustness and suitability in various real-world scenarios. Despite these limitations, our research signifies a significant step forward in advancing people counting technology, and we remain optimistic about the potential for future improvements and advancements in the field.

ACKNOWLEDGEMENT

We would like to thank Eastern International University for generous funding to implement and deploy our system, which has allowed us to bring our innovative solution to life and make a positive impact.

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PART V.

UNIVERSITY ADMINISTRATION AND OTHER TOPICS

SCIENTIFIC COMMITTEE

- *Assoc. Prof. Dr. Le Van Hao, Head, Unit of Academic Excellence, Eastern International University*
- *Dr. Nguyen Van Tan, Director, Office of Academic Affairs*
- *Meng. Tran Hoai Bao, Director, Office of Quality Assurance*

OVERCOMING COMMON LIMITATIONS IN THE DESIGN AND IMPLEMENTATION OF OUTCOME-BASED CURRICULA

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Abstract: Designing and implementing curricula based on the Outcome-based education (OBE) approach are being widely deployed in Vietnamese universities. The results of quality accreditation of academic programs at higher education institutions (according to Circular 04/2016) in recent years, however, show that there are many limitations in these activities. Based on the results of quality accreditation of academic programs compiled recently (March 2023) by the Center for Education Accreditation - Hanoi National University, and with the author's experiences as a trainer for the development of curricula and as an education quality assessor, this article aims to introduce the basic features of the OBE approach, summarize the common limitations in the field of design and implementation of curricula, discuss and propose some solutions to overcome the mentioned limitations.

Keywords: *higher education, outcome-based education, education quality accreditation, academic program, curricula*

I. SOME RESULTS OF PROGRAM QUALITY ACCREDITATION

At the end of March 2023, the Center for Education Accreditation - Vietnam National University, Hanoi reported "Education Accreditation Results" for institutions and academic programs nationwide (VNU-CEA, 2023). For programs, the report summarizes the results of 700 ones (undergraduate and master's degrees) that have been evaluated according to Circular 04/2016/TT-BGDĐT (MOET, 2016). Fig. 1 and 2 show the average scores of these 700 programs by standard and by criterion, respectively.

The results (from Fig. 1) show that the average scores of all 700 programs on criteria 1 to 5 are below 4/7 (Satisfactory level). These are five standards from Circular 04/2016/TT-BGDĐT directly related to the design and implementation of the programs. Fig. 2 shows eight criteria with an alarmingly low average score (in red), of which five criteria belong to the first five criteria mentioned above (which are the criteria: 1.2, 2.2, 3.2, 5.1,5.3). Meanwhile, Fig. 3 shows that the criteria with more than 20% of the programs are rated as "Unsatisfactory" (below 4/7), in which there are also five criteria mentioned above. Thus, these are the five criteria that are mainly related to the common limitations in the design and implementation of the programs (Table 1).

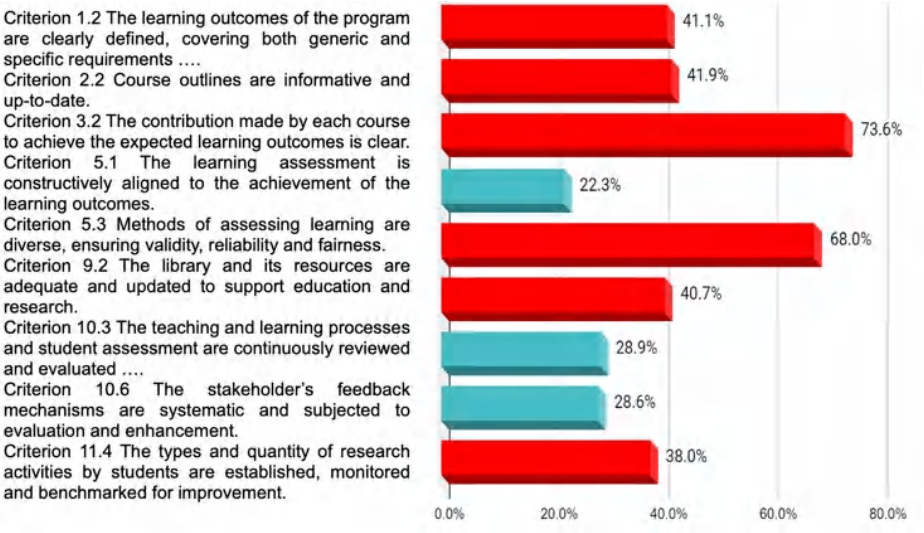

Figure 1. Average standard - based scores of 700 programs evaluated with Circular 04/2016/TT-BGDĐT

Table 1. Five criteria with more than 20% of the programs being evaluated as "unsatisfactory"

Criterion	Content
1.2	The learning outcomes of the program are clearly defined, covering both generic and specific requirements that learners need to achieve after completing the program.
2.2	Course outlines are informative and up-to-date.
3.2	The contribution made by each course to achieve the expected learning outcomes is clear.
5.1	The learning assessment is constructively aligned to the achievement of the learning outcomes.
5.3	Methods of assessing learning are diverse, ensuring validity, reliability and fairness.

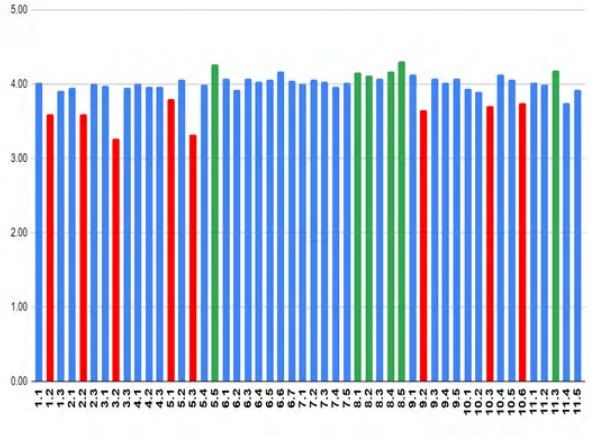

Figure 2. Average criterion - based scores of 700 programs evaluated with Circular 04/2016/TT-BGDĐT

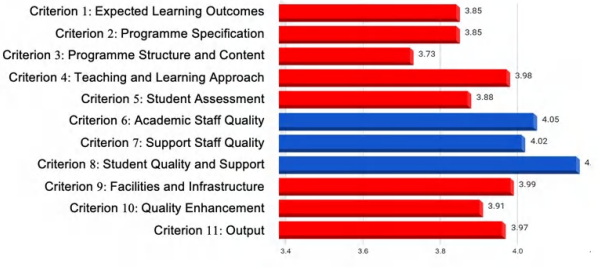

Figure 3. Criteria with more than 20% of the programs rated as "Unsatisfactory"

II. OUTCOME-BASED EDUCATION APPROACH

A. Terminologies

a) Learning outcomes

In the world, the concept of "learning outcome" (or student outcome, expected learning outcome) is defined quite abundantly. For Vietnam's higher education, the definition of this concept has also been developed over time. Some prominent definitions can be mentioned as follows:

- Outcomes are clear learning results that we want students to demonstrate at the end of significant learning experiences. They are not values, beliefs, attitudes, or psychological states of mind. Instead, outcomes are what learners can actually do with what they know and have learned – they are tangible application of what has been learned (Spady, 1994).
- Learning outcomes are the minimum requirements of knowledge, skills, level of autonomy and personal responsibility that learners achieve after completing a training program; committed by the educational institutions to learners, society and publicized together with the conditions to ensure its implementation (MOET, 2017).
- Learning outcomes are the minimum requirements to be achieved on the quality and capacity of learners after completing a training program, including the minimum requirements for knowledge, skills, level of autonomy and personal responsibility of learners (MOET, 2021).

The characteristics that need to be noted from the above definitions of learning outcome: minimum requirements; including knowledge, skills, level of autonomy and personal responsibility; demonstrating what learners can do after a learning process.

b) Outcome-based education (OBE)

OBE has been formed for a long time and is applied quite diversely in many countries and at all levels of education, therefore many definitions about OBE have also been established. The definitions cited below are commonly used when referring to this approach:

- Outcome-based education means clearly focusing and organizing everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences (Spady, 1994).
- Outcomes-based education is a learner-centered approach to education that focuses on what a student should be able to do in the real world upon completion of their course or program[1].

Two characteristics that need to be noted are reflected in the above definitions of OBE: focusing on what learners can do in reality, systematic suitability/response from the educational institution.

B. Basic principles and core features of OBE

a) Basic principles of OBE

The below basic principles of OBE are proposed by Spady (1994), who is considered

[1] https://obecurriculumsessions.wordpress.com/what-is-obe/

to have built the basic theoretical foundation for this approach:

- Clarity of focus, meaning that all activities (teaching, assessment, etc.) are geared towards what we want students to demonstrate;
- Expanded opportunity, meaning expanding the ways and numbers of times kids get a chance to learn and demonstrate a particular outcome;
- High expectations, meaning getting rid of the bell-curve and all students should achieve at the highest level;
- Design down, meaning designing the curriculum from the point at which you want students to end up.

b) Core features of OBE

Spady (1994) also summed up the core features for the OBE approach:

- All students can learn and succeed, but not on the same day in the same way.
- Success breeds success.
- Schools control the conditions of success.
- It emphasizes authentic, achievable and assessable learning outcomes.

C. OBE curriculum design

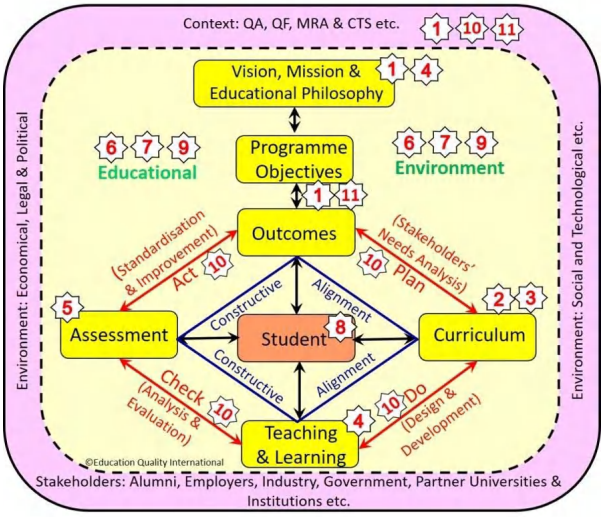

Figure 4. OBE curriculum design model[2]

Fig. 4 provides a model that can be used in developing curriculum and organizing teaching, learning and asessment activities based on learning outcomes. This model was developed by AUN-QA in order to connect with the program evaluation standards (version 3.0). Some key features of the model:

- The design and review of a curriculum should start with understanding the political, economic, social, technological, etc., which are taking place at the national and international level.
- It is necessary to base on the mission, vision, philosophy and educational goals of the institution to design the objectives and outcomes of the curriculum.
- Base on the learning outcomes of the program to design the teaching,

[2] http://johnsonongcheebin.blogspot.com/2018/03/an-integrated-aun-qa-and-obe-framework.html

learning and assessment activities which are suitable for the learner-centered approach and ensure constructive alignment with the outcomes.

– Each element in the model is associated with one or more program standards of AUN-QA's, version 3.0 (AUN-QA's version 4.0 has some changes but the relationship between the elements remains unchanged).

III. COMMON LIMITATIONS AND SOLUTIONS

The following limitations focus on the five criteria where more than 20% of the programs are assessed as "Unsatisfactory" listed in Table I. For each limitation, the author suggests related solution(s) so that institutions can refer for curriculum design and improvement.

