INTERDISCIPLINARY APPROACHES TO SUSTAINABILITY, INNOVATIONS, CULTURAL HERITAGE, TECHNOLOGY, AND URBAN DEVELOPMENT IN INDONESIA

Editor

Dr. Teena Singh

NCM Publishing

Interdisciplinary Approaches to Sustainability, Innovations, Cultural Heritage, Technology, and Urban Development in Indonesia

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Published by: NCM Publishing House

Publishing Date: 28.12.2024

ISBN: 978-625-95075-9-0

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Interdisciplinary Approaches to Sustainability, Innovations, Cultural Heritage, Technology, and Urban Development in Indonesia

Publication No: **29**

Editors	***Dr. Teena Singh***
Cover Designer	***Mr. Kerim KARADAL***
ISBN	**978-625-95075-9-0**
Publisher Certificate No	**51898**
Publisher Type	International Publishing House
Release Date	2024

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www.ceocongress.org

LIBRARY INFORMATION CARD

Singh, Teena; Editor, 12, 2024. **Interdisciplinary Approaches to Sustainability, Innovations, Cultural Heritage, Technology, and Urban Development in Indonesia**. NCM Publishing House, Bursa.
Language: English
Editors: Dr. Teena Singh
ISBN: **978-625-95075-9-0**

PREFACE

This book brings together a diverse collection of interdisciplinary studies that explore the intersection of sustainability, technology, cultural preservation, and urban development. The chapters within offer a unique perspective on these themes, particularly in the context of Indonesia, a country rich in both cultural heritage and rapidly evolving technological advancements.

As the world faces an increasing need for sustainable practices, this book seeks to address key challenges in various sectors, from architecture and tourism to environmental management and industrial production. The chapters delve into cutting-edge topics, such as the application of Artificial Intelligence (AI) in preserving cultural heritage, the role of architecture in mitigating environmental impacts, and innovative approaches to urban development. They also highlight the practicalities of implementing sustainability in industries like footwear manufacturing and oil production, offering valuable case studies from Indonesia.

One of the central themes of this book is the integration of traditional practices with modern technologies. From the preservation of the Durgā statue at the Prambanan Temple using AI tools to the role of sustainable tourism in Indonesia's tropics, the book emphasizes how technology can enhance, rather than replace, cultural practices and natural environments. In doing so, it encourages a holistic approach to development that respects both historical legacies and contemporary needs.

The chapters also explore the role of system technologies, such as Enterprise Resource Planning (ERP) systems, in improving user satisfaction and operational efficiency across various sectors. Moreover, the book highlights how innovations in design and production, from footwear manufacturing to urban planning, can lead to more sustainable and socially responsible outcomes.

The contributors to this book come from diverse backgrounds, each offering a distinct viewpoint on the issues at hand. Their research reflects a growing commitment to creating solutions that are not only technologically advanced but also culturally sensitive and environmentally sound.

As we navigate the complexities of the 21st century, the knowledge and insights shared in this book serve as a valuable resource for academics, practitioners, and policymakers alike. By presenting a multifaceted view of Indonesia’s ongoing efforts to balance progress with sustainability, we hope to inspire further research and innovation that will contribute to a more sustainable, equitable, and prosperous future for all.

Dr. Teena Singh
Bursa, Türkiye – December 2024

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CHAPTER 1

The Effect of ERP Accounting System Benefits on System User Satisfaction from the Auditor's and Accountant's Perspective

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ABSTRACT

Enterprise Resource Planning (ERP) systems are integrated software platforms used by organizations to manage and automate various business processes across departments, including finance, human resources, procurement, and supply chain management. ERP systems consolidate data from different functions, allowing for real-time visibility and improved decision-making. In the context of accounting, ERP systems streamline financial operations, enhance reporting accuracy, and support compliance by automating key accounting tasks such as financial consolidation, budgeting, and auditing. The adoption of ERP systems is increasingly widespread due to their potential to improve operational efficiency, reduce costs, and enhance transparency. However, user satisfaction with these systems can vary based on several factors, including the ease of use, the level of customization, and the perceived benefits in terms of organizational and operational outcomes. This research aims to investigate the impact of using the Enterprise Resource Planning (ERP) accounting system on user satisfaction from the perspectives of auditors and accountants. The sample was selected using a purposive sampling method, consisting of 120 respondents who are auditors and accountants with experience using the ERP system. The findings indicate that the use of the ERP accounting system affects user satisfaction from both auditors' and accountants' viewpoints.
Keywords: Organizational Accounting Benefits, Operational Accounting Cost Benefits, ERP User Satisfaction.

1. INTRODUCTION

Technological advancements are progressing rapidly, and companies are expected to stay aligned with these developments to ensure that their business operations remain effective and efficient. Information technology plays a crucial role in supporting and expanding business activities. Among these technologies, the Enterprise Resource Planning (ERP) system stands out as a tool that integrates various business processes, applications, and departments—such as accounting, finance, and marketing—by enabling data sharing and providing real-time information (Alaskari et al., 2019). Beyond improving efficiency and streamlining processes, ERP helps companies maintain consistency and avoid deviations in their operations. By adopting ERP, businesses can reduce reliance on manual tasks, which not only lowers the risk of errors but also minimizes the potential for fraud. Such inefficiencies and fraud can significantly impact the company, both in terms of time and overall value.

The implementation of ERP systems has a profound impact on various aspects of the accounting process, leading to a transformation in the roles of management and financial accountants while enhancing the overall productivity of the organization, including the accounting department (Sutton, 2006). As noted by Sardo and Alves (2018), the finance and accounting modules are key components of ERP systems and are typically the first to be activated during implementation. Consequently, organizations must understand the implications of ERP adoption, particularly in terms of accounting benefits and how these benefits are perceived by other users (Sutton, 2006). Despite its significance, global research on the advantages of ERP in accounting and its influence on the roles within the accounting field remains limited.

The decline in the number of employees at PT Dirgantara Indonesia (Persero) in 2012 reflects challenges in the company's performance. Issues such as substandard aircraft production quality and delays in project completion were key indicators. According to the Chairman of the Indonesian Aerospace Workers Union, these problems stemmed from ineffective management that struggled to oversee operations and fulfill contracts on schedule. Additionally, shortcomings in the production system, including an inadequate production administration process, frequent delivery delays, and unmet targets, exacerbated the situation. These inefficiencies disrupted the availability of accurate and timely accounting information, hindering managers' ability to plan future production and prepare product reports within monthly or quarterly timelines. As a result, PT Dirgantara Indonesia faced difficulties securing new orders.

Building on the previous arguments, there is limited information in developing countries regarding the accounting benefits derived from ERP system implementation and the extent to which accountants and internal auditors are satisfied with these benefits. This study aims to address this gap by pursuing the following objectives: (1) to examine the accounting benefits perceived by accountants and internal auditors as a result of ERP system implementation in companies; (2) to assess the relationship between ERP accounting benefits and the satisfaction levels of accountants and internal auditors.

The primary reference for this study is the article titled "Do Accounting Benefits of ERP Systems Impact the Satisfaction of End Users? From the Perspective of Accountants and Internal Auditors in Sri Lanka." The key distinction in this research lies in its focus on a different location—Indonesia—and its more recent timeframe.

This research aims to explore the extent to which accountants and auditors in Indonesia experience the benefits of ERP systems in their daily operational activities. By focusing on companies utilizing ERP systems, particularly within Indonesia, the study seeks to provide valuable insights into the perceived advantages for these professionals.

2. LITERATURE REVIEW

GRAND THEORY

The term "disruption," as defined in the Indonesian dictionary, refers to something that lacks foundation. In contrast, technological disruption is understood as a form of technological advancement that creates new markets while rendering existing ones obsolete. Clayton M. Christensen first introduced the concept of "disruption" in his book The Innovator's Dilemma (1997), framing it as a form of profitable innovation. Yurina (2020) highlights that technological innovation cannot be ignored by established companies with structured systems, as it enables them to better anticipate profits. Such technologies often provide more advanced features and improved performance compared to existing products in the main market while remaining more affordable or accessible. This innovation appeals to customers seeking greater convenience in their lives.

However, Fukuyama takes a critical stance against Christensen's view, labeling disruption as a disturbance that can lead to chaos. Despite his criticism, Fukuyama acknowledges that technological disruption has contributed to improved living standards, strengthened democracy, and heightened public awareness of human rights and environmental issues due to the rapid dissemination of information. On the downside, he argues, social conditions have deteriorated, with rising crime rates, diminished trust and kinship within communities, and an increase in divorces and children born without fathers.

Fukuyama views this decline in societal values as evidence of disruption's disruptive nature. He contends that while technological advancements are inevitable and align with scientific progress, society must address their impact. As social beings, individuals must work to reorganize their environments by fostering self-awareness and a collective inclination toward order and organization.

Hypothesis Development

Benefits of ERP Accounting for ERP User Satisfaction

In the existing literature, a study by Spathis and Constantinides (2004) explores the relationship between ERP systems and accounting. This research explains why companies opt for comprehensive ERP systems over traditional information systems and examines the changes in accounting applications that result from this shift. The findings highlight three main reasons for adopting ERP: the growing demand for real-time information, the need for information to support decision-making, and the necessity for application integration. Key benefits for accounting include enhanced flexibility in information creation, greater integration of accounting applications, improved quality of account reports, and better decision-making based on information.

Further research on ERP implementation benefits suggests that improved decision-making processes and greater corporate integration typically follow after the systems are adopted (Colmenares, 2009). Other studies, such as those by Spathis (2006) and Kanellou and Spathis (2007), demonstrate that ERP systems enhance organizational decision-making. Additional benefits of ERP include more accurate reporting, better account reports, and improved accounting services (Velcu, 2007; Colmenares, 2009). Brazel and Dang (2008) also note that ERP systems reduce the time needed for reporting. Gattiker and Goodhue (2004) examine the broader benefits businesses experience from ERP implementation.

O'Leary (2004) sought to determine whether the benefits of ERP systems vary across industries. His research, which builds on a study by Deloitte Consulting (1998), identifies a range of tangible and intangible benefits. O'Leary's expanded list includes inventory reduction, a shorter financial closing cycle, fewer personnel, improved management, reduced IT costs, on-

time delivery, enhanced information visibility, integration, flexibility, better decision-making, financial control, and new reporting capabilities.
This study proposes the following hypotheses, which are grounded in the theoretical frameworkand empirical evidence outlined above:
H1: Organizational accounting benefits positively influence ERP user satisfaction.
H2: Managerial accounting benefits positively influence ERP user satisfaction.
H3: IT accounting benefits positively affect ERP user satisfaction.
H4: Operational accounting benefits (cost) positively impact ERP user satisfaction.
H5: Operational accounting benefits (time) positively impact ERP user satisfaction.

3. RESEARCH METHOD

This research employs a quantitative descriptive approach, aiming to assess the impact of ERP accounting system usage on user satisfaction from the perspectives of accountants and internal auditors. The independent variables (predictor variables) in this study include organizational accounting (X1), managerial accounting (X2), IT accounting (X3), operational cost accounting (X4), and operational time accounting (X5). The dependent variable (outcome variable) is ERP user satisfaction (Y). Data collection was conducted through questionnaires distributed to accountants and internal auditors working in organizations that have implemented ERP systems.

The purposive sampling technique was used, with the following inclusion criteria:

1. Minimum of 3 years of experience as an accountant or internal auditor.
2. At least 1 year of experience using an ERP system.
3. A minimum education level of D3.

The questionnaire included four independent variables—organizational accounting, managerial accounting, IT accounting, operational cost accounting, and operational time accounting—and one dependent variable reflecting user satisfaction with the ERP system. The study's quality was assessed using a 7-point Likert scale, ranging from "strongly disagree" to "strongly agree," along with five demographic questions using a nominal scale (Gender, Age, Position, Length of service, Length of service using the system, Education, and Department).

Research Instruments

The questionnaire includes an instrument with 22 items designed to measure the benefits of organizational accounting, the time-related benefits of organizational accounting, cost-related benefits of organizational accounting, managerial accounting benefits, IT accounting benefits, and ERP user satisfaction.

Table 1. List of Variables and Indicators

Variable		***Indicators and items***	***Source***
Benefits of Organizational Accounting	OAB01	Internal Communication Improvement	Spathis (2006), Shang and Sheddon (2002), Kanellou and Spathis (2013)
	OAB02	Improved Coordination between Departments	
	OAB03	Improved decision making based on timely and reliable accounting information	
	OAB04	Improved decision making process	
	OAB05	Improved integration of accounting applications	
Benefits of Operational Accounting (Time)	OAT01	Reducing the time required for monthly book closing	Spathis (2006), Shang and

Variable		*Indicators and items*	*Source*
	OAT02	Reduction in time required in *quarterly book Closing*	Seddon (2002), Nguyen *et.al* (2020)
	OAT03	Reducing the time required for annual book Closing	
	OAT04	Reducing the time required to issue financial Reports	
Benefits of Operational (Cost) Accounting	OAC01	Reduction of human resources in the accounting department	Kanellou and Spathis (2013)
	OAC02	Reducing paper usage in accounting dept.	
Benefits of Managerial Accounting	MAB01	Increased flexibility in generating information	Spathis (2006), Shang and Seddon (2002), Kanellou and Spathis (2013)
	MAB02	Improved working capital control	
	MAB03	Increasing use of financial ratio analysis	
Benefits Of IT Accounting	IAB01	ERP collects data faster	Spathis (2006), Shang and Seddon (2002), Kanellou and Spathis (2013), Nguyen *et al.* (2020)
	IAB02	ERP collects data more easily	
	IAB03	ERP reduces time in processing transactions	
	IAB04	ERP processes results more easily	
	IAB05	ERP is more flexible in general	
ERP User Satisfaction	EUS01	Are you satisfied with the information obtained by using the ERP system?	Delone and Mclean (2003), Doll and Torkzadeh
	EUS02	Are you satisfied with the interaction using the ERP system?	
	EUS03	ERP systems have eliminated significant errors or disruptions	
	EUS04	The ERP system has been satisfactory Overall	

Data Analysis Techniques

Data Quality Test

Prior to processing and analyzing the data, it is essential to test its quality to ensure that respondents have answered the questions accurately. In this study, validity and reliabilitywere assessed using the Statistical Package for the Social Sciences (SPSS).

Validity Test

To test the validity of the instrument, the researchers will use the Pearson Correlation test. This will measure the correlation between the values derived from the questions. The Pearson correlation is used to determine if there is a relationship between two variables. According to Ghozali (2016), the data is considered valid if the Pearson correlation value is below 0.05.

Reliability Test

Reliability testing is performed to evaluate whether the questionnaire consistently measuresthe same construct. Valid questions, as determined in the validity test, will undergo a reliability test, and the reliability coefficient will be calculated using the Cronbach alpha formula. A value greater than 0.70 indicates acceptable reliability (Ghozali, 2016).

Classical Assumption Test

Before hypothesis testing, classical assumption tests will be conducted as follows:

Normality Test

The purpose of the normality test is to assess whether the residuals or confounding variables in the regression model are normally distributed. According to Ghozali (2013), a well-fitting regression model should exhibit normal or nearly normal data distribution. The Kolmogorov-Smirnov test is performed with the following hypotheses, as stated by Ghozali (2016:158):

- H_0: The residual data is normally distributed if the sig. 2-tailed > α = 0.05
- Ha: The residual data is not normally distributed if the sig. 2-tailed < α = 0.05

3.5.2 Hypothesis Testing

Hypothesis testing aims to validate the truth of the proposed hypothesis. The followingmethod will be used for hypothesis testing:

3.5.2.1 Coefficient of Determination (R^2)

The coefficient of determination (R^2) indicates the extent to which the model explains the variation in the dependent variable. R^2 values range from zero to one, with lower values suggesting that the independent variables have limited explanatory power over the dependent variable. Higher R^2 values suggest that the independent variables account for most of the variation in the dependent variable.

3.5.4.2 Simultaneous Test (F Test)

The F test is used to determine whether the independent variables collectively influence the dependent variable (Ghozali, 2016:171). The decision criteria are as follows:

1. If the calculated F value is greater than the F table value, the hypothesis is rejected, indicating that the independent variables have a significant collective effect on the dependent variable.
2. Conversely, if the calculated F value is less than the F table value, the hypothesis is accepted, meaning the independent variables do not have a significant collective impacton the dependent variable.

3.5.4.3 Multiple Linear Regression Analysis

In research, data analysis is the process of identifying solutions to the research questions. This study uses multiple linear regression models to examine how independent variables influence the dependent variable. The goal of multiple linear regression analysis is to assess the strength and direction of the relationship between two or more variables. This analysis also indicates the direction of the relationship between the dependent and independent variables (Ghozali, 2016:93).

The multiple regression analysis conducted in this study employed the enter method with the following model:

$$\mathbf{Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 .X_3 + \beta_4 .X_4 + \beta_5 . X_5 + \varepsilon}$$

Information :

Y = System User Satisfactionα = constant coefficient
b = regression coefficient
X_1 = *Organizational Accounting*
X_2 = *Managerial Accounting*
X3 = *IT Accounting*
X4 = *Operational Cost Accounting*
X5 = Operational Accounting Time
ε = error coefficient (nuisance variable, assumed to be zero)

Partial Test (t Test)

The t-test is used to assess the influence of each independent variable on the dependent variable (Ghozali, 2016:171). The significance level applied in this test is 5%. The regressioncoefficient indicates the direction of the effect of each independent variable on the dependentvariable. To perform the test, the significance of the calculated t value is compared with the table t value. The decision criteria are as follows:

1. The independent variable has a significant influence on the dependent variable if thecalculated t value is greater than the table t value, resulting in the acceptance of Ha and the rejection of H_0.
2. Conversely, if the calculated t value is lower than the table t value, the independentvariable does not significantly affect the dependent variable.

4. RESULT AND DISCUSSION

Validity and Reliability Test

Validity and Reliability Test of Organizational Accounting Benefits

Table 2. Correlations,

Correlations

OAB01			OAB02	OAB03	OAB04	OAB05	Organizational Accounting Benefits
OAB01	Pearson Correlation	1	,870 **	,839 **	,865 **	,838 **	,942 **
	Sig. (2-tailed)		,000	,000	,000	,000	,000
	N	120	120	120	120	120	120
OAB02	Pearson Correlation	,870 **	1	,803 **	,811 **	,766 **	,904 **
	Sig. (2-tailed)	,000		,000	,000	,000	,000
	N	120	120	120	120	120	120
OAB03	Pearson Correlation	,839 **	,803 **	1	,898 **	,878 **	,945 **
	Sig. (2-tailed)	,000	,000		,000	,000	,000
	N	120	120	120	120	120	120
OAB04	Pearson Correlation	,865 **	,811 **	,898 **	1	,888 **	,955 **
	Sig. (2-tailed)	,000	,000	,000		,000	,000
	N	120	120	120	120	120	120
OAB05	Pearson Correlation	,838 **	,766 **	,878 **	,888 **	1	,936 **
	Sig. (2-tailed)	,000	,000	,000	,000		,000
	N	120	120	120	120	120	120
Organizational Accounting Benefits	Pearson Correlation	,942 **	,904 **	,945 **	,955 **	,936 **	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	
	N	120	120	120	120	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 1. Reliability Test

Reliability Statistics

Cronbach's Alpha	N of Items
,965	5

It can be seen in table 2, namely the results for the validity test show a figure for Pearson Correlation> 0.05 which can be concluded for the results of the Accounting Organization Benefits answer is Valid . Likewise with table 3, namely the results for the reliability test show a Cronbach's Alpha figure> 0.70, meaning that it can be said that the data for the Accounting Organization Benefits variable is Reliable.

Validity and Reliability Test of Operational Accounting Benefits (Time)

Table 3. Validity Test

Correlations

		OAT01	OAT02	OAT03	OAT04	Operational Accounting Benefits (Time)
OAT01	Pearson Correlation	1	,830 **	,856 **	,797 **	,927 **
	Sig. (2-tailed)		,000	,000	,000	,000
	N	120	120	120	120	120
OAT02	Pearson Correlation	,830 **	1	,881 **	,794 **	,937 **
	Sig. (2-tailed)	,000		,000	,000	,000
	N	120	120	120	120	120
OAT03	Pearson Correlation	,856 **	,881 **	1	,859 **	,959 **
	Sig. (2-tailed)	,000	,000		,000	,000
	N	120	120	120	120	120
OAT04	Pearson Correlation	,797 **	,794 **	,859 **	1	,923 **
	Sig. (2-tailed)	,000	,000	,000		,000
	N	120	120	120	120	120
Operational Accounting Benefits(Time)	Pearson Correlation	,927 **	,937 **	,959 **	,923 **	1
	Sig. (2-tailed)	,000	,000	,000	,000	
	N	120	120	120	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5. Reliability Test
Reliability Statistics

Cronbach's Alpha	N of Items
,952	4

It can be seen in table 3, namely the results for the validity test show a figure for Pearson Correlation> 0.05 which can be concluded for the results of the Operational Accounting Benefits (Time) Valid answer. Likewise with table 5, namely the results for the reliability test show a Cronbach's Alpha figure> 0.70, meaning that it can be said that the data for the Operational Accounting Benefits (Time) variable is Reliable.

Validity and Reliability Test of Operational Accounting Benefits (Cost)

Table 6. Validity Test of Operational Accounting Benefits (Costs)
Correlations

		OAC01	OAC02	Operational Accounting Benefits (Cost)
OAC01	Pearson Correlation	1	,761 **	,940 **
	Sig. (2-tailed)		,000	,000
	N	120	120	120
OAC02	Pearson Correlation	,761 **	1	,937 **
	Sig. (2-tailed)	,000		,000
	N	120	120	120
Operational Accounting Benefits (Cost)	Pearson Correlation	,940 **	,937 **	1
	Sig. (2-tailed)	,000	,000	
	N	120	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 2. Reliability Test of Operational Accounting Benefits (Costs)
Reliability Statistics

Cronbach's Alpha	N of Items
,864	2

It can be seen in table 6, namely the results for the validity test show a figure for Pearson Correlation> 0.05 which can be concluded for the results of the Operational Accounting Benefits (Cost) Valid answer . Likewise with figure 2, namely the results for the reliability test show a Cronbach's Alpha figure> 0.70, meaning that it can be said that the data for the Operational Accounting Benefits (Cost) variable is Reliable.

Validity and Reliability Test of Managerial Accounting Benefits

Table 7. Validity Test of Managerial Accounting Benefits
Correlations

		MAB01	MAB02	MAB03	Managerial accounting benefits
MAB01	Pearson Correlation	1	,779 **	,814 **	,935 **
	Sig. (2-tailed)		,000	,000	,000
	N	120	120	120	120
MAB02	Pearson Correlation	,779 **	1	,770 **	,917 **
	Sig. (2-tailed)	,000		,000	,000
	N	120	120	120	120
MAB03	Pearson Correlation	,814 **	,770 **	1	,927 **
	Sig. (2-tailed)	,000	,000		,000
	N	120	120	120	120
Managerial accounting benefits	Pearson Correlation	,935 **	,917 **	,927 **	1
	Sig. (2-tailed)	,000	,000	,000	
	N	120	120	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 3. Reliability Test of Managerial Accounting Benefits

Reliability Statistics

Cronbach's Alpha	N of Items
,917	3

It can be seen in table 7, namely the results for the validity test show a figure for Pearson Correlation> 0.05 which can be concluded for the results of the Managerial Accounting Benefits answer is Valid . Likewise with figure 3, namely the results for the reliability test show a Cronbach's Alpha figure> 0.70, meaning that it can be said that the data for the Managerial Accounting Benefits variable is Reliable.

Validity and Reliability Test of IT Accounting Benefits

Table 8. IT Accounting Benefits Validity Test

Correlations

		IAB01	IAB02	IAB03	IAB04	IAB05	IT AccountingBenefits
IAB01	Pearson Correlation	1	,841 **	,870 **	,785 **	,721 **	,925 **
	Sig. (2-tailed)		,000	,000	,000	,000	,000
	N	120	120	120	120	120	120
IAB02	Pearson Correlation	,841 **	1	,883 **	,717 **	,763 **	,927 **
	Sig. (2-tailed)	,000		,000	,000	,000	,000
	N	120	120	120	120	120	120
IAB03	Pearson Correlation	,870 **	,883 **	1	,811 **	,785 **	,955 **
	Sig. (2-tailed)	,000	,000		,000	,000	,000
	N	120	120	120	120	120	120
IAB04	Pearson Correlation	,785 **	,717 **	,811 **	1	,687 **	,872 **
	Sig. (2-tailed)	,000	,000	,000		,000	,000
	N	120	120	120	120	120	120
IAB05	Pearson Correlation	,721 **	,763 **	,785 **	,687 **	1	,874 **
	Sig. (2-tailed)	,000	,000	,000	,000		,000
	N	120	120	120	120	120	120
IT Accounting Benefits	Pearson Correlation	,925 **	,927 **	,955 **	,872 **	,874 **	1
	Sig. (2-tailed)	,000	,000	,000	,000	,000	
	N	120	120	120	120	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4. IT Accounting Benefits Reliability Test

Reliability Statistics

Cronbach's Alpha	N of Items
,947	5

It can be seen in table 8, namely the results for the validity test show a figure for Pearson Correlation> 0.05 which can be concluded for the results of the IT Accounting Benefits answer are Valid . Likewise with figure 4, namely the results for the reliability test show a Cronbach's Alpha figure> 0.70, meaning that it can be said that the data for the IT Accounting Benefits variable is Reliable.

Validity and Reliability Test of ERP User Satisfaction

Table 9. Validity Test of ERP Usage Satisfaction

Correlations

		USO1	USO2	USO3	USO4	ERP User Satisfaction
USO1	Pearson Correlation	1	,871 **	,878 **	,866 **	,952 **
	Sig. (2-tailed)		,000	,000	,000	,000
	N	120	120	120	120	120
USO2	Pearson Correlation	,871 **	1	,846 **	,827 **	,933 **
	Sig. (2-tailed)	,000		,000	,000	,000
	N	120	120	120	120	120
USO3	Pearson Correlation	,878 **	,846 **	1	,948 **	,963 **
	Sig. (2-tailed)	,000	,000		,000	,000
	N	120	120	120	120	120
USO4	Pearson Correlation	,866 **	,827 **	,948 **	1	,955 **
	Sig. (2-tailed)	,000	,000	,000		,000
	N	120	120	120	120	120
ERP User Satisfaction	Pearson Correlation	,952 **	,933 **	,963 **	,955 **	1
	Sig. (2-tailed)	,000	,000	,000	,000	
	N	120	120	120	120	120

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 5. ERP User Satisfaction Reliability Test

Reliability Statistics

Cronbach's Alpha	N of Items
,964	4

It can be seen in table 8, namely the results for the validity test show a figure for Pearson Correlation> 0.05 which can be concluded for the results of the ERP User Satisfaction answer is Valid . Likewise with figure 5, namely the results for the reliability test show a Cronbach's Alpha figure> 0.70, meaning that it can be said that the data for the ERP User Satisfaction variable is Reliable.