A. Limitations related to program learning outcomes (Criterion 1.2)

a) Incompatible learning outcomes

The program learning outcomes (PLOs) need to be compatible with the objectives of the program (PEO), educational objectives (EO) and educational philosophy of the institution. In principle, as shown in Fig. 5 (Hao, L. V., 2023), PLOs should be developed based on PEOs and should fully satisfy these PEOs. Similarly, PEOs should be established based on EOs and should be fully responsive to EOs. Meanwhile, the institution's educational philosophy should be reflected in all EOs, PEOs, and PLOs.

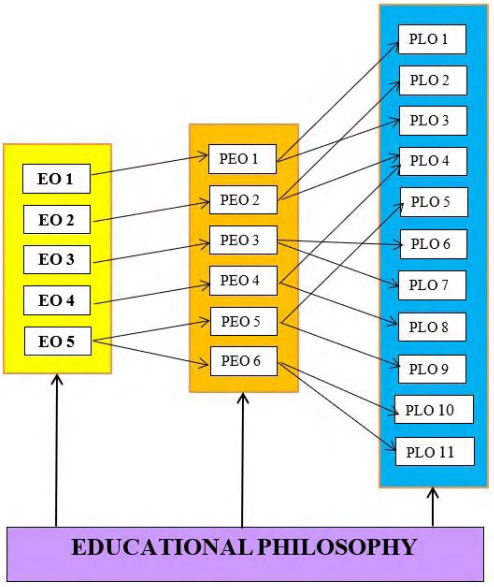

Figure 5. Compatibility among educational philosophy and EOs, PEOs, PLOs

b) Unmeasurable learning outcomes

Many institutions are currently establishing the PLOs in the form of generalized competencies. Each competency is an integration of related knowledge, skills, and attitudes. By limiting at this level, it is difficult to measure the level of achievement of the PLOs. Therefore, each PLO should be specified to some PIs (Performance Indicators) or PCs (Performance Criteria) (Figure 6).

– General note: It is recommended to use only one action verb expressing the highest possible level of competence for each PLO.

– For example, do not write PLO as: "Understand and apply PDCA principles in the design and operation of training programs" (just use the verb "**apply**").

– It is possible to use several action verbs for each PLO if they are not completely dependent on each other or independent in competence.

Example: "An ability to **design**, **implement**, and **evaluate** a computational system to meet desired needs within realistic constraints."

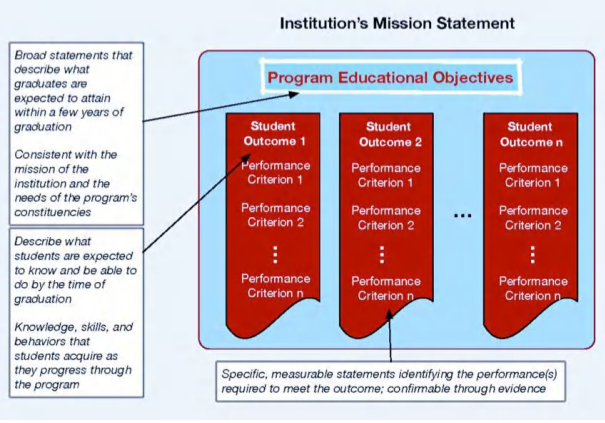

Figure 6. Requirements for objectives and learning outcomes, PIs/PCs

B. Limitations related to the development of the course outlines (Criterion 2.2)

a) Unclear "course outlines" concept

There are two concepts that are often less distinguished at Vietnamese universities: course outline and syllabus. "*A course outline gives the basic components of the course required to be taught by all instructors; whereas a syllabus describes how an individual instructor will teach that course in terms of specific assignments, dates, grading standards, and other rules of conduct required by that instructor. A syllabus can include methods and topics which go beyond the course outline*"[3]. Most institutions in Vietnam use one type of "course outline" ("Đề cương chi tiết học phần") that is mixed between the above concepts. To facilitate both academic management and teaching, these two concepts should be used simultaneously. In that case, the course outline of the subjects is considered as a required document in the profile of the program, and the syllabus needs to be updated (with references, teaching activities, assignments, etc.) by the lecturer for each class and shared to the learners.

b) Insufficient course outline content

The content of course outline as described in the Guidelines 1669 (Quality Management Department, 2016) includes the following items: name of unit/teacher in charge of the course; course title; number of credits; objectives, course learning outcomes (CLOs), matrix linking the contents of the chapters with the CLOs; course requirements; course structure; teaching methods; assessment methods; main documents and references. The majority of cases that do not meet Criterion 2.2 are due to the lack of one or more of the items mentioned above. To achieve a good level (above 4) for this criterion, the course outline needs to have more information such as: the matrix linking CLOs with the PLOs, rubrics used to assess learning.

C. Limitations related to the role of courses in the curriculum (Criterion 3.2)

a) Unreasonable program's skill matrix

A program's skill matrix can describe the contributions of all courses and educational activities within a program in fulfilling the PLOs.

[3] https://www.skylinecollege.edu/curriculumcommittee/assets/documents/Guidelines%20for%20Writing%20the%20COR%20Sept%20%202016.pdf

The majority of cases that do not meet Criterion 3.2 are due to the fact that the program's skill matrix does not clearly and reasonably show the role of the courses and educational activities in contributing to the achievement of the PLOs. Some common limitations should be avoided are as follows:

- Some courses contribute to most of the PLOs.
- Some courses contribute to many PLOs at high level (such as Mastered)
- Some PLOs have no course contribution at low level (such as Introduced) but only at medium level (such as Reinforced) and/or high level.
- Some PLOs don't have any course contributing at high level.
- Many educational activities which can contribute to PLOs are neglected in the matrix.

b) Incompatibility between CLOs and PLOs

A program's skill matrix can be considered reasonable when viewed as a whole. However, when considering about CLOs, it is possible to realize the incompatibility between these CLOs and the PLOs. Therefore, each course outline should have a compatibility matrix between the CLOs and the PLOs to help check and clarify this compatibility.

D. Limitations related to the design of methods to assess learning (Criterion 5.1)

a) Lacking of guidelines for assessment methods/tools

Regarding the assessment of learning, most institutions only develop rules and regulations on examination without necessary instructions for teachers or departments on which methods of assessment to match the targeted CLOs or PLOs. Therefore, each institution should develop or use appropriate documents as official guidelines for the design and use of learning assessment methods together with rules/regulations in order to supervise and support this activity.

b) Lacking of measuring learning outcome achievement

One of the requirements of Criterion 5.1 is "the activities/methods of learning assessment are appropriately designed to measure the level of achievement of the learning outcomes", which relates both to the course and the program. To be able to satisfy this criterion in the current period, at least the institution needs to have an appropriate method to measure the level of achievement of the CLOs. Besides, solutions for measuring PLO achievement should be soon regarded. These measurements should be conducted by both direct (based on tests and exams) and indirect (based on learners' self-assessment results or workplace evaluation) methods so that there can be a correlational comparison.

E. Limitations related to requirements for learning assessment methods (Criterion 5.3)

a) Undiversified assessment methods

Many institutions only allow the use of a limited number of learning assessment methods/techniques such as: objective test, essay, oral. The limitation of assessment methods leads to the inability to evaluate some skills or creative capacity. Therefore, institutions should allow the expansion of other learning assessment methods/techniques such as assessment based

on problem/case solving, projects, creative products, etc.

b) Not ensuring validity and reliability of assessment methods

The validity of an assessment is related to the degree of agreement between assessment contents and the objectives/outcomes to be evaluated, while the reliability of the assessment is referred to the stability of the evaluation results based on the different methods/ techniques or assessors. An optimal solution to these requirements is to design a rubric for each assessment activity, in which rubric's criteria are built closely to the objectives/ outcomes of the activity or of the course being evaluated. Together, the contents describing the quality levels of rubrics should be concise, clear, distinguishable and easy to measure for accurate grading.

IV. CONCLUSION

The above are the common limitations of the curricula when compared with the requirements of the criteria from 1 to 5 in Circular 04/2016/TT-BGDĐT. The solutions proposed by the author are basic and can be applied in popular. Depending on the actual situation of each institution and program, the institution needs to select and supplement appropriate solutions to properly overcome its limitations and improve the quality and effectiveness of the programs.

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GENERAL EDUCATION FRAMEWORK IN THE US: IMPLICATIONS FOR EASTERN INTERNATIONAL UNIVERSITY[❁]

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Abstract: General Education has long been recognized as an integral component of the undergraduate academic experience at colleges and universities in the United States. Through the General Education curriculum, students have access to broad foundational knowledge across multiple disciplines and gain core skills that are essential not only to their respective majors but also for later success in their professional lives. In this article, the authors study the frameworks for the General Education Program of higher education institutions in the United States and draw conclusions on key implications for the development of a new General Education framework at Eastern International University, Vietnam.

Keywords: *General education, higher education, curriculum development*

I. INTRODUCTION

A. The history of General Education in the US

General Education is considered an essential component of the undergraduate curriculum at most American universities and colleges. The earliest writing which attempted to define general education in higher education can be traced back to the Yale Report of 1828 which stated that "education should aim not only to teach a specific subject, but also to provide a broad understanding of everything related to life" and that students should not be limited to one subject in order to expand the human mind (Zai, 2015). The emergence of general education is also considered a response to the changing needs of society to move from the Europe-originated classical liberal education to become a more practical and selective "liberal studies" that are often seen today at liberal arts college across the US. Thus, General education can be seen as a balance between classical liberal education and practical, vocational training as it values classical education (often focusing on classic literary works, philosophy, foreign languages, rhetoric, and logic) but also provides students with much-needed utilitarian education that prepares them for the workforce (State University).

In 1945, the need for general education at college level was once again discussed in the Harvard Committee Report. In the report, the committee pointed out that "specialism is the means for advancement of our mobile social structure; yet we must envisage the fact that a society controlled wholly by specialists is not a wisely ordered society" (Jenkins, 1947). It was also in this report that the Harvard General Education program which consisted of three main areas of knowledge (natural science,

[❁] Best oral presentation award - Lecturer session

social studies, humanities) was first proposed and later adopted by universities across the country. Since then, General Education has become widely implemented in the curriculum of colleges and universities, albeit in different models and formats.

B. The current state of General Education in the US

In the 2023 Survey of College and University Chief Academic Officers published by Inside Higher Ed and Hanover Research which interviewed 347 provosts of public, private nonprofit and for-profit US institutions, around 95% responded that they somewhat agree or strongly agree that "general education is a crucial part of any college degree" (Jaschik & Ledermanm, 2023). However, since its origin from the 19th century, general education has become a "vastly diverse, institutionally specific endeavor" (Zai, 2015). Each institution has a different approach in designing and implementing their gen-ed program.

In addition, general education programs at US universities are continuously being revised and reformed in order to keep up with rapid changes in society needs and employer requirements. For instance, many universities form general education task-forces in charge of conducting periodical reviews and make recommendations on how to improve their current general education programs. This highlights the fact that general education remains as a key area of the undergraduate curriculum that require a lot of research and investment from higher education institutions. However, according to a report conducted by the American Council of Trustees and Alumni, it is rare to find a "coherent, cohesive, and rigorous general education" (2020).

C. General Education: The EIU Context

Despite its clear popularity in the States, General Education Program remains quite a new concept within the Vietnamese higher education system. For the majority of Vietnamese universities, "general education" is the part of the curriculum that consists of compulsory courses mandated by the Vietnamese Ministry of Education such as Marxism-Leninism Philosophy, Ho Chi Minh Ideology, History of the Communist party, etc.… After finishing these compulsory courses, students go straight into the foundational courses of their university major. Thus, there are not many opportunities for interdisciplinary learning during the university experience. This is an issue that need to be address if universities in Vietnam wish to have more well-rounded graduates who are capable of meeting the everchanging requirements from employers.

Eastern International University (EIU) is a corporate-founded university based in Binh Duong New City. EIU is considered to be the region's top university in with excellent facilities and high-quality teaching and learning. The university is committed to providing "high-quality experiential education, delivering excellent interdisciplinary research, and focusing on business and community engagement". In 2023, EIU programs have been undergoing a periodical curriculum review with a long-term goal of developing programs that can meet the requirements of international accreditations (ABET, AACSB, etc.). In order to satisfy the accreditation requirements and following innovative practices from top universities around the world, establishing a concrete General Education framework is crucial. The Office of Academic Affairs at EIU is tasked with the responsibility of developing

a brand-new framework for General Education that will be implemented university-wide in the following academic year.

II. METHODOLOGY

The process of developing the General Education framework at EIU can be separated into three main stages.

A. Reviewing graduate competencies required by International Associations

In order to develop a comprehensive general education framework, it is necessary to look at what knowledge and skills employers seek for in new graduates. During this process, the authors focus on International Associations with clear graduate competences/ learning outcome requirements for graduates and compare those to the Graduate Attributes of Eastern International University (See Appendix 1).

As demonstrated by the different highlighted colors in the table, it is clear that there are common skills that are required by the associations such as digital literacy, quantitative literacy, civic competence, ... Thus, it is important that the General Education framework being developed at Eastern International University can encapsulate the above key skills that are highly valued by employers.

B. Benchmarking the General Education program of top universities around the world

After determining the key skills that need to be addressed by the General Education framework at EIU, the authors started the process of researching and benchmarking general education programs of international universities to understand more about the model and structure of gen-ed each university applies. During this process, the criteria used for choosing the universities are that:

A. The universities must have a well-established General Education program.

B. The universities must offer similar programs to those of Eastern International University

C. Said programs are accredited by International Accreditation standards such as ABET or AACSB.

Originally, the authors benchmarked the General education program of 15 universities in the United States, Hong Kong and Singapore. Later on, it was narrowed down to 7 universities in the United States as follows:

1. Portland State University
2. Ohio State University
3. Virginia Commonwealth University
4. Colorado State University
5. University of Maryland
6. Pennsylvania State University
7. Purdue University

For these universities, the authors mainly focus on their university-wide requirements for their General Education Program while keeping in mind that these requirements may vary for different majors within each university.

C. Determining the objectives of the General Education framework at Eastern International University

It is important to have clear and defined objectives and learning outcomes for the General Education component of the curriculum. In

a 2015 report conducted by Hart Research for the American Association of Colleges and Universities, 76% of member institutions interviewed described their General Education program as having "clear learning outcomes" and "assess student achievement of learning outcomes". Furthermore, each knowledge area of the general education framework should have its own objectives and outcomes (if applicable) that tie closely into the overall objectives of the programs. After reviewing gen-ed program objectives of different US universities, the authors propose the below General Education objectives for Eastern International University.

EIU General Education Objectives

The General Education framework at Eastern International University is developed based on the university's educational objectives with an aim to provide learners with foundational breadth of knowledge across multiple disciplines and essential skills. General Education courses help learners develop core competencies to support life-long learning and growth as well as becoming responsible citizens of the State and the society.

III. RESULTS

Key findings

Based on results from the benchmarking process and further research, key findings are as follows:

1. While the specifics may vary, these universities typically require general education courses that make up around 25% to 33% of the undergraduate curriculum. This percentage is the minimum requirements for general education and the exact percentage are often decided by Schools/Departments for each major.

2. There are common areas of knowledge that appear in the benchmarked universities (as demonstrated in Appendix 2):

- Social Sciences
- Natural Sciences
- Quantitative Reasoning
- Communicative fluency
- Information literacy
- Arts and Humanities

However, it is important to note that different institutions will define and interpret each area of knowledge in different ways.

3. Most universities the authors benchmarked employ a "distribution model" for their general education program except Portland State University with a more unique "theme-based" model. Distribution model is considered one of the most commonly used general education model in the US. It is seen as a "cafeteria-stye" model that allows students to pick and choose from a "menu" of approved courses in required areas of knowledge to meet the minimum general education requirements. These courses are managed by their own Schools/Departments and typically every course in the catalog will satisfy at least one general education distribution requirement. In recent years however, many critics have pointed out the flaws that come with the distribution model. For instance, these requirements don't necessarily encourage student to be thoughtful in choosing what they study as many will simply look for the easiest courses to check the requirements off - Think "physics for poets" (Jaschik, 2016). Keeping this in mind, the proposed General Education framework for Eastern International University will have specific requirements within each area of

knowledge to ensure in-depth inquiry within the selected areas of the general education curriculum and more thoughtful integration of different fields of study while still allowing our students to choose courses that will be required for progress within their major.

IV. CONCLUSION

Based on previous findings, the authors have proposed a framework for General Education at Eastern International University (See Appendix 3 for details).

The framework will consist of the following 6 main areas of knowledge:

1. Political theory and laws

2. Social & Behavioral Sciences

3. Natural Sciences & Quantitative reasoning

4. Communications, Arts & Humanities

5. Digital Literacy

6. University studies

Each of the above area of knowledge will equip EIU students with skills and knowledge that can prepare them for a journey of lifelong learning even after their graduation.

Above is the overall General Education framework at Eastern International University. For the next step, Eastern International University will form a General Education committee to oversee the development and implementation of the General Education framework. During this process, the Office of Academic Affairs will be working closely with Schools' leaders and lecturers to successfully implement the new General Education framework at EIU.

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APPENDIXES

Appendix 1. International Associations graduates competencies/learning outcome

European Commission's Recommendation on key competences for lifelong learning	American Association of Colleges and Universities' Essential Learning Outcomes	ASEAN Qualifications Reference Framework	EIU Graduate Attributes
1. Literacy competence 2. Multilingual competence 3. Mathematical competence and competence in science, technology and engineering 4. Digital competence 5. Personal, social and learning to learn competence 6. Civic competence 7. Entrepreneurship competence 8. Cultural awareness and expression competence	1. Knowledge of Human Cultures and the Physical and Natural World - Through study in the sciences and mathematics, social sciences, humanities, histories, languages, and the arts 2. Intellectual and Practical Skills, Including - Inquiry and analysis - Critical and creative thinking - Written and oral communication - Quantitative literacy - Information literacy - Teamwork and problem solving 3. Personal and Social Responsibility, Including - Civic knowledge and engagement—local and global - Intercultural knowledge and competence - Ethical reasoning and action	**Knowledge and Skills:** Demonstration of knowledge and skills that: - is at the forefront of a field and show mastery of a body of knowledge - involve critical and independent thinking as the basis for research to extend or redefine knowledge or practice **Application and Responsibility:** The contexts in which knowledge and skills are demonstrated: - are complex and changing - require initiative and adaptability as well as strategies to improve activities and to solve complex and abstract issues	Education and training activities at Eastern International University are aimed at developing graduates with: 1. Sense of self-responsibility towards their family, community and country; sense of professional ethics (Self-awareness and Professional Ethics). 2 In-depth, practical and comprehensive knowledge and skills in their specialization; Basic knowledge of natural sciences, social sciences and politics. (Knowledge). 3. Ability to communicate, collaborate in groups, use foreign languages effectively, integrate and adapt to career requirements in the context of globalization. (Communication and Integration). 4 Critical thinking, innovation and creativity mindset, and problem-solving capability. (Critical Thinking and Problem Solving).

European Commission's Recommendation on key competences for lifelong learning	American Association of Colleges and Universities' Essential Learning Outcomes	ASEAN Qualifications Reference Framework	EIU Graduate Attributes
	- Foundations and skills for lifelong learning Anchored through active involvement with diverse communities and real-world challenges. 4. Integrative and Applied Learning, Including - Synthesis and advanced accomplishment across general and specialized studies Demonstrated through the application of knowledge, skills, and responsibilities to new settings and complex problems.		5. Ability to self-study, self-research and apply science – technology in the digital age. (Lifelong Learning). 6 Ability to organize, lead, improve the quality of work and the entrepreneurship spirit (Leadership and Entrepreneurship).

Appendix 2. General Education program of benchmarked US universities

University	General Education program components
Portland State University (PSU) **(Quarter-system)**	**1. Freshman Inquiry themes (15 credits)** - Design & Society - Health, happiness & human rights - Human/Nature - Immigration, Migration & Belonging - Life unlimited? - Portland - Power & Imagination - Race & Social Justice - Sustainability - What are great books? - The work of art

University	General Education program components
Portland State University (PSU) **(Quarter-system)**	**2. Sophomore Inquiry (12 credits) – select 3 courses** - American Identities - Understanding Communities - Design Thinking - Environmental Sustainability - Families and Society - Gender and Sexualities Studies - Global Environmental Change - Global Perspectives - Healthy People/Healthy Places - Interpreting the Past - Knowledge, Values, Rationality - Leading Social Change - Examining Popular Culture - Natural Science Inquiry **3. Upper Division Cluster (12 credits)** - Science in Social Context Cluster - Community Studies Cluster **4. Senior Capstone (6 credits)** 4 Learning objectives: - Communication - Inquiry and Critical Thinking - Diversity, equity and social justice - Ethics, agency and community
Ohio State University (OSU) **(Semester system)**	**1. Bookend courses** - Launch and Reflection seminar **2. Foundation courses (22-25 hours)** - Race, ethnicity and gender diversity - Social and Behavioral Sciences - Historical and Cultural Studies - Writing and Information Literacy - Literary, Visual and Performing Arts - Natural Sciences - Mathematical and Quantitative Reasoning

University	General Education program components
Ohio State University (OSU) **(Semester system)**	**3. Theme courses (8-12 hours)** - Citizenship for a Diverse and Just World Theme (required) - Lived Environments - Migration, Mobility, Immobility - Number, Nature, Mind - Origins and Evolution - Sustainability - Traditions, Cultures, and Transformations - Health and Well-being
Virginia Commonwealth University (VCU) **(Semester system)**	**A. Foundations of Learning (12-13 credits)** - Communicative fluency - Ethical reasoning - Global and cultural responsiveness - Information literacy - Problem solving - Quantitative literacy **B. Areas of Inquiry (17-18 credits)** 1. Diversities in the Human Experience 2. Creativity, Innovation, and Aesthetic Inquiry 3. Global Perspectives 4. Scientific and Logical Reasoning **C. Breadth of knowledge (9 credits included in Areas of Inquiry)** - Humanities and fine arts - Natural sciences - Social behavior sciences
Colorado State University (CSU) **(Semester system)**	**I. Fundamental Competencies (12 credits)** Category 1A. Intermediate Writing (3 credits) Category 1B. Quantitative Reasoning (3 credits) Category 1C. Diversity, Equity, and Inclusion (3 Credits) Category 2. Advanced Writing (3 credits) **II. Foundations and Perspectives (19 credits)** Category 3A. Biological and Physical Sciences (7 credits) Category 3B. Arts and Humanities (6 credits) Category 3C. Social and Behavioral Sciences (3 credits) Category 3D. Historical Perspectives (3 credits) **III. Depth, Application, and Integration (5 credits)** 4A. Applying Fundamental Competencies 4B. Integrating Foundations and Perspectives 4C. Capstone Experience