Normality Test

Table 10. Normality Test

One-Sample Kolmogorov-Smirnov Test

				Unstandardized Residual
N				120
Normal Parameters [a,b]	Mean			,0000000
	Std. Deviation			1.35068682
Most Extreme Differences	Absolute			,100
	Positive			,100
	Negative			-,084
Test Statistics				,100
Asymp. Sig. (2-tailed)				,005 [c]
Monte Carlo Sig. (2-tailed)	Sig.			,169 [d]
	99% Confidence Interval		Lower Bound	,159
			Upper Bound	,178

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. Based on 10000 sampled tables with starting seed 2000000.

Based on the results of this normality test, it can be seen from the Sig (2-tailed) value > 0.05, so the results of this test can be concluded that the distribution of this data is normal or in other words, the distribution of answers to this questionnaire is normally distributed.

Test of Determination Coefficient

Figure 6. Determination Coefficient Test

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,973 [a]	,947	,944	1,380

a. Predictors: (Constant), Organizational Accounting IT Accounting Benefits, Benefits, Managerial Accounting Benefits , Operational Accounting Benefits (Cost), Operational Accounting Benefits (Time)
b. Dependent Variable: ERP User Satisfaction

It can be seen in Figure 15 that the value for R Square is 0.947. Where the number is close to 1, which means that the independent variable has the ability to provide the information needed to predict the dependent variable.

Partial Test (T Test)

Table 11. T-test

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-,950	,542		-1,752	,082
	of Organizational Accounting	,180	,044	,208	4,054	,000
	Benefits of Operational Accounting (Time)	,252	,061	,254	4,143	,000
	Benefits of Operational (Cost) Accounting	,437	,105	,207	4,167	,000
	Benefits of Managerial Accounting	,201	,065	,133	3,098	,002
	Benefits of IT Accounting	,197	,055	,245	3,616	,000

a. Dependent Variable: ERP User Satisfaction

The T-test value (Table) for 120 respondents is 1,658 while the T-test value (Count) in the SPSS application is 4,054, 4,143, 4,167, 3,098, 3,616. so it can be concluded that the T-test (Count)>

T-test (Table) then partially each independent variable affects the dependent variable. And the value is positive, thus the independent variable has a positive effect on the independent variable.

Simultaneous Test (F Test)

Table 12. F test

ANOVA [a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3860,068	5	772,014	405,390	,000 [b]
	Residual	217,098	114	1,904		
	Total	4077,167	119			

a. Dependent Variable: ERP User Satisfaction
b. Predictors: (Constant), IT Accounting Benefits , Organizational Accounting Benefits , Managerial Accounting Benefits , Operational Accounting Benefits (Cost), Operational Accounting Benefits (Time)

Based on the data we obtained as in Figure 16. That the calculated F value > F table. So it can be concluded that the Benefits of Using ERP have a simultaneous effect on ERP User Satisfaction.

CONCLUSION AND RECOMMENDATIONS

The results of the calculations and tests on several samples examining the impact of ERP accounting system benefits on ERP user satisfaction from the perspectives of auditors and accountants indicate that the independent variables—Organizational Accounting Benefits, Operational Accounting Benefits (Cost), Operational Accounting Benefits (Time), Managerial Accounting Benefits, and IT Accounting Benefits—all have a positive and significant effect on ERP system user satisfaction. These findings align with previous studies, such as Saaticoglou (2009), Kanellou and Spathis (2013), and Weli (2018).

This study demonstrates that the benefits of using the accounting system significantly influence ERP user satisfaction, with positive implications. The ERP system proves to be beneficial to the company, especially in the accounting domain.

A limitation of this study is the challenge of recruiting respondents, as it is restricted to accountants and auditors. ERP users in Indonesia are relatively few, and this study specifically focuses on accountants and auditors. Future research could consider expanding the subject pool to include other departments, such as warehouse, sales, marketing, or HR, to explore whether they experience similar benefits from using their ERP systems.

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CHAPTER 2

Spatial and Cultural Significance Study in Jakarta Old Chinatown: Urban Acupuncture Approach to Enhance Tourist Attraction of Glodok

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ABSTRACT

Founded as a commercial center during the Dutch colonial era, Glodok, Jakarta's Old Chinatown, has a rich cultural legacy distinguished by distinctive Chinese architecture with elements like dragon motifs and curving roofs. The area's historical significance and multicultural identity are reflected in notable landmarks like the Santa Maria de Fatima Church and the Dharma Bhakti Temple. Particularly during holidays like Chinese New Year and Cap Go Meh, Glodok's thriving economy—which includes stores selling gadgets, traditional Chinese products, and unique gastronomic offerings—increases its allure as a travel destination. However, its growth as a sustainable attraction is hampered by infrastructure issues such a lack of green spaces, pedestrian areas, and sanitary facilities. An urban acupuncture method pinpoints important areas for improvement in order to maximize Glodok's potential as a destination for cultural and gastronomic tourism. The commercial and cultural appeal of places like the Chinatown Market, Jalan Pancoran, Petak Sembilan, and Jalan Kemenangan Raya can be increased with targeted upgrades. Reviving the busy Jalan Gajah Mada corridor and preserving heritage monuments like the Dharma Bhakti Temple and Santa Maria de Fatima Church through infrastructural improvements are essential. Glodok's growth plan aims to make it a "GLOCAL CHINA-TOWN," fusing the local way of life with the allure of foreign travel. Initiatives center on public infrastructure improvements, green spaces, cultural preservation, and trade-friendly zoning. Prioritizing cultural events, community involvement, and thorough infrastructure renovation promotes local company expansion and maintains cultural authenticity. Glodok may develop into a vibrant, sustainable tourism destination that enhances its cultural heritage and economic vitality by integrating strategic interventions and public engagement. This all-encompassing strategy enhances local and international ties while guaranteeing a competitive, lively tourism experience.

Keywords: Urban Acupuncture, Chinatown, Glodok Jakarta, Heritage Tourism, Glocal Chinatown.

1. INTRODUCTION

Glodok Chinatown is an area in the old part of Jakarta, Indonesia that is filled with cultural richness, historical heritage, and distinctive urban dynamics. As one of the oldest areas in the history of Jakarta, Glodok holds a significant place in Indonesian Chinese history and culture. Like Chinatowns in other colonial cities, Glodok has become a center of trade which is the main activity of ethnic Chinese who have migrated to various cities around the world. This is marked by the existence of shophouses as a characteristic of overseas Chinatown buildings, temples as places of worship as well as social centers, markets as centers of economic activity, and small alleys with a typical atmosphere of ethnic Chinese life (Andiani & Ekomadyo, 2021; Sulistyo, 2021). The cultural richness of Glodok is formed by the combination of historical buildings, places of worship, traditional markets, and distinctive traditional cuisine, making it an attraction for visitors. With its unique cultural characteristics, Glodok is a trading center and a tourism destination with the potential to develop historical and cultural tourism (Alfandi & Krisnadi, 2023; Andini & Dewi, 2022). Glodok tourism has become more important because of its role in creating cross-generation cultural interactions and increasing visits by local as well as foreign tourists. The government, businesses and local communities have tried to transform Glodok into a more contemporary cultural tourism destination and encourage local economic growth without erasing the area's significance as an important part of Jakarta's history by organizing various events such as cultural festivals and restoration of historic buildings (Andini & Nugraha, 2023).

However, despite its rich historical and cultural heritage, Glodok faces several issues that involve traffic congestion, the decay of historic structures, and inefficient utilization of public areas. Glodok's growing tourism industry may be an attempt to protect the area's cultural legacy while boosting the local economy and community involvement. Increasing tourism in Glodok can be an effort to preserve cultural heritage while encouraging economic growth and community engagement. Tourism plays a vital role in revitalizing the economy and culture of many cities. Enhancing Glodok’s attractiveness as a tourist destination can boost local economic growth, increase visitor numbers, and support the preservation of its cultural heritage(Andini & Dewi, 2022; Andini & Nugraha, 2023). In order to achieve this goal, this requires creative urban design strategies that go beyond conventional development models and more focus on local interventions. At this point, urban acupuncture becomes a potential method that can make a significant development.

Urban acupuncture is a method of urban design by intervention that focuses on strategic actions to drive positive change in a wider area. Urban acupuncture's procedural definition is to stimulate the city's significant points or places using low-cost, small-scale techniques that penetrate the city's skin to activate and revive it (after analyzing the city's social, economic, and cultural aspects). This will restore the energy and have a positive effect that spreads upward between the city's segments and throughout the entire city (Salman & Hussein, 2021). Taking inspiration from medical practice, this concept aims to trigger positive development in urban areas through small yet precise interventions at strategic “pressure points” that have a rippling impact on the surrounding area so that it can save more cost and time by dealing on smallest point for largest impact (Apostolou, 2018; Harjoko, 2009; Nassar, 2021). This technique is similar to needles that "prick" vital points of the body to restore the flow of energy; urban acupuncture targets specific areas as "acupuncture points" to improve the dynamics of the surrounding social, cultural, and ecological environment. In practice, urban acupuncture focuses on specific points and optimizing the potential of existing assets, increasing social cohesion, and developing the city’s fabric sustainably rather than concentrating on large-scale transformation.

The urban acupuncture approach is best implemented in areas with high intensity of buildings and activities where large-scale development is not possible, such as in Glodok. Thus,

a delicate and executable intervention at small strategic points can have significant effects. This method proved to be quite successful in revitalizing public spaces and areas that have experienced degradation of physical and socio-economic environmental quality (Apostolou, 2018; Daugėlaitė & Gražulevičiūtė - Vileniškė, 2018; Margono & Zuraida, 2019). This study aims to analyze the potential of Glodok Chinatown through an urban acupuncture approach by identifying important intervention areas that can stimulate the vitality of the area as a whole to encourage sustainable tourism growth that is in line with its spatial and cultural characteristics. More specifically, this study includes three specific objectives. First, to identify "pressure points" that can become more attractive and useful as a tourist destination. Second, it will look at how urban acupuncture interventions can balance modern development with cultural heritage preservation and ensure that the essence of Glodok is maintained while meeting contemporary urban needs. Finally, this study will look at how urban connectivity and community involvement can drive the Glodok area to become a more attractive tourist destination for local and foreign tourists. By implementing this concept, it is expected to unlock the potential in Glodok, creating a more attractive destination that has significant cultural value for visitors and locals.

2. LITERATURE REVIEW

Urban Acupuncture as an Urban Design Approach

Acupuncture is an alternative medicine technique that involves inserting thin needles into specific points on the body (called acupuncture points). This method was created and developed in China more than 2,000 years ago and used throughout the whole world as an alternative and complementary therapy (Salman & Hussein, 2021). Urban acupuncture is an urban design concept with a primary approach of small, focused interventions that can trigger major transformations in urban environments. This approach was initially offered by a theorist named Manuel De Sola-Morales in 2004 (Casagrande, 2020), and was employed more systematically by Jaime Lerner, who targeted four acupuncture points, i.e., transportation, affordable housing, parks, and recycling, to benefit the entire city (Baumgardt, 2021; Lerner, 2016). Lerner stated that appropriate minimal handling in strategic locations can have a positive effect on the surrounding area and improve its viability. In contrast to large-scale development approaches that are top-down, urban acupuncture emphasizes small-scale initiatives that respect the identity and needs of existing communities (Hemingway & De Castro Mazarro, 2022; Main, 2016; Pascaris, 2012). Urban acupuncture aims to improve the vitality of urban spaces by targeting strategic acupuncture "points" without the need for expensive and time-consuming large-scale development (Salman, 2021; Lerner, 2014).

The urban acupuncture approach involves implementing small-scale projects with a large impact on the social, cultural, and economic environment of an area. Using low-cost small-scale methods that penetrate the city's skin to awaken and invigorate it, urban acupuncture's procedural definition is to stimulate the city's primary points after studying the city's social, economic, and cultural characteristics. Restoring the energy of a strategic point will have a positive impact that ripples up to the city's various sections and across the city as a whole. Contextual awareness, community involvement, cultural responsiveness, and sustainable methods are among the fundamental tenets of urban acupuncture. Therefore, the implementation of urban acupuncture is often combined with urban design principles and modern technologies such as digital social networks to create significant social change in urban areas (Salman & Hussein, 2021).

Urban Acupuncture in Enhancing Tourism Attractiveness

In the context of tourism, urban acupuncture can be used to enhance the appeal of tourist destinations by revitalizing forgotten or declining spaces. Urban acupuncture can be used to

increase the attractiveness of destinations by targeting strategic “points” such as public spaces that are appropriate for the community and visitors.Some practices and studies show that this strategy can create public spaces that are engaging, interactive, and tailored to the needs of the community and tourists, emphasize that urban acupuncture can revitalize “sick” or “tired” areas of a city through small, effective interventions, creating positive reactions that extend throughout the neighborhood (Moskow & Linn, 2010). Urban acupuncture offers a cost-effective and community-oriented solution to strengthen the tourism appeal of an area. With this approach, public spaces, cultural facilities, or other aesthetic elements can be renewed in a way that highlights local cultural identity, enhances social interaction, and creates unique experiences for tourists (UN Habitat, 2020). Interventions with an urban acupuncture approach can revitalize the historic city center, increasing the social, economic, and environmental vitality of the area. (Bell et al., 2007; Daugėlaitė & Gražulevičiūtė - Vileniškė, 2018; Harjoko, 2009; Hemingway & De Castro Mazarro, 2022; Tousi et al., 2022). Another example that shows the effectiveness of urban acupuncture is in developing low-carbon tourism villages. A study highlighted that cultural and spatially oriented interventions in the context of rural tourism can reduce carbon emissions and increase tourist appeal through more sustainable management (Opačić, 2019). This proves that the application of the urban acupuncture approach can help improve physical appeal while creating added value for local communities. Additionally, this approach proved to be quite powerful in activating and re-functioning underutilized urban spaces by encouraging social interaction and community involvement. Urban acupuncture can improve the relationship between locals and their urban spaces by utilizing social networks and digital engagement. This enhances the visitor experience and raises the destination's attractiveness (Houghton et al., 2015). In general, with a targeted, sustainable, and community-based strategy, urban acupuncture can be a potent instrument to revive and enhance a certain area's appeal to tourists.