University	General Education program components
University of Maryland (UM) (Semester system)	**I. Fundamental Studies (15 credits - 5 courses)** - Academic Writing - Professional Writing - Oral Communication - Math - Analytic Reasoning **II. Distributive Studies (25 credits - 8 courses)** Natural Sciences - 7 credits History and Social Sciences - 6 credits Humanities - 6 credits Scholarship in practice - 6 credits **III. I-Series (6 credits - 2 courses): Investigate a significant issue in depth – integrated with Distributive studies** **IV. Diversity (4 to 6 credits - 2 courses)** 2 Understanding Plural Societies courses or 1 Understanding Plural Societies course AND 1 Cultural Competence course
Purdue University (Purdue) (Semester system)	**I. Foundation learning outcomes (university-wide)** 1. Written communication **(3 credits)** 2. Information literacy **(3 credits)** 3. Oral communication **(3 credits)** 4. Science, Technology and Society **(9 credits)** 5. Mathematics/ Quantitative reasoning **(3 credits)** 6. Human cultures **(6 credits)** • Humanities • Behavioral and Social sciences **II. Embedded learning outcomes (discipline-specific)** 1. Communication 2. Ways of thinking 3. Interpersonal skills and intercultural knowledge
Pennsylvania State University (PennState) (Semester system)	**Foundations (15 credits)** - Writing/Speaking (9 credits) - Quantification (6 credits) **Knowledge domain (30 credits)** - Health and Wellness (3 credits) - Natural Science (6 credits) - Arts (6 credits) - Humanities (6 credits) - Social and Behavioral Sciences (6 credits) **Additional University requirements** First-Year Engagement; United States Cultures; International Cultures; Writing Across the Curriculum

Appendix 3. Proposed General Education framework at Eastern International University

Component	Credits	Objectives
Political theory and laws	Minimum 12 credits	*The Political theory and laws area of knowledge introduce learners to the basic topics of politics and law. These topics provide learners with political qualities, ethical values and an understanding of the law and their basic civil rights and civic duties in order to become responsible citizens of the society.*
Social & Behavioral Sciences	Minimum 4 credits	*The Social & Behavioral Sciences area of knowledge introduces learners to principles of social sciences, economics, business, psychology, and the human behavior. Learners can apply what they have learnt to come up with solutions that address a wide range of issues faced by modern society.*
Natural Sciences & Quantitative reasoning	Minimum 4 credits	*The Natural Sciences and Quantitative reasoning area of knowledge helps learners build a solid foundation in math, chemistry, physics and familiarize themselves with scientific research methods to better understand, interpret, and evaluate the impact of natural sciences on the society. Quantitative reasoning skills equip learners with knowledge of quantitative methods, statistics, data collection, analysis and evaluation to develop critical and analytical thinking in learning and during daily lives.*
Communications, Arts & Humanities	Minimum 4 credits	*Communications area of knowledge help learners communicate information in oral, written and visual forms in both social and professional settings.* *Arts area of knowledge help learners develop the capacities for aesthetic understanding, creative thinking and artistic sensibility.* *Humanities area of knowledge help learners gain an understanding of ethical, historical, religious issues, etc.*
Digital Literacy	Minimum 4 credits	*The Digital Literacy area of knowledge provides learners with basic information technology skills to effectively use devices and software to access and explore available data and information.* *In addition, this area of knowledge helps learners find, evaluate and use information in a manner that can support both professional work and lifelong development.*
University studies	Minimum 4 credits	*University studies introduce students to a variety of thought-provoking topics from a wide range of different disciplines to provide students with new perspectives that go beyond what they learn in their respective major. Students are inspired to think critically and make deeper comprehension and self-judgement about different issues in an increasingly complex and interconnected world.*
Total	**Minimum 52 credits**	

ACCELERATING DIGITAL TRANSFORMATION IN CONSTRUCTION AND QUALITY ASSURANCE SYSTEM OPERATION WITHIN A UNIVERSITY: A CASE STUDY AT EASTERN INTERNATIONAL UNIVERSITY

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Abstract: Digital transformation is an inevitable trend aimed at enhancing the quality of academic activities and creating opportunities for strong autonomous university development, as well as establishing breakthrough mechanisms to attract and maximize diverse investment resources from organizations, individuals, businesses, and society. This process requires educational institutions to enhance scientific and technological investments, apply digital technologies and solutions to improve management processes, and ensure quality throughout operations and development. Information systems serve as specialized quality assurance tools to effectively support the digital transformation efforts in construction and the operation of quality assurance systems within the university. This article focuses on elucidating the role of information systems in ensuring quality in higher education institutions, while also highlighting the current situation and proposing solutions to enhance the quality of information systems in the context of the digital transformation era.

Keywords: *digital transformation, 4.0 revolution, information system, internal quality assurance, university*

I. INTRODUCTION

In the context of the ongoing robust Industrial Revolution 4.0 across all sectors, the trend of digital transformation has become an essential component in the developmental trajectory of higher education institutions (Alenezi, 2023). Digital transformation entails a profound overhaul of business activities, organizations, processes, competencies, and models to fully leverage the potential of a technology blend and its rapid societal impact. This strategic and prioritized approach aims to maximize the benefits of various technological changes and opportunities (Gobble, 2018). In light of this trend, the Internal Quality Assurance system is perceived as a potent support tool for enhancing and elevating the overall quality of the institution's operations. Additionally, it meets the requirements from governing bodies and ensures the autonomy and accountability of the educational establishment. Hence, the imperative to bolster the application of technology and techniques in the functioning of the Internal Quality Assurance system within the institution is paramount (Hidayah & Syahrani, 2022).

According to the network of leading universities in the Southeast Asia region (2023), the information system is one of the specialized tools to ensure the quality of education and support effective self-assessment and accreditation activities. Simultaneously, it provides accurate and timely information for carrying out specialized activities, professional tasks, and decision-making support. Recognizing the importance of digital transformation through the establishment of a quality assurance information system, the Eastern International University (EIU) has implemented an internal information management system to support the collection, processing, reporting, and exchange of information across the university's units.

The EIU's system is built on an information technology platform, which enables effective and easy access, exploitation, utilization, and relatively synchronized deployment of quality assurance information within the units. However, the separate management software for different aspects of university operations, such as training, scientific research, and community service, has resulted in certain difficulties and limitations in data usage and exchange. In this article, the author team clarifies the role of the quality assurance information system during the digital transformation period and the current state of the internal quality assurance information system at EIU.

II. METHODOLOGY

The author team utilized a combination of literature review methods (Fraenkel, Wallen & Hyun, 2012) and educational activity research (Gast & Ledford, 2014) in this study:

(1) The literature review method was carried out by collecting, studying, and analyzing theoretical documents and research outcomes from domestic and international research works, scientific papers, conference proceedings, articles on various websites, and other relevant sources related to the research topic. This approach aimed to gain an overall understanding of the research landscape regarding the internal quality assurance information system in universities and establish a theoretical foundation for the study.

(2) The educational activity research method involved data synthesis and analysis of various educational products such as academic year-end reports, self-assessment reports, meeting minutes, management software, processes, and other relevant materials. This method aimed to provide further clarity and insight into the research findings.

III. RESULTS

A. Role of the quality assurance information system

- Information System: Le and Hai (2014) define the information system as a collection of components (information, information processing methods, people, and media) organized to gather, process, store, and utilize information to support decision-making and control within an organization.

Ensuring educational quality: This is an ongoing activity conducted in educational institutions to continuously improve the quality of education, aiming to meet the increasing demands of the labor market and various stakeholders while ensuring the institution's existence and development. According to the Southeast Asian University Network (2015), an

internal quality assurance system is "the overall systems, resources, and information dedicated to establishing, maintaining, and enhancing the quality and standards of teaching, learning, research, and community service. It is a system in which managers and staff are satisfied with the control mechanisms in place to maintain and improve the quality of higher education".

The Ministry of Home Affairs of The Socialist Republic of Vietnam (2018) has defined the information system with five fundamental components as follows:

Humans: This includes users and experts in information systems. Users or customers are individuals directly using the information system and the information products it generates. Information system experts are the ones who build and operate the information system, such as system analysts, programmers, and computer engineers.

Hardware: This includes all devices and technical means used to process information. It mainly consists of computers, peripheral devices used for data storage and input/output, and telecommunications networks used for data transmission.

Software: This includes computer programs, system software, specialized software, and procedures for users.

Data Sources: Data is the raw material of the information system. Data can come in various forms, such as text data, image data, audio data, etc.

Procedures: This involves elements like operational processes, human-machine communication procedures, and the data sources of the information system.

From the perspectives mentioned above, the author asserts that an information system ensures internal quality and comprises a set of elements: humans, hardware devices, software, and data, all serving the activities of individuals and organizations in collecting, processing, storing, distributing, and representing information trends. This system assists in decision-making to improve the quality of management at various levels, supports effective self-assessment and external evaluation of educational quality, and provides specific feedback on educational activities to relevant stakeholders.

Nguyen (2010) mentioned the role of an information system in ensuring internal quality as follows:

Providing essential solutions in the overall development strategy of the organization.

Meeting the new management requirements, leading to the necessity of developing a new information system project to fulfill the demands of the Government, governing agencies, organizations, and units.

The emergence of new technologies and new database management systems prompts many organizations to review their information systems to update and align them with the appropriate information system.

The information system plays a crucial role in enhancing information assurance capabilities in universities and has a positive impact on education and scientific research. It also serves as a measure to evaluate the effectiveness of educational activities in universities (Do, 2016).

The role of the internal quality assurance information system, as defined by Nguyen,

Nguyen & Doan (2020), can be summarized as follows:

- To take responsibility for all matters related to documents, information, evidence, and statistics of the university;
- To ensure that documents, information, evidence, and statistics within functional units and the university are maintained and managed correctly;
- To ensure that statistical data is analyzed, documented, and disseminated to facilitate evidence-based decision-making mechanisms for the university.

The general roles of the information system in ensuring internal quality at universities are as follows:

- Serving the needs of various stakeholders such as officials, lecturers, staff, students, parents, employers, governing bodies, etc.;
- Supporting decision-making processes of management levels;
- Assisting in specialized and professional activities;
- Addressing weaknesses in management, especially in educational decision-making;
- Providing specific feedback from relevant parties.

Prerequisites for implementing digital transformation in the functioning of an internal quality assurance information system (Quan Vu, 2021) are as follows: (1) A requisite ability to embrace swift changes and embrace alterations, transitioning from established routines to operational procedures; (2) Fundamental technological proficiency expected from administrators, educators, and students; (3) Enhancement of technology infrastructure, encompassing network and computing systems, equipment, along with teaching and learning software.

B. The current state of the quality assurance information system within EIU

EIU's internal quality assurance information system comprises three primary information domains: educational data, scientific research data, and community service data (EIU, 2019 & 2022).

Regarding personnel, the University establishes an organizational structure and staffing for internal quality assurance endeavors, aiming to maintain coherence with the University's developmental guidelines and directions. This is accomplished through collaboration with the quality assurance team, which offers insights and guidance, the Quality Assurance Department, and the unit-level Quality Assurance Teams.

The University vice President assumes the responsibility of overseeing the execution of quality assurance activities, ensuring the attainment of predetermined strategic objectives.

The Information Technology Department is segmented into three specialized teams: The Technical Team, the Application Deployment Team, and the Network Infrastructure and Server System Team. These teams are tasked with the efficient management, operation, and deployment of applications. In doing so, the information technology system is promptly repaired, maintained, and updated, thereby supporting instructional and research activities and guaranteeing the continuous and seamless functioning of the system.

Hardware, the institution has directed its focus towards investing in and efficiently utilizing the information technology system for school management. This is achieved through robustly enhancing the application and growth of the information system, thereby guaranteeing the transparency and security of this system. The school places an emphasis on upholding the security of its information technology and data system. Routine examination plans and upgrade strategies for the information infrastructure are formulated to ensure that information transmission, processing, and storage are executed optimally.

A high-speed WiFi network system envelops the entire school, effectively supporting educational and administrative operations. Nonetheless, certain office computers, having been in use for an extended period, possess low configurations that no longer suffice to meet the operational requisites of faculty and staff members.

Sotfware, the institution has made investments in computer hardware and licensed software, including applications such as Edusoft Training Management Software, FAST Financial Management Software, Libol 6.0 Software, and Emiclib Library Management software. Additionally, the school has independently developed software to aid in the management, evaluation, and retrieval of training-related information. Examples include MoodleEIU, Learning Advisor Support Management Software, online admission examination software, and the EIU mobile application. These software tools are distributed to cater to specific user groups, such as administrators and users. The school provides Portal Office accounts and email addresses for all officials, lecturers, and specialists to facilitate logins for monitoring and task tracking. Periodic reviews and updates are conducted to enhance user-friendliness and efficacy, thereby optimizing management tasks with precise data storage and accessible information retrieval.

The institution utilizes management software to establish an internal quality assurance information management system from an early stage. However, the current software setup remains fragmented and lacks integration, resulting in information and data only supporting partial aspects of university operations. Consequently, comprehensive support for decision-making is yet to be fully realized.

Procedure, the school has established numerous guidelines concerning the gathering and retention of data and information across its premises. These encompass regulations focused on bolstering the security and integrity of information systems, procedures for ensuring the safety of data, and protocols for data backup. Additionally, comprehensive instructions have been provided for the adept utilization of software and databases. These measures are in place to effectively assist students and departments within the University in proficiently navigating information technology systems, all while upholding the paramount principles of information security and confidentiality.

The dissemination of knowledge regarding software manipulation has been facilitated through easily accessible editing manuals. Furthermore, the University has undertaken the initiative of organizing training sessions, which cover the use of applications and the intricacies of manipulating new software. A notable milestone achieved in 2023 involves

the establishment of dedicated database frameworks tailored to various fields of operation and advancement. These frameworks prove invaluable as units within the University embark on data collection endeavors.

Database resource, the school has established a diverse internal quality assurance information management system, ensuring the timely receipt, processing, reporting and transfer of information to stakeholders, ensuring consistency, confidentiality and data security.

Collecting, processing and periodically reporting information from functional units about the school's general activities and quality assurance activities are strictly implemented in accordance with regulations and guidelines. implementation, ensuring the truthfulness and objectivity of information and timely reports of units such as year-end reports, enrollment reports, academic reports, etc.

Data is collected through various channels, such as: meetings, written announcements, regular reporting activities, face-to-face interactions, personal emails, etc.

Data is obtained through extraction from management software for analysis and reporting by the School Board.

The data collected through surveying relevant parties helps establish a foundation for improvement efforts.

According to research based on the reports of the School, it is evident that the databases of the units within the institution are relatively comprehensive and regularly collected as per regulations. However, there is a lack of systematic and centralized storage, as well as limited data connectivity between the units.

IV. CONCLUSION AND RECOMMENDATION

The study indicates that the development of the internal information system quality at EIU is receiving significant attention and investment, meeting the requirements of the digital transformation landscape. In summary, enhancing the internal information system's quality within EIU is a crucial priority. However, to achieve maximum efficiency, the institution needs to focus on reviewing and upgrading its infrastructure, developing information system management software, and integrating existing management software. Simultaneously, establishing a core set of KPIs will aid in evaluating and optimizing the institution's activities.

Review and upgrade of equipment: To ensure system reliability and performance, regular review and upgrading of equipment are essential. This helps maintain system stability, ensuring it operates smoothly and meets the growing demands of the institution.

Development of information system management software: The development and enhancement of management software that supports administrative, teaching, and research activities at the institution are pivotal points. This helps optimize workflow and enhances the efficiency of staff and faculty members.

Integration of existing management software: To ensure effective data collection and analysis, it is necessary to establish a roadmap for integrating existing management software into a unified management system. This facilitates the uniform collection and analysis of information, thereby supporting prompt and accurate management decisions.

Establishing core KPIs: To evaluate the effectiveness and progress of the institution's activities, building a set of core Key Performance Indicators (KPIs) is essential. KPIs measure the attainment level of strategic objectives and provide crucial information for the institution's strategic decision-making.

The results obtained are quite similar to the study "IT as a Tool: Quality Assurance System in Higher Education" by Jayanti and Sarja (2019). This study highlights that both information technology and human factors are crucial in implementing a quality assurance system. The application of information technology plays a significant role as a tool to acquire data for decision-making accurately and promptly. However, the implementation of quality assurance in higher education hasn't fully maximized the potential of information technology as a supportive tool.

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THE ACTIVITIES OF DEVELOPING HUMAN RESOURCES AT PRIVATE HIGHER EDUCATION INSTITUTIONS: OVERVIEW, REALITY AND SOLUTION

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Abstract: People have a pivotal role in achieving an institution's goals. The foundation upon which organizational success is created and preserved is the strategic management of human resources. The organization has headhunted the suitable one to match the needs for today, also strategy in the future. Higher education human resources play a crucial strategic role in influencing the organizational environment of private higher education institutions, which are not an exception. In this article the role and function of human resources management are defined through the basis of the overview and the reality of human resources activities at private universities. Moreover, the private universities are also recommended how to enhance their employment, retain the talent and operate education mechanism.

Keywords: *Human resources, human resources development, private higher education institution*

I. INTRODUCTION

The role of the HRM department, formerly known as personnel management, has likewise evolved significantly since its inception (Wright, 2017). The term "industry 4.0" initially came out in 2011 at a fair in Hannover (Germany), where a strategic government-led program aiming at facilitating the transition to smart manufacturing technology was introduced (Lasi, 2014). In terms of HRM system changes in the smart convergence of cyber-physical stages, recruiting and selection practices are two examples of HR processes that are undergoing significant transformations as a result of the spread of social media and advances in artificial intelligence. These modifications allow for a significant advancement in résumé screening, as well as the use of intelligent machines to execute part of the selection process. People analytics, which allows for the prediction of employee behaviors and decisions such as intention to quit or organizational commitment, is an archetypal example of modern HR tools supported by new technologies. Thus, the introduction of new HR tools or the modification of existing HR processes is the first influence of Industry 4.0 on HR (Van Esch, 2019).

The efficient use of human resources is crucial in a sector as labor-intensive as higher education. This essay was created to ascertain whether universities engage in strategic human resources management (Bowen, 2003). One of the most difficult challenges that university administrations face today is ensuring that the right faculty are in the right place at the right time. Through human capital plan, they should

forecast the needs of the talent to avoid human capital shortages in the following days. Without proper forecasting, universities get involve in being overstaffed or understaffed, or having an insufficient team gain a competitive advantage. Little research has been published to present how much readiness they are although human capital strategy has always been highlighted. (Khasawneh, 2011).

Therefore, universities (both public education and private education) are undergoing significant changes as a result of globalization, increased competition for financing and staff, and increased institutional autonomy. The university's responsibility to its employees has shifted from administration to management. To successfully adjust to this institutional transition and become more competitive in a complicated context, an increasing number of universities are implementing various ways to better employ their human resources. Given that employee investment accounts for the majority of university expenditure, human resources are the most valuable asset of universities and are growing in importance in university affairs (Evans, 2012).

II. THE OVERVIEW AND CONCEPTS

A. The overview

Our country's university education system is divided into two types: private institutions and public universities. Private universities are becoming increasingly popular in our country, with many diverse organizations, such as firms or families, establishing them with substantial capital investments. They establish a university that provides both economic benefits and serves the community more effectively, with a lofty goal and strategy for developing and training future human resources. What development plans are in place, and what are the benefits of teaching students to ensure social demands, for training quality to be effective, what policy or personnel changes have they implemented? We studied typical universities to clarify their primary human resource policies and compare their human resources development plan to better comprehend family-owned schools and corporate-managed schools (Tien, 2020).

It is similar to Vietnam's reality, a long-term orientation country, Thailand also has private higher education institutions that have contributed to both study and education, offering society academic information and preserving national arts and culture (Bank, 2009). The expansion of private higher education institutions in Bangkok and other provinces to meet the social demand for higher education and the need to extend the nation's educational system has brought the rise of such schools to public attention. Today, more than 70 private higher education institutions exist in Thailand, reflecting the country's rapid social and economic change as well as the challenges posed by Thailand's national education development plan (Council, 2017). Private education institutions, like any other business, are subject to market pressures, and most private higher education institutions have had issues with the quality of professional teachers and hurdles in generating research work for many decades (Karuoya, 2017). As a result, human resources (HR) departments of educational institutions must seek to improve their human assets, both quantitatively and qualitatively, by attracting, developing, and retaining talent. The human resources department is an essential requirement in today's enterprises and plays a critical role in the supply of human people as the primary resource of organizations (Burma, 2014).

Workforce development is a challenging role for almost universities. Their HR aims to attract and retain top talent, develop employee capacity and enhance campus culture. The task of HR gets involves in developing comprehensive people strategies that drive operation throughout an institution and the employee ability, from onboarding to retirement.

B. Human resources concept

The workforce is the collection of people who work for a company, industry, or government. A company's workers or contractual staff are referred to as human resources. The economist John R. Commons (1984) coined the term "Human Resources" first in his work, "Distribution of Wealth". However, the word Human Resources did not become common until 1910-1920. Companies began to see their employees as capital assets within their enterprises at about this time.

Human resources are a unique source of survival, development, and competitiveness for organizations. Human resources development helps to increase people's cognitive ability and morale, it is conducive to new ideas and changing lifestyles, and it provides intellectual support and spiritual power for enterprise development (Wu, 2016).

C. PHEIs' human resources

In the education organization, "human resources" is considering all persons who work in educational institutions. Academic staff include faculties' task is lecturing or researching or assistants is supporting to transmit knowledge; staffs providing professional support (study, health and social service) for students, supervisors involved in institution management and administration, and personnel who support the maintenance and operations of institutions (facility, security, ancillary services) (OECD, 2020).

Academic staff play a critical role in assuring quality of teaching and research. Other personnel, particularly highly skilled and well-paid professional staff in specialized jobs or administrative responsibilities that play crucial roles in assisting high-performing institutions in in higher education. (Bossu, 2019).

III. THE REALITY OF HUMAN RESOURCES MANAGEMENT IN PRIVATE HIGHER EDUCATION INSTITUTIONS

In reality, many strategies, plans, policies have not reflected that spirit for a long time although the education policy was declared to be the top national policy fairly early on, for example, in Vietnam. In comparison to other nations, Vietnam's financial resources for education investment remain quite limited, accounting for a very small proportion of GDP with only 0.33 percent in higher education. Higher education investment rates in several nations are two to six times higher than in Vietnam ("Higher education: Việt Nam must focus on quality not quantity," 2022).

Human capital, particularly entrepreneur human capital, which private universities had disadvantages in human resources management. According to a survey, the most percentage of private educational organization account for financial management authority, which the primary family members take in the hand, and around the second large rest of senior management personnel is a close relationship (Mpolokeng, 2011). Whenever the organization reached to any certain size, it found difficulty to escape the "family management" stereotypes,

and human resources management is still stuck in the "family workshop " type of arbitrary decision-making stage. As a result, that has a direct impact on human enthusiasm for work, hinders university development, such as inbreeding, as well as will be degraded, resulting in negative effects (Kuhn, 2000). Moreover, there is a lack of modern management knowledge and management capacity. Thoughts on the market economic system and its operation are hardly absorbed, resulting in high-level decision-making that is short-sighted, unable to consider long-term development strategy, and even committing mistakes, lead to bankruptcy.

Some private universities recruit for rich earnings and decent working conditions to attract talent, allowing many individuals to fulfill their dreams and join with a passion, but when they attend to the unit, the unit is unable or unable to honor previous agreements. Some ones have even made investments in terms of working conditions and treatment, among other things. It means that personnel cost pressure is extremely low as an added expense to labor cost (Asghar, 2010).

Universities finds really hard to operate in an environment based on a long-term vision for the human resources development without enthusiasm and initiative. Because they do not want to spend manpower and energy, financial resources, on the introduction of high-quality individuals, causing the pace of business development to stall or even result in the loss of a rare opportunity for development. Therefore, this easily leads to job purpose is not obvious, or human resources management was only run on with low capacity. (Piwowar-Sulej, 2021).