Spatial Planning and Tourism

Spatial planning is in essence the coordination of the relationship between humanity and space and is used to mitigate the consequences of human and economic activities including tourism activities. Planners have to deal with a number of concerns such as land use, transport and other infrastructural development, conservation of cultural and natural resources and the environment, urbanization, provision of social amenities and infrastructure among others. It follows that spatial purchasing power cannot be overlooked due to its relevance in the area of social or economic issues wherein various fields may include urbanism, geography, tourism, architecture and others. Spatial planning finally becomes a relevant concept in defining and understanding the full impact of tourism in a tourist spot, as well as tourism planning in terms of the local environment and communities. Natural resources, social infrastructure, the population and their activities constitute elements of spatial planning and therefore cannot be alienated from tourism, while infrastructure and tourism activities taking place within specific geography are spatial in nature and hence tourism planning should be included in spatial planning processes at different levels (Sivac & Banda, 2016). In particular, spatial planning is the most critical step in the process of tourism of sustainable development. It was mentioned that, in general, the benefits of spatial planning are economic, social and environmental. The benefits of spatial planning for the advancement of sustainable tourism include: 1) financial benefits through ensuring the quality of nature to create conditions that support investment activities while still trying to meet the needs of the surrounding community; 2) social benefits by paying attention to community needs and supporting social order, maintaining safe and healthy conditions; and 3) natural benefits from the restoration and utilization of appropriate land and buildings, maintaining the sustainability of biological and social resources,

maintaining the sustainability of public buildings, empowering energy savings and energy productivity. (UN, 2008).

The process of tourism of sustainable development is closely linked with the principles of environmental protection and, as such, includes a spectrum of different research activities and studious analysis of geo-ecological processes, an analysis of natural laws, and regularities in specific areas. Attitudes towards the concept of sustainability in tourism vary, and according to some authors, this concept identifies with the process of intensification of tourist activities in the area, while other authors have diametrically opposed opinions and understand this concept as an alternative tourism, and they strongly oppose the development of mass tourism. This is to state that, according to Hunter (1997), it is hard to see how any approach to sustainable tourism could be formulated or implemented in the absence of strong local-including regional-authority planning and development control and without the involvement of local communities in the planning process to some degree. One of the main solutions for a number of problems that may occur in tourism resources management is tourism planning. Identification and evaluation of tourism resources, increased revenues, reduced costs-this respecting a holistic attitude towards the environment. Hall, 2008, believes it is about defining the roles and relationships of various control mechanisms to operate in all levels that are included in the process of tourism planning, including local and national ones. It also includes within the control system, the involvement of the local communities in the decision-making process. The local community is the first link in the complexed tourism planning process; thus, their consideration of views is very important for the residential population. Interests of all stakeholders have to be reconciled, and cooperation among them is necessary for the purpose of carrying through a successful planning process. According to Ministerial Regulation No. 14/2016, which adopts the Global Tourism for Sustainable Development (GTSD) guidelines, tourism must preserve culture, empower locals, and safeguard the environment. According to recommendations released by the World Tourism Organization (UNWTO) in 2005, sustainable tourism needs to consider the needs of locals, businesses, and the environment in addition to the economic, social, and environmental effects that it will have now and in the future (Basbeth, 2024).

3. RESEARCH METHOD

The study was conducted to answer three questions related to the development of Glodok Chinatown tourism potential using the urban acupuncture approach. First, what are the prospects and obstacles in improving the tourist attractions of the Glodok area using the urban acupuncture method? Second, what are the strategic problems in Glodok that can be fixed to maximize tourism potential, increase cultural values, and improve relationships around it? Third, how can urban acupuncture interventions help maintain culture and sustainable development in Glodok? This study focuses on spatial and cultural analysis using an urban acupuncture approach. The research framework consists of several stages:

1. Literature Review and Conceptualization: The study begins with a literature review on urban acupuncture theory as a theoretical basis and its application in developing tourist destinations. As a conceptual framework for this study, relevant literature on spatial theory in tourism and cultural preservation studies in Chinatown areas will be used.
2. Data Collection which includes Primary and Secondary data. Primary Data is collected through field surveys and interviews with local stakeholders such as communities, traders, tourists, and local governments in Glodok, while Secondary Data is obtained from government documents, historical archives, city spatial plans, and research on tourism planning and revitalization in historical areas.
3. Spatial Analysis and Acupuncture Point Identification: Spatial analysis techniques are used to find strategic points in Glodok that have the greatest potential for intervention. The

aspects analyzed include accessibility and connectivity, quality and functionality of public space that can be optimized to attract visitors; cultural and historical significance or values of the area that can be the main attractions of the area.

4. Implementation and Simulation of Urban Acupuncture Intervention: After identifying the pressure points, the study will simulate an urban acupuncture intervention. Revitalization of public spaces, creation of thematic tourism trails, and strengthening cultural connections through community-based activities and infrastructure are all part of this intervention.

4. RESULT AND DISCUSSION

4.1 Overview of Glodok Chinatown

History of Glodok

Glodok is one of the oldest Chinatowns in Jakarta and has been the center of trade for the Chinese community since the Dutch colonial era. Established as a special settlement for ethnic Chinese after the “Geger Pecinan” incident in 1740 (Lestari & Tohjiwa, 2023), Glodok became the center of Chinese culture and economy in Jakarta, with significant development in terms of social, cultural, and economic. The Glodok City area has experienced a very substantial change in spatial pattern, as shown in Figure 1.

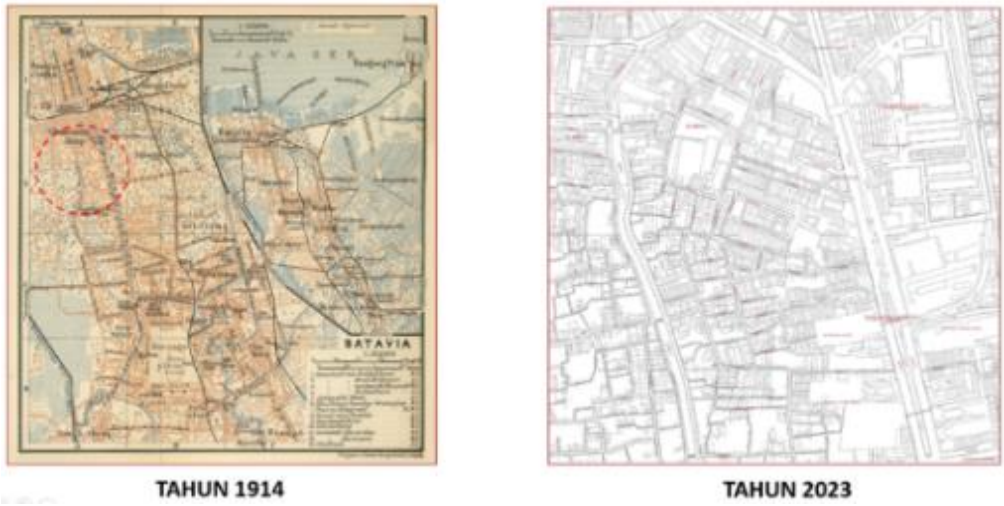


Figure 1. Map of Glodok City in 1914 and 2023
Source: Pemda DKI; cadmapper, 2023

The Chinatown area of Glodok or what was once called Pancoran Glodok has strong historical roots related to the Dutch colonial period in Indonesia. In the 17th century, VOC (Vereenigde Oost-Indische Compagnie) established the area as a trading center, especially for the commodities of spices that were very valuable at that time (Leonardo & Ratnaningrum, 2020) The word “Pancoran” itself comes from "shower" which was an identity during the VOC occupation, where the area had a water reservoir to meet the water needs of Batavia residents. In its development, this area was used as a place to live by the Chinese, especially after the massacre of ethnic Chinese in Jakarta by the VOC in 1740 (Lestari & Tohjiwa, 2023; Shodiq, n.d.). The locality of urban villages in Jakarta is important to understand as a basic character that cannot be eliminated. Likewise, the Chinatown area is a part of the development of Jakarta.

Formation of the Chinese Community

People from different parts of China came to Indonesia with different cultures and languages. Most of them married women from other parts of Indonesia, resulting in a cross-culture that is very different from the culture that developed in China. Ultimately, they communicate using Malay interspersed with words from the Minnan dialect (Clement &

Mustaram, 2023). The Dutch colonial government established a tradition of dividing Indonesian society based on race and ethnicity, where the Chinese community at that time was placed as a separate group, which required them to live in special villages and also to apply for permits if they wanted to travel to other areas, which caused some of them to remain as a group of people who were different from the Chinese and other Indonesians (Andiani & Ekomadyo, 2021). The realization of differences that occurred in the early 1900s increased the nationalistic spirit of the Chinese community, and at the same time they replaced the word "Chinese" with "Tionghoa". Amid the assimilation policy, the New Order government forced the Chinese community to remember their identity and required them to be ready to show the Surat Bukti Kewarganegaraan Republik Indonesia (SBKRI); where their identity cards were given special markings (Andiani & Ekomadyo, 2021). Such policies have certainly strengthened the awareness of the Chinese community as an ethnic group distinct from Indonesian society.

The Chinatown neighborhood was usually a mix of residential, retail, and market buildings that defined the land use. The architectural design of certain structures in Chinatown demonstrates a distinctive fusion of Indische Tropical and Chinese architectural features. The characteristic block/lot layout found in a number of Indonesian Chinatowns is typified by slender plots that stretch to the back. The typical city pattern that existed in Batavia after Dutch colonial rule overlapped with the city pattern of the Dutch Indies. Nonetheless, the city's spatial organization exhibits social stratification according to the involvement of ethnic groups in economic activity when it comes to functional zoning (Purwaningsih et al., 2024).

Architectural and Cultural Heritage

The thickness of Chinese culture in this area can be seen from the existence of various historical buildings that still stand firmly and cultural festivals that are still held in the Glodok Chinatown. Historical buildings that are strong evidence of the presence of ethnic Chinese in Glodok include *Dharma Bhakti Temple (Jin De Yuan Temple), Toa Se Bio Temple, Tan Seng Ong Temple (Tanda Bakti Temple), Fat Cu Kung Temple, Pak Kung Altar, Santa Maria De Fatima Church, Ricci School, Pantjoran Tea House, Chandra Naya Building,* and various buildings scattered in Petak Sembilan (Andini & Nugraha, 2023).

Spatial and Infrastructure Conditions

Glodok Chinatown has rich spatial potential with many historic buildings. In contrast, much of the infrastructure in the area is deteriorating, with many of the narrow streets being used by pedestrians alongside street vendors' stalls.

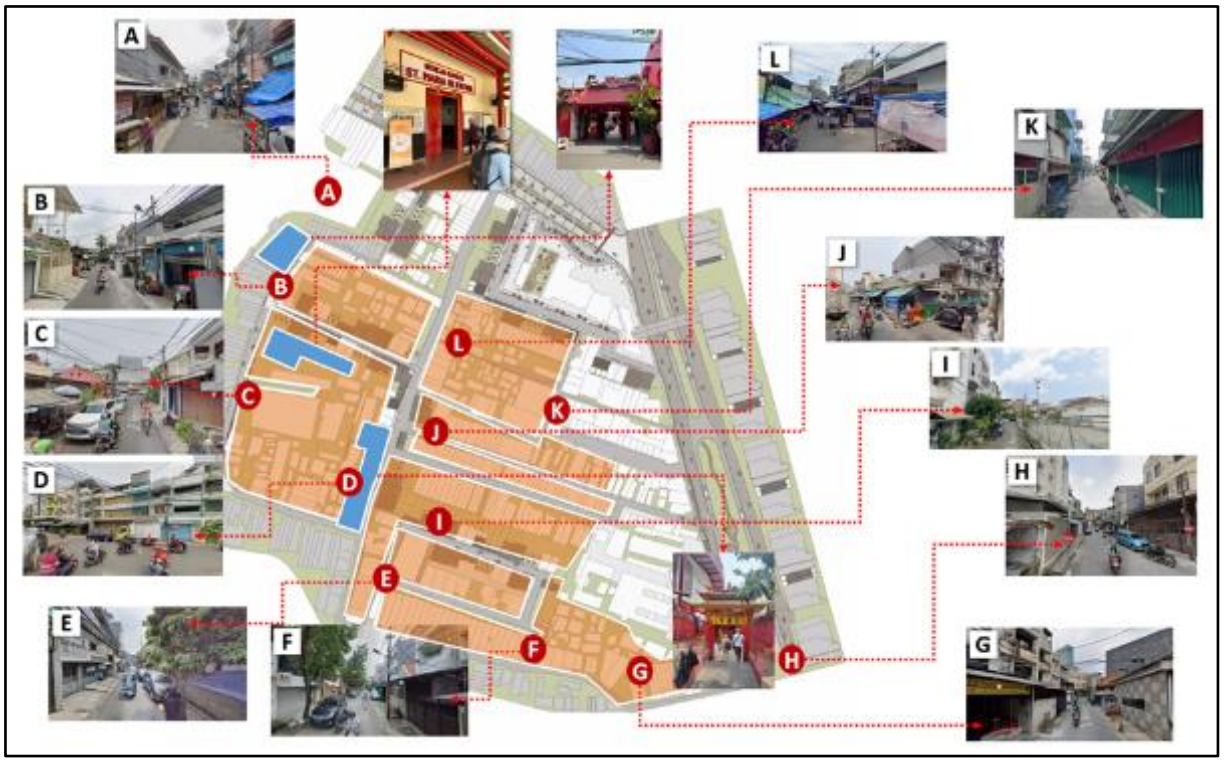


Figure 2. Map of Spatial Condition in Glodok

As it is shown in Figure 2. Glodok is a place with various historical buildings that illustrate the traces of Chinese culture in Jakarta, which are scattered at various important points, including *Jin De Yuan Temple (Kim Tek Ie), Traditional Shops at Petak Sembilan Market, Colonial Buildings Along Pancoran Street*. Some of these buildings are starting to wear out and are in need of repair so that they can still be enjoyed as cultural heritage. The road and sidewalk network in Glodok presents major challenges in terms of convenience and mobility for tourists, such as *the streets of Petak Sembilan* have narrow streets that are congested with pedestrian, vehicular, and street vendor traffic, which often obstructs traffic flow and creates congestion that reduces visitor comfort. Most of the sidewalks in the Glodok area are narrow and poorly maintained. There are not enough sidewalks to accommodate tourists, not to mention the large number of street vendors that occupy most of the sidewalks. This causes visitors to have to walk on roads filled with vehicles, making them accident-prone and less comfortable. An organized and integrated path is urgently needed to help tourists explore the area without any difficulties. Public facilities in Glodok are still less supportive of meeting the needs of tourists. Currently, Glodok does not have enough parking lots to accommodate tourists' vehicles. As a result, vehicles park haphazardly on narrow streets, worsening the congestion. Moreover, there are littering issues everywhere, creating an unsightly appearance and reducing visitor comfort. Glodok has almost no green open space or seating for tourists who want to take a break. Much of the area lacks sufficient lighting, which makes the streets dark and potentially unsafe.