Human resources management played little role and instead increased organizational costs. The causes of private enterprises' challenges in the development of talent are numerous; how to lead individuals and private enterprises in improving talent management people, assisting private businesses; particularly, private higher education institutions in speedy and healthy development, is an essential task before us (Jiang, 2012).

IV. RECOMMENDATION

Private higher education institutions confront a challenge in the labor market; how to overcome these challenges and adapt to the situation will not be eradicated; the solution lies in the application of individual attention and management.

To establish an effective system, for retaining the talent, the stage of development of private educational institution was thought, from a strategic height, and cultivate human awareness reserves, as well as seek to create mechanisms to attract talent and the environment. Firstly, we must strengthen our talent introduction strategy. Manpower planning must be forward-thinking and strategic to keep up with the introduction of institutions' development requirements (Bagheri, 2016). Secondly, we should aim for a diverse talent pool that not considers quantity but also emphasizes quality and age diversity. This means introducing a number of individuals while prioritizing professional expertise and appropriate management positions (Cappelli, 2008). And the last one, we should allow candidates to obtain more objective, precise information about their positions and what they must perform during the recruitment process. As a result, they will be more content with the employment they choose (Williams, 2022).

Face with a brain drain, they are thinking of creative steps to attract and retain people.

The present problem to be tackled is building mechanisms, which have practically required universities to become an academic organization for individual development, and even rather than a "surplus" phenomenon in traditional way. The tremendous importance of the organization's culture of energy costs has resulted in brain drain, leading to the loss of human capital. In recent years, several private institutions have entirely transformed the traditional manner of working, creating employee self-management groups. The knowledgeable development and employment skills should be taken in strategy to retain talent (Iris, 2011). The level of adapting work environment (flexible tasks or project purpose) will reflect on employee's ability. The job description is a secondary role for design tasks. Also, with talent in the market's strong competition, they should adopt the old approach of designing tasks, chores sculptures employing techniques meant to allow workers to employ tasks, to retain the greatest talent (Tarallo, 2020).

V. CONCLUSION

Higher education development must be built on training in order to deliver high-quality human resources to the country. This is the first and most significant condition for a high-income developed industrialized country. Only when the majority of laborers have strong technical qualifications can we raise commodity prices ("Higher education: Việt Nam must focus on quality not quantity," 2022).

Faculty and staff play critical contributors to whether educational organization (particularly private higher education institutions) can catch their strategic goals, which range from improving expected student outcomes. The diversity of their student and faculty structure leads to a more inclusive culture and an educational research impact on local society. However, higher education institutions, also the same as other firms, face increased competition in the hunt for talent—both for HR staff and for the candidates HR recruits (Bryan, 2022).

Human resources management is modern scientific research of mental and behavior human for effective management, giving full role to people's initiative to achieve strategic goals. Moreover, they require organizations to design the strategic objectives with modern science and technology and operational theory through continuous obtaining human capital with policy for integration, regulation, development, compensation and reward. This cycle process contains six functional emphases that are not independent but interconnected and mutually reinforcing. With the introduction of "knowledge economy" age, human resources management has maintained constant contact with its internal human elements, and the need to do so is becoming more apparent by the day (Jiang, 2012).

When higher education institutions aim to adapt to a rapidly changing environment, the proper personnel may have an impact on how well colleges manage new obstacles and continue to provide excellent student experiences. HR is crucial in this, but it faces specific obstacles. Universities might invest in converting HR from a compliance and administration department to an agile, empowered partner that advances the institution's strategic goals by using HR workers' commitment to learning and growth (Mohamed, 2022).

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THE DETERMINANTS OF ONLINE EDUCATION TECHNOLOGY ADOPTION IN HIGHER EDUCATION: PERSPECTIVES FROM VIETNAMESE UNDERGRADUATES

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Abstract: The COVID-19 pandemic and information technology development have boosted online education, especially at higher education institutions. Using the UTAUT-typed model, stratified probability sampling method, the survey technique, 232 valid Vietnamese undergraduates as respondents, reliability and Pearson correlation tests, confirmatory factor analysis, and SEM, this study shows that the performance expectancy is not statistically significant in affecting the Vietnamese undergraduates' behavioral intentions related to learning technology adoption. Also, the facilitating conditions are not statistically significant in affecting usage behavior. However, effort expectancy and social influence are statistically significant and positively affect Vietnamese undergraduates' behavioral intentions related to learning technology adoption. Further, the empirical results support behavioral intention's positive and significant impact on usage behavior.

Keywords: *Online education, UTAUT, LMS, higher education, behavioral intention, usage behavior*

I. INTRODUCTION

In the literature, many studies show the benefits of online compared with traditional classroom education. Recent studies (Bradley, 2020; Dinh et al., 2022; Tuckel & Pok-Carabalona, 2023; Watson et al., 2023) point out that online education offers students many advantages, such as efficiency, flexibility, safety, affordability, and accessibility over traditional education. Also, most students can maintain and success in their learning progress with online education using learning management system (LMS) such as Google Classroom and Moodle (Dinh & Nguyen, 2020; Swart, 2015).

In the Internet of Things (IoT) era, online education using LMS has become popular, especially in developed countries (Smalley, 2021; Pham & Ho, 2020), with the number of users estimated at 73.8 million worldwide (Bouchrika, 2023). To adapt and respond to the social distancing call due to the Covid-19 pandemic, with 94% of students worldwide negatively affected (Pokhrel & Chhetri, 2021), nearly all universities around the world have turned to online classes via television or internet (Ho et al., 2021; Mukuka et al., 2021), including Vietnamese universities (Pham & Ho, 2020; Pham et al., 2021). The other reasons are that the LMS provides the tools for all parts of the learning process, e.g., a virtual place for lecturers to upload their teaching materials and notify and grade the students' works (Watson & Watson, 2007). However, what makes online education exciting and valuable and influences student acceptance is only sometimes clear.

In addition, as the Covid-19 pandemic has gradually faded, most universities in Vietnam, U.S., and around the world have reverted to the online trend and delivering classes in-person format.

In literature, some studies used the theory of acceptance and use of technology (UTAUT, Venkatesh et al., 2003)) to explain the use of the LMS in literature. A recent study (Abbad, 2021) examined the undergraduates' intentions to use and their actual usage of Moodle in public university. The results showed that the performance expectancy (PE) and effort expectancy (EE) affected behavioral intention (BI) to use Moodle, whereas social influence (SI) did not. Also, the BI and facilitating conditions (FC) directly affected the students' usage behavior (UB) of Moodle. Another study (Garone et al., 2019) examined the lecturers' technology acceptance and use of a new LMS using the predictor variables of UTAUT. The results showed three groups of technology acceptance in university lecturers: high, moderate, and low. The lecturers in the high group are most likely to innovate and use a new LMS. However, the lecturers in the moderate and low groups most likely need additional support and social influence from policy and decision-makers to use a new LMS. One study (Alshehri et al., 2019) applied the UTAUT model and structural equation modeling techniques to investigate the Saudi Arabian students' BI and UB of Blackboard. This study showed that technical support is fundamental in determining students' acceptance and use of a new LMS. Another study (Raman et al., 2014) examined the level of acceptance of Moodle using the UTAUT. This study claimed that PE, SI, and FC positively influenced BI. However, under the moderate influence of gender, PE, EE, SI, and FC did not significantly and positively influence BI. Another study (Sumak et al., 2010) investigated the undergraduates' perceptions of Moodle using the UTAUT and the structural equation modeling (SEM) approach. This study claimed that PE and SI significantly impacted students' attitudes toward using Moodle. The social influence and attitudes toward using were significant determinants of students' BI. Also, students' BI was a significant determinant of the actual use of Moodle.

Other studies in literature also studied the relationship between the factors of UTAUT and BI in education. Using the UTAUT and intrinsic values of enjoyment and interest, one study (Khechine et al., 2020) examined the determinants of LMS acceptance in which a social media tool is embedded. This study showed that the FC and intrinsic value variables explained the BI to use the LMS that integrates social media technology. Also, the FC could be used to predict the UB. Another study (Fathema et al., 2015) investigated how university lecturers' beliefs and attitudes influence their intention and actual use of the LMS. The results showed that the three proposed external variables: system quality, perceived self-efficacy, and facilitations conditions were significant predictors of faculty attitude towards the LMS. Another study (Sung et al., 2015) examined the structural relationship among self-efficacy, social influence, effort expectancy, performance expectancy, and behavioral intention of online education acceptance. The results claimed self-efficacy positively affected SI, EE, PE, and BI. The SI positively affected EE, PE, and BI. The EE yielded positive effects on PE and BI. Also, the PE yielded a positive effect on BI.

II. METHODOLOGY

A. Model and hypotheses

To examine the nexus between independent variables (PE, EE, SI, and FC), intermediate variable (BI), and dependent variable (UB), this study employed the UTAUT-typed model as in Fig. 1.

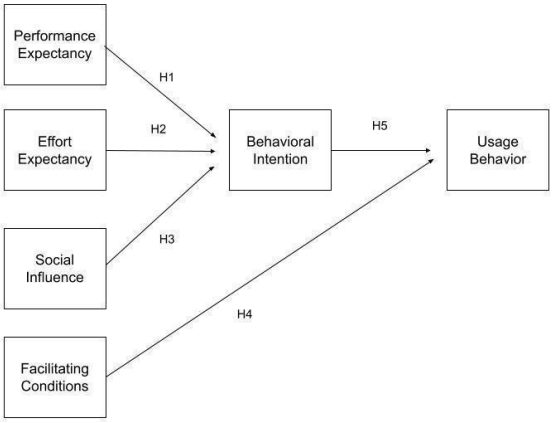

Figure 1. The UTAUT-typed model

B. Variables

This study adapted the proven items from other studies to measure the variables PE, EE, and SI (Attuquayefio & Addo, 2014; Venkatesh et al., 2011). Similarly, to measure the FC, this study adapted the proven items from similar studies (Attuquayefio & Addo, 2014; Venkatesh et al., 2011). Next, to measure the variable BI, this study adapted the proven items from other papers (Agudo-Peregrina et al., 2014; Davis, 1986; Venkatesh et al., 2011). Last, to measure the variable UB, this study adapted the proven items from other papers (Agudo-Peregrina et al., 2014; Attuquayefio & Addo, 2014).

C. Statistical analysis methods

This study used descriptive and inference statistics to analyze the data and test the hypotheses. In the beginning, the demographics and descriptive statistics were analyzed. Then, this study employed the reliability test using the Cronbach's alpha and corrected item-total correlation to analyze the reliability of the used variables. Next, the Pearson correlation test was used to examine the correlation between independent, intermediate, and dependent variables. Then, the confirmatory factor analysis (CFA) was applied to examine the variable structure and the relationship between variables. Last, this study employed structural equation modeling (SEM) using the analysis of moment structures (AMOS) software to examine the structural relationship between variables. It is worth noting that the variables and questionnaire items used in this study are from the well-established framework. So, the exploratory factor analysis (EFA) was ignored.

D. Data

This study employed the survey technique to collect the data. At first, all items in the questionnaire were translated into Vietnamese to ensure understanding among the Vietnamese undergraduates. Next, the survey was sought the comments from three researchers in this field. Then, the revised survey was tested on a small group of 30 undergraduates from three universities in a pilot study. This study also applied the 5-point Likert scale (1 - strongly disagree, 2 - disagree, 3 - neutral, 4 - agree, 5 - strongly agree) to ask for responses for each item. The gender and age of respondents were also collected to gain more knowledge and control the sampling bias.

E. Sampling method and sample size

Most and high-ranked Vietnamese universities are located in major metropolitan areas. They have more resources to invest in new technology and LMSs than universities in rural areas. So, this study used the stratified probability sampling technique to collect the

data and minimize sampling errors and bias. With 1,672,000 undergraduates in Vietnam (Vietnam Ministry of Education and Training, 2021), we initiated the maximum sample size of 400 from Slovin's formula (Tejada & Punzalan, 2012). Then, we sent out 433 surveys to respondents in case of non-responses or missing items. However, there were only 232 respondents that answered all the items in the survey. So, the final and valid sample size considered 232 respondents with a sampling error of 4.8% (excluding the 30 respondents from the pilot study). This sample size 232 met the threshold that other studies suggested (Comrey & Lee, 1992; Hair et al., 2019; MacCallum et al., 1999). Also, the sample size 232 to 6 variables ratio is more than 38, which is more than adequate for this type of study (Everitt, 1975; Hair et al., 2019).

III. RESULTS

A. Demographics of respondents

The results show the gender and age of respondents in this study, with 54.3% male and 45.7% female. Also, most respondents (85.3%) were 18-25. These results align with gender equality and age among Vietnamese undergraduates and statistics of Vietnam higher education (Vietnam Ministry of Education and Training, 2021). Hence, the respondents in the sample and their opinions well represented the population of Vietnamese undergraduates in terms of gender and age.

B. Descriptive statistics of variables

The result showed that the mean of each item of PE, EE, SI, and FC, BI, and UB exceeded the cut-off point 3. Among items of independent variables, EE4 got the highest mean of 4.23. In contrast, PE2 got the lowest mean of 3.87. Among items of the dependent variable, UB4 got the highest mean of 3.79, while UB2 scored the lowest mean of 3.69. Hence, these descriptive statistics mean that the undergraduates liked to use a LMS for their study, at least in this sample.

C. Reliability test using Cronbach's alpha and corrected item-total correlation

The results showed that the Cronbach's alphas were 0.81 - 0.90, exceeding the threshold of 0.7 (Bonett & Wright, 2014; Hair et al., 2019). This finding means that the variables used in this study are very reliable. Also, the corrected item-total correlation coefficients of items were from 0.58 to 0.80, exceeding the threshold of 0.5 (Kim & Stoel, 2004). This result means that the questionnaire items are strongly correlated. Hence, this finding is another evidence of the reliability of the variables used in this study.

D. Pearson correlation test

The results showed that the Pearson correlation coefficients were 0.14 - 0.47. However, the Pearson correlation tests between variables PE and BI, EE and BI, and SI and BI yielded p-values of 0.03, 0.002, and 0.005, respectively. Similarly, the Pearson correlation test between variables FC and UB and BI and UB yielded p-values of 0.000. These p-values are less than the critical significant level of 5%. Therefore, these findings mean that correlations between variables exist.

E. Confirmatory factor analysis (CFA)

This study employed the CFA (DiStefano & Hess, 2005) using model fit and construct validity tests to examine the variable structure and relationship between variables in the model.

a. Model fit test

The results showed that the ratio of chi-square/degrees of freedom (chi-square/d.f.) was 1.256, less than the cut-off point 2. Similarly,

goodness of fit index (GFI) and comparative fit index (CFI) were 0.956, 0.977, respectively, greater than the cut-off point of 0.95. Lastly, root mean square error of approximation (RMSEA) was 0.033, less than the cut-off point of 0.06. Hence, these findings mean that the model, as in Fig. 1, fits the observed data well (Byrne, 2001; Carmines & McIver, 1981; Hair et al., 2019; Sun, 2005).

b. Validity test

To assess variable validity, we examine convergent validity using composite reliability (CR) and average variance extracted (AVE) (Fornell & Larcker, 1981; Hair et al., 2019; Henseler et al., 2015; Netemeyer et al., 2003). The results showed that the CRs of variables were 0.807 – 0.897, exceeding the threshold of 0.8. Also, the AVE ranged from 0.511 – 0.686, exceeding the threshold of 0.5. So, these findings support the convergent validity of the measurement model.

This study also examined the construct validity using discriminant validity of items of variables using AVE and maximum shared variance (MSV); the AVE and inter-variable squared correlations (Hair et al., 2019; Henseler et al., 2015; Netemeyer et al., 2003). The results showed that the MSV was less than the corresponding AVE for each variable. Specifically, the variable PE's MSV of 0.17 was less than the corresponding AVE of 0.586. Variable EE's MSV of 0.17 was less than the corresponding AVE of 0.639. Variable FC's MSV of 0.317 was less than the corresponding AVE of 0.571. Variable SI's MSV of 0.317 was less than the corresponding AVE of 0.562. Variable BI's MSV of 0.319 was less than the corresponding AVE of 0.557. Similarly, variable UB's MSV of 0.319 was less than the corresponding AVE of 0.511.

In addition, the results showed that variable PE's AVE of 0.686 exceeded 0.412^2, 0.140^2, 0.256^2, 0.158^2, and 0.031^2, the squared correlation coefficient between PE and EE, PE and FC, PE and SI, PE and BI, and PE and UB, respectively. Similarly, variable EE's AVE of 0.639 was greater than 0.412^2, 0.263^2, 0.330^2, 0.227^2, and 0.110^2, the squared correlation coefficient between EE and PE, EE and FC, EE and SI, EE and BI, and EE and UB, respectively. Similar results held for variables FC, SI, BI, and UB. Hence, these findings support the discriminant validity of the measurement model.

F. Structural equation modeling

Next, this study employed structural equation modeling (SEM) (Hair et al., 2019; Fan et al., 2016), as shown in Fig. 2, to analyze the structural relationship between measured variables and latent constructs of the model, as in Fig. 1.

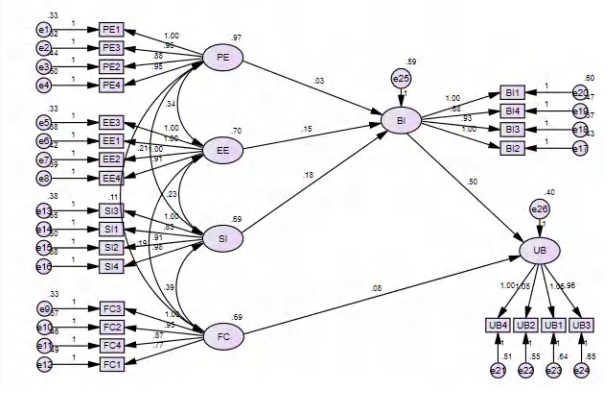

Figure 2. The structural relationship of the model

Table 1 shows the hypothesis testing of the model, as in Fig. 1, using the SEM technique. The results showed that for hypothesis H1: PE → BI, the weight was 0.03, and the corresponding *p*-value of 0.632 (63.2%). This finding means that the H1 is not significant at the level of 10%. So, the causal relationship in H1 does

not exist. This conclusion is not consistent with other studies (Abbad, 2021; Chao, 2019; Sumak et al., 2010; Sung et al., 2015). Similarly, for hypothesis H4: FC → UB, the weight was 0.08, and the corresponding *p*-value of 0.213 (21.3%). This finding means that the H4 is insignificant at 10%. So, the causal relationship does not exist in H4. This conclusion is not consistent with other studies (Fathema et al., 2015; Khechine et al., 2020; Taylor & Todd, 1995). The possible reason for the difference in conclusions from H1 and H4 between this study and others is that online education is not a preferred format compared to the traditional classroom education in the Vietnamese higher education system. So, Vietnamese higher institutions do not make a good investment in online education infrastructure and training. Also, most Vietnamese undergraduates were not used to online education until the COVID-19 pandemic spread. Another possible reason is that other studies were conducted in more developed countries such as Korea, Taiwan, and European countries where higher education environments are not the same as in Vietnam.

For hypothesis H2: EE → BI, the weight was 0.15, and the corresponding *p*-value of 0.081 (8.1%). This finding means that the H2 is significant at the level of 10%. So, the causal relationship exists in H2. This conclusion aligns with another study (Abbad, 2021). For hypothesis H3: SI → BI, the weight was 0.18, and the corresponding *p*-value of 0.025 (2.5%). This finding means that the H3 is significant at the level of 5%. So, the causal relationship exists in H3. This conclusion aligns with other studies (Raman et al., 2014; Sumak et al., 2010; Sung et al., 2015). Similarly, for hypothesis H5: BI à UB, the weight was 0.50, and the corresponding *p*-value of 0.000 (0%). This finding means that the H5 is significant at the level of 1%. So, the causal relationship exists in H5. This conclusion aligns with another study (Sumak et al., 2010).

Table 1. The hypothesis testing using SEM

Hypothesis	Weight	*p*-value
H1: PE → BI	0.03	0.632
H2: EE → BI	0.15	**0.081** (*)
H3: SI → BI	0.18	**0.025** (**)
H4: FC → UB	0.08	0.213
H5: BI → UB	0.50	**0.000** (***)
Notes: *: significant al the level of 10% **: significant at the level of 5% ***: significant at the level of 1%		

IV. CONCLUSION

With the development of technology today, online education is growing rapidly, especially during the pandemic period such as COVID-19. This study examines the determinants of technology adoption in Vietnam higher education. Using the UTAUT-typed model, stratified probability sampling method, the survey technique, 232 valid Vietnamese undergraduates as respondents, reliability and Pearson correlation tests, confirmatory factor analysis, and SEM, this study shows that the performance expectancy is not statistically significant in affecting the Vietnamese undergraduates' behavioral intentions related to learning technology adoption. Also, the facilitating conditions is not statistically significant in affecting usage behavior. However, effort expectancy and social influence are statistically significant and positively affect Vietnamese undergraduates' behavioral intentions related to learning technology adoption. Further, the empirical result also supports a positive and significant impact of behavioral intention on usage behavior.

All these findings provide insights into student behavioral intentions related to technology adoption in higher education. So, they can help educators and their higher education institutions understand their students' needs and invest more in technology for the success of their students and universities. Also, higher education institutions are encouraged to spend more time and resources to train their students using technology to boost their online education acceptance.

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UNDERSTANDING THE DETERMINANTS OF NOVEL TECHNOLOGY ADOPTION AMONG UNIVERSITY LECTURERS IN BINH DUONG: THE CASE OF 3D PRINTING

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Abstract: 3D printing, also known as additive manufacturing, has gained significant interest in academic and business institutions since its emergence in the 1980s. It offers the ability to create intricate structures using three-dimensional model data. In the field of education, integrating 3D printing can enhance spatial thinking and creativity. Although 3D printing is a promising innovation in vary field, there is little academic research written about the behavior of 3D adoption in the field of education where could nurture the technology evolution. This research contributes to the existing literature on exploring the factors influencing university teachers' intention to use 3D printing technology in Binh Duong, Vietnam. The Unified Theory of Acceptance and Use of Technology (UTAUT) was applied as the fundamental theory to develop the model. The research uses a quantitative approach to survey 157 lecturers in Binh Duong examining their decision-making process to adopt 3D printing. Furthermore, the research aims to shed light on improving technology integration in teaching and learning in the research context. Overall, this study provides valuable insights into the factors influencing 3D printing adoption among university lecturers in Binh Duong, Vietnam, and establishes a foundation for future analyses.