Current Attractions in the Glodok Area

Glodok Chinatown is one of the capital's most fascinating cultural tourism destinations. As it shows many tourist attractions are held in Glodok. First, History and Religious Tourism contains various historical temples, such as *Jin De Yuan Temple (Kim Tek Le)* and *Vihara Dharma Bhakti*, as both of them are famous for their authentic traditional Chinese architecture with ornamental details full of symbolic meaning. Glodok has many old buildings that reflect

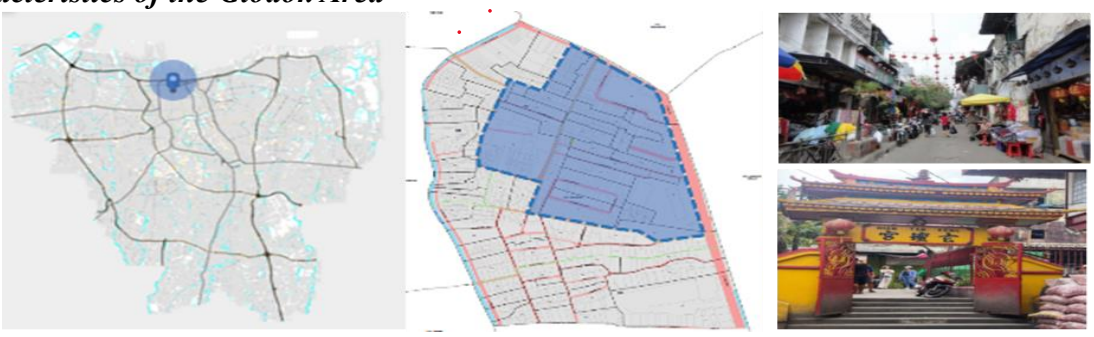
the history of the Chinese community in Jakarta, including some colonial-style buildings that bear witness to the relationship between the Chinese community and the Dutch government in the past. Jalan Pancoran, for example, has many buildings with ancient facades that are an attraction for visitors interested in historical architecture. Amongst the historic buildings in Glodok are many narrow alleys that provide an authentic and different atmosphere from the major streets of Jakarta. These alleys are often decorated with Chinese lanterns and decorations, creating a distinctive and interesting atmosphere to explore. Second, the Traditional Culinary Tour occurs in Petak Sembilan Market and its surrounding area. This market is a traditional culinary center in Glodok, where tourists can find a variety of Chinese food and spices, and herbal medicines. One of the popular culinary spots in Glodok is *Kedai Kopi Es Tak Kie* which has been serving legendary coffee since 1927. Moreover, many street vendors are offering Chinese specialties such as traditional pastries, fried dumplings, and other unique snacks. Third, Traditional Shopping Attractions which means Glodok has many shops selling Chinese trinkets, such as Buddha statues, red lanterns, Chinese calligraphy, and various accessories and decorations for Chinese New Year celebrations. Fourth, Cultural Celebrations and Events mark special moments in the Chinese Calendar, such as *Chinese New Year and Cap Go Meh celebrations*, the *Lion Dance Festival, and Other Performing Arts*. Fifth, the Cultural Educational Attractions program includes Calligraphy and Chinese Language Classes and visiting the Prayer Paper Shop to buy "heavenly banknotes" used in Chinese religious rituals. One of the main attractions of cultural tourism in Glodok is the interaction with the Chinese community who live and trade in the area. Although dominated by the Chinese community, Glodok is an interesting example of cultural diversity and harmony in Jakarta. Travelers can witness how the Chinese community interacts and coexists with people from other cultural backgrounds. This diversity is a special attraction for tourists who want to understand social harmony in Indonesia.

4.2 Urban Acupuncture Analysis in Glodok

Planning Location

The Glodok area is located on Jalan Pancoran RT 2/ RW 1, Glodok, Taman Sari District, West Jakarta. This area is known as the center of the Chinese community in Jakarta and has a long history since the colonial era. Its main function is trade, especially with the Chandra Glodok Building, an old building that is the oldest shopping center in Jakarta, as well as restaurants and shophouses as places to shop for Chinese goods and food. In addition, it is also a place of worship for the Chinese community with the presence of a temple. There are culinary tourism spots such as Petak Enam located in the Chandra Glodok Building, offering a variety of Chinese food and drinks. There are typical Chinese buildings and a combination of Chinese-style buildings with modern buildings (Figure 3).

Characteristics of the Glodok Area



(a) Map of Jakarta Province (b) Glodok Subdistrict Map (c) Temple and shop

Figure 3. Planning Location
Source: Jakarta Satu and survey results, 2023

Based on the results of the 2023 survey, the physical characteristics of the Glodok area are the presence of distinctive building architecture with Chinese touches, such as curved roofs, dragon ornaments, and bright colors that are predominantly red and gold. These buildings reflect Chinese cultural heritage and are a strong visual attraction. In addition, it has many historical buildings, including temples such as the Dharma Bhakti Temple and the Santa Maria de Fatima Church, which are symbols of cultural diversity and harmony. Meanwhile, the building typology is dominated by row buildings such as shops selling electronic goods, traditional medicines, and typical Chinese knick-knacks. This market infrastructure is important for daily economic activities (Figure 4).

Figure 4. Physical Characteristics
Source: survey results, 2023

As for the characteristics of the activities, the Glodok area is a heaven for culinary lovers, with a variety of traditional Chinese cuisines. This culinary activity is one of the main attractions for local and international tourists. The Glodok area is often the center of cultural celebrations such as Chinese New Year and Cap Go Meh, colored by barongsai performances, fireworks, and cultural parades. These celebrations attract many visitors and create a festive atmosphere. Trading activities in the Glodok Chinatown Market are very busy, with many traders offering various goods ranging from electronics to antiques. This trading activity is an important part of the local economy (Figure 5).

Figure 5 Typical Chinese New Year and Cap Go Meh foods and activities in Glodok
Souce : https://tirto.id/semarak-festival-pecinan-di-glodok-dhm3

Glodok is rich in historical and cultural values that are reflected in its architecture and the community life. This environment provides an authentic experience for tourists who want to experience Chinese culture in Indonesia. Although some parts still need improvement, the sidewalks and public spaces in Glodok Chinatown are important for pedestrian activities and social interaction. However, to improve the quality of the environment, the development of green spaces and parks along with security and cleanliness are crucial (Figure 6).

Figure 6 Environmental Characteristic
Source : survey results, 2023

Identification of Acupuncture Points

Acupuncture points are specific areas or locations in an urban environment that require intervention because they are in less than optimal condition or face significant problems. Interventions at these acupuncture points aim to improve, enhance, or optimize urban conditions, so that they can have a broader positive impact. Acupuncture points are selected based on their potential to stimulate urban regeneration, such as areas with degraded infrastructure or reduced community activity. The focus is on implementing small projects, such as green spaces or recreational areas, that can lead to broader urban revitalization. The acupuncture points in the form of buildings and road corridors include: 1) Pecinan Market and Pancoran Street Corridor; 2) Petak Sembilan and Kemenangan Raya Street Corridor; 3) Dharma Bhakti Temple; 4) Santa Maria de Fat ima Church; 5) Gajah Mada Street Corridor (Figure 7).

Figure 7 Characteristics of Glodok Acupuncture Points

Source: Survey Results, 2023

The acupuncture points in Glodok Chinatown that are relevant to the rules of urban acupuncture are following the criteria of acupuncture points. Based on a field survey, the location, potential and problems can be identified as follows :

a. Chinatown Market and Pancoran Street corridor known as a historical trading center, especially in the trade of electronic goods, traditional medicines, and Chinese knick-knacks. This market is also popular for its various Chinese culinary specialties, such as siomay, bakmi, and traditional cakes. The problem is that inadequate infrastructure can be an obstacle to further development. Improvement of infrastructure such as roads, parks, and

public facilities is needed to improve visitor comfort. Uncontrolled development can threaten the authenticity and uniqueness of Glodok Chinatown culture (Figure 8).

Figure 8 Condition of Petak Sembilan Corridor
Source: Survey Results, 2023

b. Petak Sembilan and the Victory Raya street corridor are the center of Chinese culture in Jakarta, attracting tourists interested in Chinese history and culture. The area is rich in Chinese values and culture reflected in the architecture of the buildings and the lives of the Chinese community. The area has great potential as a culinary tourism destination with various restaurants and food stalls offering typical Chinese food. Visitors can enjoy a variety of unique and delicious cuisines. Petak Sembilan is the location for various festivals and cultural events, such as Cap Go Meh, which attracts many visitors and increases economic activity in the area. The infrastructure around Petak Sembilan still needs improvement, including narrow roads and lack of public facilities such as parking (Figure 9).

Gambar 9 Kondisi koridor Petak Sembilan
Sumber : Hasil Survei 2023

c. Dharma Bhakti Temple is located on Jl. Kemenangan III, known as Jin De Yuan or Kim Tek Ie, is the oldest temple in Jakarta, built in 1650. This long history attracts tourists who are interested in Chinese history and culture in Indonesia. This temple is a center of worship for the Chinese community in Jakarta, especially on sacred days such as Chinese New Year. The building has traditional Chinese architecture with beautiful ornaments and stunning

Figure 10 Dharma Bhakti Temple
Source: Survey Results, 2023

statues of deities. In 2015, Dharma Bhakti Temple experienced a fire that destroyed most of the building. Although it has been repaired, there are some parts that still need further maintenance. The infrastructure around the temple still needs improvement, including narrow roads and lack of public facilities such as parking (Figure 10).

d. The Church of Santa Maria de Fatima is located on Jl. Kemenangan III, has a long history that began in 1650, and became the center of religious activities for the Chinese community in Jakarta. The church was built in Chinese architecture in the early 19th century, featuring beautiful ornaments and stunning statues of deities. This architectural style makes the church a great visual attraction for tourists. It is also part of the cultural tourist attractions in Glodok, adding historical and cultural value to the area (Figure 11).

Figure 11 Church of Santa Maria de Fatima
Source: https://g.co/kgs/fgtYmMk, 2024

e. Jalan Gajah Mada corridor, many restaurants and food stalls along the road offering a variety of Chinese and Indonesian specialties. This makes this area an attractive culinary destination for local and international tourists. Jalan Gajah Mada is a busy trading center, with many electronic stores, traditional medicine stores, and markets. This high economic activity contributes greatly to the local economy. Jalan Gajah Mada is connected to various other main roads in Jakarta, facilitating access and increasing the mobility of people and goods. This also makes it easier for visitors to explore the Glodok Chinatown area. Jalan Gajah Mada often experiences traffic jams, especially during peak hours. This can disrupt the mobility and comfort of visitors and local residents. The presence of irregular street vendors can disrupt pedestrian paths and add to congestion on the road. Better arrangement is needed to overcome this problem. Some parts of the sidewalks and infrastructure along Jalan Gajah Mada may be poorly maintained. Infrastructure improvements are needed to improve the comfort and safety of pedestrians (Figure 12).

Figure 12 Condition of Jalan Gajah Mada Corridor
Source: Survey Results, 2023

4.3 Need for Treatment Programs

To handle the Glodok area and optimize its potential as a culinary and cultural tourism destination, here are some programs that can be implemented as follows:

a. Infrastructure Improvement and Maintenance Program, a program aimed at improving visitor comfort and safety and supporting trade and tourism activities. The program consists of activities to improve the quality of roads, sidewalks, and public facilities such as seating, public toilets, and lighting.
b. Infrastructure Improvement and Maintenance Program, organizing cultural festivals, exhibitions, guided tours, and educational events to promote Chinese cultural heritage with the aim of increasing tourist appeal and strengthening the cultural identity of the area.
c. Cultural Preservation and Promotion Program, organizing the location of street vendors by setting up neat and orderly kiosks and designating special zones for them. This program aims to improve order, cleanliness, and comfort in the area.
d. Street Vendor Arrangement Program, aims to improve order, cleanliness, and comfort in the Area. This program organizes the location of street vendors by setting up neat and orderly kiosks and designating special zones for them.
e. Waste Management and Cleanliness Program, implementing a more efficient waste management system by adding trash bins and increasing the frequency of cleaning. The program's goal is to create a cleaner and healthier environment for visitors and local residents.
f. Green Space and Park Development Program, building city parks and green open spaces in strategic areas and reforesting along main roads. The program's goal is to improve environmental quality and provide recreation for visitors and residents.
g. Security Improvement Program, by adding lighting in public areas, installing CCTV in strategic locations, and increasing security patrols. With the aim of increasing the sense of security for visitors and local residents, especially at night.
h. Digital Promotion and Marketing Program, utilizing social media and digital platforms to promote cultural and culinary attractions in the Glodok area in order to reach more potential visitors and increase awareness of the area's appeal.
i. Collaboration Program with Local Communities, working with local communities to develop programs that promote and preserve Chinese culture and increase community involvement. The program's goal is to strengthen relationships between communities and increase participation in the development of the area.

5. Policy Direction and Development Concept

5.1 Policy Direction for Glodok Area Development

The policy direction for tourism development in Glodok is as follows :

a. Cultural Preservation and Development: develop a program to preserve Chinese culture in Glodok by involving the local community. This can include arts activities, festivals, and culinary.
b. Infrastructure Revitalization: repair and beautify public infrastructure such as roads, sidewalks, and lighting in tourist areas. This will improve the comfort and safety of visitors.
c. Promotion and Marketing: hold a marketing campaign to promote Glodok as a tourist destination. This can be done through social media, advertising, and cooperation with travel agents.
d. Accessibility Improvement: improve accessibility to Glodok by improving public transportation and providing clear information for tourists.

e. Local Economic Development: support small and medium enterprises in Glodok by providing training and financial assistance to improve the quality of their products and services.
f. Community Cooperation: involve the local community in decision-making related to tourism development to ensure the sustainability and relevance of the policies implemented.
g. Waste Management and Cleanliness: implement a more efficient waste management system by adding trash bins and increasing the frequency of cleaning. This will create a cleaner and healthier environment for visitors and residents.
h. Education and Awareness: conducting education and awareness programs on the importance of preserving culture and the environment for the community and tourists.
i. Arrangement of Street Vendors: arranging the location of street vendors by setting up neat and orderly kiosks and designating special zones for them. This program aims to improve order, cleanliness, and comfort in the area.
j. Development of Green Spaces and Parks: building city parks and green open spaces in strategic areas and carrying out greening along main roads. This aims to improve environmental quality and provide recreational areas for visitors and residents.

5.2 General Concept of Development

Development vision

The vision for Glodok development is to become a "GLOCAL CHINA-TOWN" by improving infrastructure, developing diverse local businesses, and creating a dynamic mix of local heritage and international appeal.

a. Land Use Concept

Land use allocation is based on the needs for the development of the Glodok area consisting of zoning: trade, preservation areas, education, and green open spaces (Figure 13) :

1) Trading

Designated Traditional and Modern Markets, namely allocating land for traditional markets that sell various daily necessities and Chinese specialties. In addition, establishing a modern shopping center that offers local and international products. While the designation of Ruko and Kios provides ruko (shop houses) and kiosks to support trade activities and small and medium enterprises (SMEs) in this area.

2) Preservation

Preservation is carried out on historical buildings by allocating land for the preservation and revitalization of historical buildings in Glodok. This includes the restoration of ancient architecture and the rearrangement of the surrounding environment to maintain its historical value. Within the preservation area, a museum and information center for Chinese culture in Indonesia are needed. This can be a place of education and recreation for visitors..

3) Education

Allocating land for schools and educational institutions that offer formal and non-formal education programs. This could include Chinese language courses, art classes, and skills training. Establishing libraries and information centers that provide access to a variety of knowledge sources on Chinese culture and history.

4) Green Open Space and Recreation

Building city parks and green open spaces equipped with recreational facilities such as children's play areas, jogging tracks, and picnic areas. Providing indoor recreational areas such as cinemas, game centers, and family entertainment venues.

5) Settlement

Providing land for the development of affordable housing for local communities. Improving the quality of existing settlements by improving infrastructure, provision of clean water, sanitation, and other public facilities.

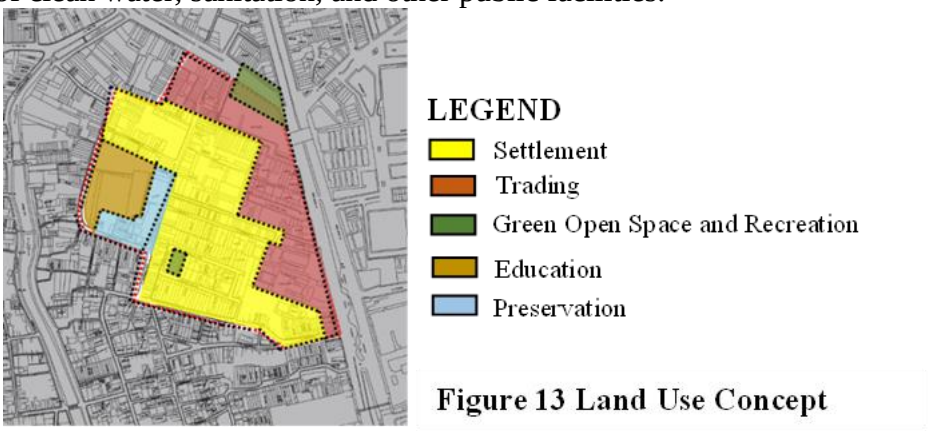


Figure 13 Land Use Concept

b. Circulation and Parking Concept

1) Strengthening the Jalan Gajah Mada Corridor

Strengthening the corridor of Jalan Gajah Mada Corridor by giving character to the city space and make it as a receiving area before entering Glodok. It will make the existing social space more liveable and functional. The concept of arrangement: development of road and pedestrian areas, strengthening transit points for public transportation modes, development of city park areas, arrangement of building facades, strengthening pedestrian access and circulation, improvement of signage and information boards. main destination.

2) Strengthening of Pancoran Road

This strengthening refers to the buffer corridor that breaks the concentration of socio-economic activity movement, with improving environmental quality, adding supporting components, strengthening business values and areas. The concept of arranging the development of road and pedestrian areas, arranging parking areas and circulation routes, developing city park areas, arranging building facades, strengthening pedestrian access and circulation, improving signage and information boards.

3) Strengthening of Road Corridors Within the Area

Strengthening the Area corridor refers to the rearrangement of the quality of the corridor in the Glodok Area which is an important distribution route for the flow of activities in, inside and out of the area. This arrangement is important so that the community concerned can clearly and directedly, and comfortably go to the point of activity or exploration, both residents, business visitors and tourists. Arrangement concept: Physical arrangement of road areas and pedestrian paths, arrangement of parking areas and circulation paths, development of commercial areas, arrangement of building facades, improvement of signage and information boards, fulfillment of social infrastructure facilities.

4) Parking and Pedestrian Ways

Optimization of parking points is carried out by utilizing the potential of existing parking pockets in several large buildings in the Glodok area, with shared and mutually beneficial use, where parking facilities can be optimally utilized, bringing people to visit buildings and strengthening the distribution of movement between buildings. This utilization needs to be synchronized with the strengthening of distribution routes from parking points to activity areas by increasing the economic value of each circulation route. The concept of arrangement: opening parking lanes for the public related to

Glodok activities while still taking into account blockages when needed, improving the movement of people from and to the parking area, both on-ground and sky walk routes, arranging commercial areas along the movement route, establishing supporting signage and information boards. Arrangement of pedestrian paths in the area, becomes connectivity for achievements throughout the area.

c. Open Space Concept

The determination of Open Space in the limited area of the Glodok Area does not lead to quantity, but to quality, so the focus of the arrangement is to strengthen the quality of the existing open space. The limited availability of this land can be synchronized with the circulation pattern and the determination of parking pockets so that it is more ideal to be applied to strengthening the nodes/junctions in the alleys leading to the Area, which are potential areas socially and economically. In the case of the dense Glodok area, open areas are difficult to find, so the approach of utilizing the potential of open space between buildings is a logical and most possible approach. This approach that focuses on quality over quantity is carried out by opening the building boundary into an activity space that enlivens the social and economic sectors of the Area. The concept of arrangement opens the property fence and changes it into a socio-economic space while maintaining the privacy of each area, changing the fence into a circulation area/park and trade kiosk.

d. Preservation Concept

As an area that has grown and developed and has a strong history of development, the value of the area will be formed and recorded in the values contained in the buildings and other components. So the arrangement of the area should not be far from the value and character of the area itself by default. For that, one of the approaches needed is to maintain the existing values to be strengthened, the preservation approach is important, to be synchronized with the previous arrangement pattern.

5.3 Concept of Acupuncture Point

The concept of developing Glodok can include several important acupuncture points such as the Chinatown market, Pancoran Street Corridor, Petak Sembilan, Kemenangan Raya Street Corridor, Dharma Bhakti Temple, Santa Maria de Fatima Church, and Gajah Mada Street Corridor. Here are some concepts:

a. Chinatown Market and Pancoran Street Corridor: Developing Chinatown Market as a cultural and trade center that attracts tourists. This can be done by improving market infrastructure, adding public facilities, and holding cultural events and festivals. For Pancoran Street Corridor: Improving connectivity and accessibility of Pancoran Street Corridor by improving roads and public transportation. In addition, revitalizing buildings around this corridor can be done to increase tourist appeal.
b. Petak Sembilan and corridors within the Area: Develop Petak Sembilan as a recreation and shopping area by adding city parks, green open spaces, and other public facilities. This program can also include the arrangement and maintenance of buildings around this area. The concept of arranging the Jalan Kemenangan Raya corridor: Improving the environmental quality in the Jalan Kemenangan Raya corridor by revitalizing buildings, arranging sidewalks, and improving public facilities such as lighting and seating.
c. Around Dharma Bhakti Temple and Santa Maria de Fatima Church: Develop these two places of worship as religious tourism destinations by improving infrastructure, adding public facilities, and holding educational programs and cultural exhibitions.
d. Jalan Gajah Mada Corridor: Improving connectivity and accessibility of Jalan Gajah Mada corridor by improving roads and public transportation. In addition, revitalization of buildings around this corridor can be carried out to increase tourist appeal.

5. CONCLUSION AND RECOMMENDATIONS

The goal of this study is to employ urban acupuncture to revitalize Glodok Chinatown as a tourist and cultural destination. According to the study, focused interventions in important strategic places can boost local economic growth, draw tourists, and improve spatial and cultural relevance. Small-scale, targeted improvements in particular "pressure points" like the Pecinan Market, Pancoran Street Corridor, and historic sites like the Dharma Bhakti Temple and Santa Maria de Fatima Church can completely change the urban fabric, according to the principles and generalizations deduced. The study demonstrates how targeted efforts can have significant ripple effects across a community by improving infrastructure, protecting heritage, and increasing accessibility.

This strategy has several drawbacks despite its efficacy. Significant obstacles include deteriorating infrastructure, traffic, a dearth of green areas, and uncontrolled street vendor activity. Additionally, striking a balance between modernization and history preservation can be difficult and calls for tactful management to preserve cultural authenticity. Budgetary restrictions, legal requirements, and the requirement for constant stakeholder participation may limit the impact's reach. Standardized solutions are less effective due to the difficulties presented by Glodok's distinct social and spatial dynamics.

The work's theoretical ramifications highlight how urban acupuncture can be used to develop community-driven, sustainable urban environments through culturally sensitive techniques. Practically speaking, it shows how cities may revitalize heritage districts without undergoing extensive renovation by using affordable interventions that promote tourism, enhance local culture, and enhance public areas. This strategy supports more general objectives of improving community well-being, sustainability, and urban resilience.

This study concludes by showing that combining urban modernization with heritage preservation is necessary for Glodok's revitalization. Among the recommendations are:

1. Infrastructure Improvements: Give top priority to the construction of green spaces, improvements to roads and sidewalks, and upkeep of public infrastructure. Increasing the number of pedestrian-friendly areas would increase accessibility and safety.
2. Cultural Preservation and Promotion: Through festivals, educational initiatives, and heritage site upkeep, include local communities in the preservation of Chinese cultural heritage. Creating community centers and museums can improve the experiences of visitors even more.
3. Regulation of Street Vendors and Improvements to Public Facilities: To improve hygiene and ease traffic, group sellers into certain areas. A more visitor-friendly atmosphere will be produced by improving public amenities and garbage management effectiveness.
4. Digital Marketing and Community Engagement: Make use of digital marketing techniques to advertise Glodok's distinctive features. Culturally sensitive developments and wider support for tourism activities will be ensured through cooperative efforts with local communities.
5. Safety and Security: To create a secure atmosphere for locals and visitors alike, improve street conditions, lighting, and public security measures.
6. Glodok can be developed into a thriving, sustainable, and culturally rich tourism destination by emphasizing well-thought-out, community-focused initiatives that combine local legacy with international appeal.

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CHAPTER 3

Towards Sustainable Tourism: The Role of Architecture in Mitigating Environmental Impacts

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ABSTRACT

Tourism plays an important role in global economic growth, it has a direct impact on GDP, employment and regional development. Along with the rapid development of tourism, it has its effects on the environment, such as increased pollution and carbon emissions. Sustainable tourism architecture as a form of mitigation of the effects of tourism on the environment is the focus of this study. The main issue of the study centers on the contribution of tourism to climate change and its impact on the environment. The research method uses a qualitative approach with a literature review and review of case studies from regions such as the Douro Valley, Portugal, and urban areas in China. Sustainable tourism architecture uses local materials, energy-efficient design, and resource management discussed in the case study. The study results show that sustainable design is able to reduce carbon emissions, save energy, and participate in resource conservation. In this study, the benefits of environmentally friendly buildings increase environmental resilience to climate change. This can be achieved by maximizing environmentally friendly design by considering the costs incurred, it is necessary to understand how to choose environmentally friendly technology with minimal costs. Future research should look at the long-term benefits of sustainable tourism as well as how technology can make travel more desirable while still adhering to net zero carbon emissions.
Keywords: Sustainable Tourism, Climate Change, Green Architecture, Smart Technologies.