Keywords: *3D printing, novel technology adoption, behavioral intention, university teachers, Unified Theory of Acceptance and Use of Technology (UTAUT)*

I. INTRODUCTION

Since its emergence in the 1980s, additive manufacturing, also known as 3D printing, has garnered immense interest from both academic and business institutions (Ambrosi & Pumera, 2016). Essentially, 3D printing is an additive manufacturing technique that utilizes three-dimensional model data to create a diverse range of structures and intricate geometries (Ngo et al., 2018). When integrated into education, 3D printing provides an excellent opportunity to enhance spatial thinking and creativity (Sheng, 2022). Novak believes that 3D printing is an evolving educational technology (Novak, 2022), and large-scale 3D printing enables teachers and students to learn more effectively through the use of 3D-printed models in classrooms (Badyal & Bhatia, 2015). It is becoming increasingly crucial to train teachers to integrate technical, pedagogical, and content knowledge (Ley et al., 2021). With the assistance of 3D printing, students can learn about STEAM holistically

(Ng, 2017). Groundbreaking technologies that combine various components are more likely to have a significant technological impact and broader applications once they surpass their initial (Pezzoni et al., 2022). 3D printing is among the newest technologies, along with 5G, IoT, and Blockchain (Duggal, 2018), and adopting new technology allows teachers to incorporate graphics, music, video, and other media into lecture materials, enhancing the learning experience (Beecham, 2009). As a result, new technology-based pedagogies must be established, evaluated, and taught, necessitating changes in teaching and learning procedures. Teacher training programs for technology-enhanced instruction have historically concentrated on instructors' abilities and principles (Twining et al., 2013). Since it is fascinating and has tremendous potential, 3D printing technology is poised to change and revolutionize the world, incorporating multiple technologies with economic and social benefits (Saxena & Kamran, 2016).

II. METHODOLOGY

A. Research approach

- Quantitative research involves examining the relationship between variables to test objective hypotheses, often using tools to measure the variables and obtain numerical data that can be analyzed using statistical methods (Creswell & Creswell, 2018). This study employed a cross-sectional, questionnaire-based approach to investigate the correlation between six factors (Performance expectancy, Effort expectancy, Social influence, Anxiety, Attitude toward using technology, Facilitating conditions) and the adoption of 3D printing technology by university instructors in Binh Duong. The researchers used a 5-point Likert scale with response options ranging from "Strongly agree" to "Strongly disagree" to measure the impact of these six variables on teachers' willingness to implement 3D printing technology in their teaching methods. The data collected will be analyzed using SPSS 20.0 software.

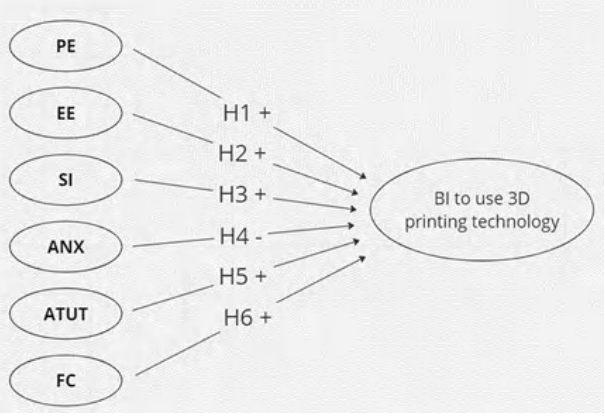

Figure 1. Research model adapted from Holzmann et al., (2018)

B. Sampling method

For this study, the sample will conduct a survey with Vietnamese university lecturers in Binh Duong. The sample size was determined using Comrey and Lee's formula (1992), which states that the sample size should be 5 times the number of questions. Since there are 26 questions in this study.

n=5*m (Helen & Steve, 2006)

n: is the sample size.

m: is the number of questions.

The sample size was calculated as 5*26=130 samples.

III. RESULTS

A. Research findings

The analysis of the data gathered from 157 participants has uncovered noteworthy relationships and influences between the independent variables and the dependent variables in the study. The key findings can be summarized as follows:

Table 1. Hypothesis test results

Hypothesis	Hypothesis content	Sig.	Std. Coefficient Beta	Testing result	Ranking impact
H1	Performance Expectancy has a positive effect on the intention to use 3D printing	0.000	0.370	Supported	1st
H2	Effort Expectancy has a positive effect on the intention to use 3D printing	0.000	0.335	Supported	2nd
H3	Social Influence has a positive effect on the intention to use 3D printing	0.167	-0.086	Not Supported	-
H4	Attitude Toward Using Technology has a positive effect on the intention to use 3D printing	0.000	0.341	Supported	3rd
H5	Anxiety has a negative effect on the intention to use 3D printing	0.991	-0.001	Not Supported	-
H6	Facilitating Conditions has a positive effect on the intention to use 3D printing	0.206	0.076	Not Supported	-

According to the findings presented in the Table, the significance value (Sig.) of 0.167 for Social Influence (SI) in relation to Behavioural Intention (BI) is greater than 0.05. This suggests that the variable SI does not have a significant effect on BI. Similarly, the significance value of 0.991 for Anxiety (ANX) in relation to BI indicates that ANX does not influence BI. Additionally, the significance value of 0.206 for Facilitating Conditions (FC) in relation to BI is also greater than 0.05, indicating that FC does not have a significant impact on BI.

On the other hand, the variables Performance Expectancy (PE), Effort Expectancy (EE), and Attitude Toward Using Technology (ATUT) all have significance values lower than 0.05. This indicates that these relationships are statistically significant. Consequently, the author rejects hypotheses H3, H5, and H6, while accepting the remaining hypotheses H1, H2, and H4.

B. Discussion

This research investigates how Performance Expectancy, Effort Expectancy, Social Influence, Attitude Toward Using Technology, Anxiety, and Facilitating Conditions influence the behavioral intention of university lecturers in Binh Duong regarding the use of novel technology, specifically 3D printing. The study supported three hypotheses: H1 (Performance Expectancy), H2 (Effort Expectancy), and H4 (Attitude Toward Using Technology). However, three hypotheses were not supported: H3 (Social Influence), H5 (Anxiety), and H6 (Facilitating Conditions).

The findings indicate a statistically significant and positive correlation between

Performance Expectancy (PE) and the Behavioral Intention of lecturers to use 3D printing technology. The research findings by Abd Rahman et al. (Abd Rahman et al., 2021) demonstrate a statistically significant and positive correlation between Performance Expectancy (PE) and the Behavioral Intention of lecturers to utilize 3D printing technology. According to their study, lecturers who perceive 3D printing as a useful tool for fast task accomplishment and high productivity are more inclined to adopt and use it in their teaching practices at the university level. These results support the first hypothesis, suggesting that the intention to adopt new technology like 3D printing in teaching is positively influenced by Performance Expectancy factors. In other words, when lecturers perceive the benefits and advantages of 3D printing technology, they are more likely to have the intention to use it.

The results of this research support the second hypothesis, indicating a significant and positive correlation between Effort Expectancy (EE) and the Behavioral Intention to adopt new technology in teaching. This aligns with prior studies by Nguyen & Teng (2022), Lin et al. (2013), and Aldraiweesh (2023), highlighting the importance of perceived benefits in motivating lecturers to embrace 3D printing technology. When university lecturers perceive the benefits of using 3D printing, such as improved student engagement and enhanced learning outcomes, they are more likely to view the effort required as worthwhile, positively influencing their intention to adopt the technology. Additionally, the user-friendly nature of 3D printing, characterized by easy-to-use interfaces and intuitive software, reduces the perceived effort and enhances lecturers' inclination to integrate the technology into their teaching practices. Comparing these findings with previous research emphasizes the significant role of perceived benefits and ease of use in shaping lecturers' intention to adopt and utilize 3D printing technology for teaching purposes.

This study further supports hypothesis 4 by demonstrating a positive impact of Attitude Toward Using Technology (ATUT) on Behavioral Intention. These findings are consistent with previous research conducted by Ali Alasmari (2022) and Marwan & Sweeney (2010). A positive attitude toward using technology indicates that lecturers in Vietnam hold favorable perceptions regarding the benefits and value that technology can bring to their teaching practices. This positive attitude may be influenced by various factors, including the perceived usefulness of technology, its potential to enhance teaching effectiveness, and its alignment with the lecturers' educational goals and pedagogical approaches. The convergence of findings from previous research reinforces the notion that a positive attitude toward technology is a significant determinant of lecturers' intention to adopt and utilize it in their teaching practices.

The findings of this research present a contrast to the initial hypotheses, as they indicate that Social Influence (SI), Anxiety (ANX), and Facilitating Conditions (FC) were not significant predictors of Behavioral Intention (BI) to adopt new technology in teaching. This outcome diverges from previous studies, such as the one conducted by Holzmann et al. (2018), which suggested a positive influence of Social Influence (SI) and Facilitating Conditions (FC) on teachers' Behavioral Intention to adopt new technology.

In the specific research context of Binh Duong, Vietnam, the low familiarity and limited practical experience with technologies like 3D printing in teaching among lecturers

may explain these divergent results. Many barriers exist, and lecturers in this context have a limited understanding of 3D printing technology. Variables like Social Influence (SI), Anxiety (ANX), and Facilitating Conditions (FC) may require experiential exposure and a clearer understanding to have an impact on Behavioral Intention (BI) in this study.

Previous research conducted by Do (2019), Nguyen (2021) supports the notion that experiential exposure and improved understanding of new technologies are crucial factors for these variables to influence Behavioral Intention. In the current study, where lecturers have limited exposure and understanding of 3D printing technology, it is understandable that these variables did not significantly predict Behavioral Intention (BI).

These contrasting findings highlight the importance of considering the specific context and level of familiarity with technology when examining the predictors of Behavioral Intention. In the case of 3D printing technology in the Binh Duong context, the lack of familiarity and limited practical experience among lecturers may have minimized the influence of Social Influence (SI), Anxiety (ANX), and Facilitating Conditions (FC) on Behavioral Intention (BI).

IV. CONCLUSION AND RECOMMENDATIONS

The objectives of this were (1) To identify the factors that affect the behavior intention of university teachers towards 3D printing technology in Binh Duong. (2) To analyse and examine the identified factors influence on the behavior intention of university teachers towards 3D printing technology in Binh Duong. (3) To identify the factor that has the most significant impact on the behavior intention of university teachers towards 3D printing technology in Binh Duong. With a sample size of 157 respondents, this research focuses on lecturers in Binh Duong province, especially Eastern International University.

The results of the statistical analysis reveal that approximately 67% of the variations in Behavioural Intention (BI) can be attributed to the six independent variables: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Anxiety (ANX), Attitude Toward to Use Technology (ATUT), and Facilitating Conditions (FC). The findings support the hypothesis that there are positive relationships between Performance Expectancy, Effort Expectancy, Attitude Toward to Use Technology, and Behavioural Intention. Notably, Performance Expectancy factors have the most significant impact on the Behavioural Intention to use new technology among university lecturers. However, in the case of Social Influence, Anxiety, and Facilitating Condition, no empirical evidence was found to establish a positive relationship with the Behavioural Intention to use new technology among university lecturers. In conclusion, it can be inferred that university lecturers in Binh Duong, particularly those from EIU, experience a significant influence of Performance Expectancy on their Behavioural Intention to use new technology.

Throughout the course of this study, several limitations emerged that were not initially anticipated. Firstly, sample size and representativeness: One of the limitations of this study is the sample size and its representativeness. The study was conducted with a specific sample of university lecturers particularly at Eastern International University (EIU) in Binh Duong, Vietnam. The sample

size may not be sufficiently large to capture the full diversity and characteristics of all university lecturers in the region or beyond. Therefore, the generalizability of the findings to other populations or contexts should be done cautiously. The results may not fully reflect the experiences, perspectives, and behaviors of lecturers in different settings or regions, and further research with larger and more diverse samples is recommended to enhance the generalizability of the findings. Secondly, Self-Reported Measures: This study relied on self-reported measures to assess variables such as Performance Expectancy, Effort Expectancy, Social Influence, Attitude Toward Using Technology, Anxiety, and Facilitating Conditions. Self-report measures are subject to certain limitations, including potential biases and inaccuracies in participants' responses. The accuracy and reliability of the data depend on the participants' ability to accurately recall and report their attitudes, beliefs, and intentions. There may also be social desirability bias, where participants provide responses that they believe are socially acceptable or desirable rather than their true perceptions. Therefore, caution should be exercised when interpreting the findings based on self-reported data. Future studies could consider incorporating objective measures or alternative data collection methods to complement self-report measures and provide a more comprehensive understanding of the variables under investigation.

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