1. INTRODUCTION

The tourism industry is one of the largest and fastest growing economic sectors in the world, contributing significantly to GDP, job creation, and regional development (UNWTO, 2023). Despite its economic benefits, the tourism industry's rapid expansion has given rise to several environmental challenges, including increased pollution, habitat destruction, and carbon emissions. The need for sustainable methods to lessen negative environmental effects grows as tourism activities increase in intensity. The need for sustainable tourism architecture has grown as a result of the global climate crisis. Human activities like burning fossil fuels and deforestation have increased greenhouse gas emissions, which are the primary cause of global warming. Human activity is primarily to blame for global warming. Various activities, such as coal mining, industrial processes, waste management, air and land transportation, and deforestation, are responsible for around 95% of this warming. Another impact for 35% of global energy consumption, 12% of water use, 25% of waste, and 40% of greenhouse gas emissions, buildings have a significant impact on climate change.

Global weather patterns are changing significantly as a result of the atmospheric concentration of CO_2 reaching its greatest level in over 800,000 years, according to the Intergovernmental Panel on Climate Change (IPCC, 2007). Rising sea levels, longer droughts, and more frequent and severe storms are some of these changes that seriously jeopardise the infrastructure supporting tourism, particularly in coastal and island regions (Understanding Climate Change, 2019). The Paris Agreement was established in 2015 with the intention of keeping the increase in global temperatures to 1.5 degrees Celsius and no more than 2 degrees Celsius over pre-industrial levels. Most recently, in 2019, the IPCC released a special report emphasizing the urgency of keeping global temperature rise below 1.5 degrees Celsius to prevent more severe impacts of climate change. As climate change continues to affect global ecosystems, the need for adaptive and resilient tourism infrastructure has become more apparent.

Sustainable architecture addresses this need by incorporating climate adaptation measures, such as elevated building designs in flood-prone areas, green roofs to reduce urban heat, and natural barriers to protect against storm surges. By integrating these strategies, sustainable tourism architecture not only reduces environmental impact but also enhances the resilience of tourism facilities to climate-related risks.

While tourism is a major force for development it has a number of negative aspects such as Tourism is a significant and growing contributor to climate change, responsible for approximately 5% of global CO2 emissions, primarily due to transportation and the operation of tourism facilities like accommodations. Additionally, in some areas, local pollution of land and water from inadequate waste management by tourism businesses, as well as from tourist activities, can become a major issue.

The tourism sector in the accommodation sector can be the main source of the largest use of non-renewable energy, in some areas water use at resorts tends to be more. The importance of mitigating climate change and adapting to its impacts must be recognized in tourism policies and strategies for the short and long term. The effects of climate change on tourism have been the subject of much discussion and research in recent years. "A clear commitment for action to respond to the climate change challenge, including the urgent adoption of a range of sustainable tourism policies" was demanded in the 2007 Davos Declaration.

In response to these issues, the field of sustainable tourist architecture has grown in importance. Its main objective is to design and build tourism-related infrastructure in a way that maximises sociocultural and economic benefits while minimising environmental impacts (Gössling et al., 2021). In line with the more general objectives of sustainable tourism development, this strategy places a strong emphasis on lowering carbon footprints, protecting natural resources, and encouraging cultural preservation.

Adopting sustainable architectural techniques is essential for improving resource efficiency and lowering greenhouse gas emissions, as buildings account for almost 40% of global energy consumption (Asif & Muneer, 2020). In order to meet the demands of tourists, the industry, the environment, and host communities, sustainable tourism must fully consider its present and future economic, social, and environmental implications, according to the UNWTO. 12 goals for sustainable tourism were established by the UNWTO and UNEP:
(1) Economic viability: Ensuring that tourist attractions and enterprises maintain their long-term competitiveness and sustainability so they can thrive and provide enduring advantages. (2) Local Prosperity: Making the most of tourism's beneficial effects on the community by guaranteeing that a sizable amount of visitor expenditure remains in the host area. (3) Employment Quality: Ensuring equitable compensation, healthy working conditions, and equal opportunity for all, irrespective of gender, race, or disability, while also increasing the quantity and calibre of jobs created by tourism. (4) Social Equity: Ensuring that the societal and economic advantages of tourism are widely shared within the community, with a focus on improving services, income, and opportunities for underserved populations. (5) Visitor Fulfilment: Ensuring access and giving every visitor a secure, pleasurable, and fulfilling experience. (6) Local Control: Working with other pertinent stakeholders, actively empowering and including local people in tourism planning and decision-making. (7) Community Wellbeing: Preventing exploitation or social deterioration by promoting and maintaining a high standard of living for the local populace, bolstering social infrastructure, and guaranteeing access to essential resources, services, and life-support systems. (8) Cultural Richness: Promoting cultural appreciation and preservation by honouring and preserving the customs, heritage, and distinctiveness of host communities. (9) Physical Integrity: Preventing any deterioration of the physical or aesthetic environment while preserving and improving the quality of both urban and rural environments. (10) Biological Diversity: Supporting the preservation of species, ecosystems, and natural environments while reducing adverse effects on these resources is known as biological diversity. (11) Resource Efficiency: minimising the use of finite and non-renewable resources in the development and management of services and facilities associated with tourism. (12) Environmental Purity: lowering air, water, and land pollution as well as waste generation from tourists and tourism-related enterprises.

It has been identified that climate change mitigation in tourism should focus on four main strategies: (a) reducing energy use – including influencing travel patterns through length of journeys, length of stay and mode of transport. (b) improving energy efficiency – using new technology and improved practices in aviation, road transport and accommodation design and operations. (c) increasing the use of renewable energy – such as solar power for tourism enterprises. (d) sequestering carbon – including use of offsetting, although this should not be as an alternative to reducing emissions.
Studies have shown that tourism is both a contributor to and a victim of climate change. On one hand, tourism generates substantial greenhouse gas emissions through travel and building operations, while on the other, it is vulnerable to the effects of climate change, leading to the need for adaptive strategies (Gössling et al., 2012). By implementing sustainable design techniques that lower energy usage, make use of renewable resources, and foster climate resilience, architectural practices can lessen these effects (Sullivan et al., 2020).

2. LITERATURE REVIEW

The Concept of Sustainability in Tourism

The goal of sustainable tourism is to maximise socioeconomic advantages while reducing the environmental impact of travel-related activities. Its main goal is to strike a balance between the three pillars of sustainability: social justice, economic viability, and environmental

preservation (Smith & Scott, 2020). This all-encompassing strategy aims to protect the natural integrity of travel sites, conserve cultural heritage, and advance the welfare of nearby populations. The Impact of Climate Change on Sustainable Tourism Architecture: The evolution of sustainable tourism architecture is now significantly impacted by climate change. Human activity has exacerbated global warming, increasing environmental vulnerabilities, according to historical climate data. Severe weather events including hurricanes, floods, and heatwaves have been connected to growing levels of greenhouse gases, especially CO_2 (Arrhenius, 1896; Plass, 1955). Infrastructure related to tourism is directly at risk from these changes, especially in coastal areas that are vulnerable to erosion and sea level rise (IPCC, 2007). The tourism sector is under serious risk from the effects of climate change. Mountainous regions, island nations, and coastal places are especially susceptible to disruptions brought on by climate change. For example, beaches and coastal resorts are under risk from rising sea levels, while ski tourism may be impacted by a decrease in snow cover due to rising temperatures. Furthermore, severe weather conditions like hurricanes and floods can harm infrastructure, interfere with travel schedules, and make places less appealing (UNWTO, 2013). Design elements that are resilient to severe weather conditions are incorporated into sustainable tourist architecture as a response to these issues. Permeable pavements, rain gardens, and green roofs, for instance, are used to control stormwater runoff and lessen the heat island effect in urban tourist destinations. Furthermore, the incorporation of renewable energy sources, including wind and solar electricity, helps lessen dependency on fossil fuels, which lowers the carbon footprint of tourist destinations (Elahi et al., 2024).

Key Principles of Sustainable Tourism Architecture such as (1) Energy Efficiency: One of the main tenets of sustainable architecture is the use of energy-efficient technology, such as LED lighting, natural ventilation, and passive solar design. These tactics assist in lowering the carbon footprint of tourism facilities, operating expenses, and energy usage (Asif & Muneer, 2020). By supplying clean, low-carbon electricity, renewable energy sources like solar panels can further improve a building's sustainability. (2) Water Conservation: As a result of climate change, water scarcity is becoming a bigger issue in many tourist locations. Water-saving strategies including rainwater collection, greywater recycling, and low-flow fixture installation are all included into sustainable building designs. Even during times of drought, these actions assist maintain a consistent water supply and lower overall water usage (Elahi et al., 2024). (3) Use of Local and Recycled Materials: Using recycled or locally sourced building materials boosts local economy and lessens the environmental effect of transportation. In keeping with eco-tourism's tenets of minimising environmental disturbance, this approach also improves the cultural authenticity of tourism infrastructure (Fu et al., 2024). (4) Cultural Preservation: Through its design, sustainable architecture seeks to protect and honour the region's rich cultural legacy. Structures that use regional materials and traditional architectural designs give visitors a one-of-a-kind experience while also preserving cultural identity. This strategy not only improves the experience of tourists but also makes local residents feel proud (Zhao et al., 2024).

The Role of Policy and International Cooperation

Global accords like the Paris Agreement and the Kyoto Protocol have established goals for lowering greenhouse gas emissions and advancing sustainable development. However, achieving these targets in the tourism sector requires stronger policy frameworks and increased investment in sustainable infrastructure. Governments and industry stakeholders need to collaborate to implement green building standards, provide incentives for sustainable practices, and promote awareness of climate change impacts (IPCC, 2007). Reducing carbon emission should be disclosed in sustainability report in order to inform stakeholders regarding

companies' effort to support environmental preservation (Simon, F., Ferdiansyah, Gunawan, J., Lee, J. 2024)

Sustainable Architecture for Tourism

Sustainable architecture, in the context of tourism, focuses on designing and constructing buildings and spaces that have minimal environmental footprints, optimize energy use, and incorporate environmentally friendly technologies. Several studies emphasize the integration of renewable energy systems (solar, wind, geothermal) and sustainable materials (local, recycled, and low-impact materials) in tourism architecture (Baker & Fisher, 2018). Furthermore, passive design techniques like daylighting, natural ventilation, and thermal insulation can drastically lower operating expenses and energy requirements (Hernandez et al., 2020). For instance, eco-friendly materials and green building certifications such as BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design) have gained popularity in developments related to tourism (Chung et al., 2018). These guidelines promote ethical building techniques that lessen their negative effects on the environment while still preserving the structures' aesthetic and functional coherence with their surroundings.

Climate Resilience in Tourism Architecture

Architecture's response to climate change involves both adaptation and mitigation strategies. The primary objective of mitigation is to decrease the carbon footprint of buildings used for tourism, whereas adaptation looks at how architecture may adapt to the difficulties presented by climate change. Resilience design is becoming more and more crucial in regions vulnerable to impacts of climate change like hurricanes, wildfires, and flooding (Liu & Ramaswamy, 2017).

To solve the issues brought on by climate change, architectural design must incorporate sustainable tourist techniques. By emphasising climatic resilience, energy efficiency, and the use of sustainable materials, architecture in the tourism sector can greatly lessen the industry's environmental effect. Furthermore, sustainable tourist development is ensured by the capacity to adjust to climate change through careful planning and community engagement. In order to ensure that tourism is a viable and sustainable enterprise for future generations, architecture will play an ever-more-important role in reducing the consequences of climate change as the global tourism industry grows.

3. RESEARCH METHOD

In order to examine sustainable tourist architecture, this study uses a qualitative research approach and focusses on case studies and literature reviews. The framework includes an analysis of design principles, digital tools, and their implementation in real-world tourism projects. A comparative analysis was conducted to evaluate the environmental, economic, and social impacts of sustainable tourism architecture compared to conventional practices.

4. RESULT AND DISCUSSION

Sustainable tourism is increasingly recognized as a critical strategy for addressing the global impacts of climate change. The relationship between tourism and climate change is multifaceted, as the sector is both impacted by and contributes to environmental changes. Tourism, accounting for around 5% of global CO_2 emissions, primarily through transportation and accommodation, plays a significant role in exacerbating climate change. At the same time, the sector is vulnerable to the effects of a changing climate, including extreme weather events, sea-level rise, and biodiversity loss, which can affect popular tourist destinations (UNWTO, 2013)

Tourism has emerged as a vital economic sector, contributing approximately 9% of global GDP and providing over 200 million jobs worldwide. Its growth, particularly in developing countries, highlights its potential as a driver for sustainable development. However, this growth brings significant environmental concerns, necessitating well-planned and managed tourism activities to minimize negative impacts. In line with more general sustainable development goals, sustainable tourism seeks to strike a balance between social inclusion, environmental protection, and economic growth (UNWTO, 2013).

Case Study Analysis

Sustainable Tourism Architecture in Douro Region, Portugal

The Douro region in Portugal, a UNESCO World Heritage Site known for its wine production, has been a focal area for implementing sustainable tourism practices. According to Feio and Guedes (2013), the tourism development in this region is heavily tied to its cultural and natural heritage, making sustainability a crucial aspect of its architectural projects (feio2013). The researchers highlighted that traditional tourism infrastructures in the region often lead to increased energy consumption and resource usage compared to local residential buildings. As a response, the focus has shifted to developing sustainable architectural solutions that align with the ecological, cultural, and aesthetic values of the Douro region.

- Energy Efficiency: The architectural projects in the Douro region have integrated sustainable building techniques such as using local materials and energy-efficient designs. The use of traditional construction methods combined with modern sustainable technologies, such as solar panels and water recycling systems, has reduced the carbon footprint of tourism infrastructures.
- Visitor Comfort and Resource Consumption: The study found a strong correlation between tourist comfort demands and the increased consumption of resources. This emphasizes the need to balance luxury tourism experiences with sustainable resource use, particularly in water-scarce areas like the Douro Valley(feio2013).
- Certification and Assessment: The study aimed to refine environmental certification criteria for tourism buildings, using standards like LEED and BREEAM, tailored to the specific context of the Douro region. This approach has helped to identify areas for improvement and set higher benchmarks for eco-efficiency in tourism infrastructure.

The case study of the Douro region illustrates the complex balance between enhancing tourist experiences and maintaining environmental sustainability. While sustainable architecture has improved the energy efficiency of buildings, the region still faces challenges in fully integrating green tourism practices, especially when aligning visitor expectations with resource conservation. The use of local materials and traditional architectural styles also highlights the role of cultural preservation in sustainable tourism development.

Smart Tourism in China’s Urban Areas

The study by Lu et al. (2021) explores the implementation of smart city technologies to promote sustainable tourism in urban areas of China. The authors developed a Data-Driven Sustainable Smart City Framework (DDSSCF), focusing on integrating information technologies like the Internet of Things (IoT) to enhance energy efficiency, waste management, and urban mobility

- Smart Technologies for Green Tourism: The incorporation of IoT and cloud-based solutions has enabled better management of tourist flows, energy consumption, and waste. For instance, smart sensors and real-time data analytics are used to optimize resource use in tourist areas, reducing the environmental impact of tourism activities.
- Energy Efficiency: The study showed that smart cities implementing the DDSSCF model achieved a significant improvement in energy efficiency, particularly through smart lighting systems and automated energy management. For example, the use of

smart LED streetlights in tourist areas reduced energy consumption by up to 20%, contributing to lower overall greenhouse gas emissions.

- Enhanced Tourist Experience: The use of smart technologies, including mobile apps and digital information systems, has improved the overall experience of tourists by providing real-time updates on local attractions, transportation options, and eco-friendly activities. This not only enhances visitor satisfaction but also promotes sustainable travel behaviors by encouraging the use of public transportation and eco-friendly services.

The implementation of smart tourism initiatives in China illustrates how technological innovations can enhance the sustainability of urban tourism. The integration of smart systems has provided significant improvements in energy efficiency and waste management, key components of sustainable tourism. However, the study also noted challenges related to the high costs of technology implementation and the need for extensive stakeholder collaboration to achieve long-term sustainability goals. Moreover, the emphasis on technological solutions must be balanced with considerations for social and cultural sustainability, ensuring that smart tourism developments align with local needs and heritage preservation.

Comparative Analysis of Case Studies

The case studies from the Douro region and urban areas in China provide valuable insights into different approaches to achieving sustainable tourism:

- Focus on Cultural vs. Technological Solutions: The Douro region emphasizes the preservation of cultural heritage and traditional architectural styles, integrating sustainable practices within this context. In contrast, the Chinese urban case study focuses heavily on the use of technology to enhance sustainability, showcasing the potential of smart city solutions to reduce environmental impacts in densely populated areas.
- Energy Efficiency and Resource Management: Both case studies highlight the importance of energy efficiency in sustainable tourism. The Douro region uses architectural designs tailored to its local climate, while the Chinese smart city model leverages digital technologies to optimize energy use.
- Challenges and Opportunities: The challenges in the Douro region include aligning luxury tourism demands with sustainable resource use, while in China, the high implementation costs of smart technologies pose a barrier. However, both regions demonstrate significant opportunities for improving sustainability through tailored interventions, whether through eco-friendly architectural practices or innovative technological solutions.

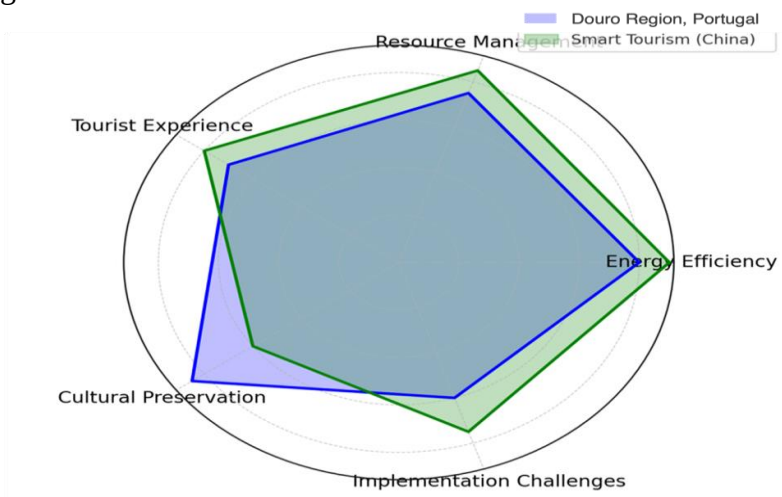

Figure 1. Comparative Analysis of Sustainable Tourism Case Studies

Figure 1 shows a radar chart comparing the key aspects of sustainable tourism practices between the Douro Region (Portugal) and Smart Tourism in China based on the result and discussion analysis. The comparative analysis of these case studies underscores the diverse strategies available for promoting sustainable tourism. While traditional architectural solutions focus on cultural preservation and minimal environmental impact, smart technologies offer innovative ways to enhance energy efficiency and waste management in urban settings. Both approaches highlight the need for a holistic strategy that integrates environmental, cultural, and social sustainability to address the challenges of climate change in tourism development effectively.
These findings contribute to a broader understanding of how sustainable tourism can be achieved in different contexts, emphasizing the importance of adaptive strategies that consider the unique characteristics and challenges of each region. The integration of sustainable architecture and smart technologies offers promising pathways for reducing the carbon footprint of tourism and enhancing the resilience of destinations against climate change.

Economic, Social, and Environmental Impact Analysis

The analysis shows that sustainable tourism architecture leads to significant environmental benefits, including reduced carbon emissions and resource conservation. Economically, green buildings often have higher initial costs but result in long-term savings due to lower energy and water usage (Han et al., 2023). Socially, sustainable architecture enhances tourist experiences by providing eco-friendly and culturally immersive environments (Fu et al., 2024).
Adaptation strategies in tourism focus on enhancing the resilience of tourism infrastructure to climate change impacts. This includes implementing flood-resistant designs, building elevated structures in coastal areas, and using materials that can withstand extreme weather. Mitigation strategies, on the other hand, aim to reduce the carbon footprint of tourism activities. These include increasing energy efficiency in accommodation facilities, promoting the use of public transportation, and encouraging carbon offset programs (UNEP, 2005).
The integration of renewable energy sources, such as solar panels and wind turbines, into tourism infrastructure is an effective mitigation strategy. Additionally, implementing waste management systems, water conservation measures, and promoting eco-friendly practices among tourists can significantly reduce the environmental impact of tourism activities.
While the benefits of sustainable tourism are widely acknowledged, there are significant challenges in its implementation. High initial investment costs for sustainable infrastructure, lack of expertise, and resistance from stakeholders are common barriers. Additionally, the complexity of coordinating various stakeholders, including governments, private businesses, and local communities, often hampers the effective implementation of sustainable practices (UNWTO, 2013) The main challenges include high initial costs, lack of expertise, and resistance from stakeholders. Overcoming these challenges requires increased awareness, policy support, and training for developers and architects (Olya et al., 2024). However, there are also substantial opportunities for growth in sustainable tourism. Increasing global awareness of climate change and a growing demand for eco-friendly travel experiences have created a favorable market for sustainable tourism products. Investments in sustainable infrastructure and practices not only reduce environmental impacts but also enhance the competitiveness and attractiveness of destinations. Compared to conventional architecture, sustainable tourism architecture demonstrates better performance in terms of resource efficiency and environmental impact. The use of digital tools further enhances the sustainability of tourism facilities by optimizing energy use and reducing waste (Nelson et al., 2024).

5. CONCLUSION AND RECOMMENDATIONS

Sustainable tourism plays a crucial role in mitigating climate change and promoting long-term economic, social, and environmental benefits. The tourism sector may lessen its carbon

footprint, improve climate resilience, and aid local people by using sustainable practices. Addressing the issues caused by climate change and promoting sustainable tourism require investment in green technologies, stakeholder collaboration, and effective policy frameworks. The results highlight the significance of incorporating sustainable architectural practices, such as energy-efficient designs, renewable energy systems, and cultural preservation, into tourism infrastructure. These tactics help to reduce carbon emissions, improve climate resilience, and offer environmentally responsible travel experiences. One important step in decreasing the negative environmental effects of tourism is the incorporation of renewable energy sources and sustainable architecture into the infrastructure of the tourism sector. Adopting sustainable practices will be crucial as the world's tourist industry grows to make sure that tourism supports sustainable development and climate action. The involvement of developing technologies and the long-term economic effects of sustainable tourist architecture should be the main topics of future research. Enhanced cultural preservation, stronger economic performance, and less environmental effect are only a few advantages of sustainable tourism design. By improving resource management more effective, the incorporation of digital tools may increase these advantages even further. For tourism developers, adopting green building standards and leveraging digital technologies can lead to significant long-term savings and improved environmental performance.

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CHAPTER 4

Empirical Study on the Impact of Exports and Imports on Refinery Gas Production in Indonesia

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ABSTRACT

This study investigates the impact of export and import activities on refinery gas production in Indonesia using multiple linear regression analysis. The research utilizes data from 2013 to 2023 to examine how variations in export and import volumes influence domestic refinery output. The regression results reveal a statistically significant negative relationship between import volumes and refinery gas production, suggesting that increased imports may reduce domestic output due to heightened competition and reliance on foreign supplies. Conversely, export volumes show a positive but statistically insignificant effect, indicating that domestic production levels are less responsive to export fluctuations. The model's goodness of fit, with an R-squared value of 0.783 and an Adjusted R-squared value of 0.730, demonstrates strong explanatory power, indicating that approximately 78.3% of the variation in refinery gas production is accounted for by the combined effects of exports and imports. The F-statistic (14.42, p-value = 0.00222) further confirms the overall significance of the model. These findings suggest that reducing import dependency could enhance local production capacity, while a balanced export strategy is essential to maintain domestic supply stability. The study provides valuable insights for policymakers and industry stakeholders in optimizing trade policies and supporting the sustainable growth of the refinery gas sector. Future research should incorporate additional factors, such as technological advancements and domestic consumption trends, to deepen the analysis.

Keywords: Gas production, Exports, Imports, Multiple linear regression, Goodness of fit.

1. INTRODUCTION

The energy sector is a critical pillar of economic growth and development worldwide, providing the fuel necessary for industrial processes, transportation, and household consumption. Within this sector, the production of refinery gas holds a prominent place due to its versatile applications across various industries. Refinery gas, a by-product of the oil refining process, consists of a mixture of light hydrocarbons, including methane, ethane, propane, and butane. These gases are widely used as fuels for heating, cooking, and power generation, as well as feedstock in the petrochemical industry for producing essential chemicals such as ethylene and propylene. The efficient production and utilization of refinery gas are key to supporting energy security, reducing dependency on imported fuels, and fostering economic resilience, particularly in developing economies like Indonesia (Wijayanti et al., 2021).

Indonesia, as the largest archipelago nation in the world and one of Southeast Asia's most populous countries, faces unique challenges and opportunities in the energy sector. With a rapidly growing economy and a population of over 270 million, Indonesia's demand for energy has increased significantly over the past decade (Worldometer, 2023) . This surge in demand has put immense pressure on the country's refining industry to boost its output and meet domestic needs. However, the refining capacity in Indonesia has historically been constrained by limited infrastructure investments, aging facilities, and a heavy reliance on imported crude oil. These limitations have made the country vulnerable to fluctuations in global oil prices and exposed it to the risks associated with international trade dependencies (Maulani et al., 2021).

The Indonesian government has recognized these challenges and, as part of its long-term energy strategy, has implemented various policies aimed at increasing domestic refining capacity and reducing dependency on imports. These initiatives include the expansion and modernization of existing refineries, the construction of new refining facilities, and the promotion of investments in advanced refining technologies. Despite these efforts, the refinery gas sector continues to grapple with structural issues, including inefficiencies in production processes, supply chain disruptions, and regulatory hurdles. Moreover, the volatility of global trade dynamics, influenced by factors such as geopolitical tensions, trade disputes, and shifts in global demand patterns, adds an additional layer of complexity to the industry's performance (Ridaliani et al., 2021).

Exports of refinery gas and related products represent a critical opportunity for Indonesia to capitalize on its refining capabilities and earn valuable foreign exchange revenue. By tapping into international markets, Indonesian refineries can potentially increase their production volumes, achieve economies of scale, and enhance their profitability. Export activities also provide a mechanism for diversifying revenue streams and reducing the economic risks associated with fluctuating domestic demand. However, there are trade-offs involved, as an aggressive export strategy may lead to reduced availability of refinery gas for local consumption, potentially driving up domestic prices and creating supply shortages. Balancing the needs of the domestic market with the benefits of export revenue generation is a delicate task that requires careful policy formulation and strategic planning (The Ministry of Energy and Mineral Resource Republic of Indonesia, 2023).

Imports, on the other hand, play a dual role in the context of Indonesia's refinery gas industry. On one hand, imports serve as a necessary supplement to domestic production, particularly during peak demand periods or when local refineries are unable to produce sufficient quantities of specific gas products. By importing these products, Indonesia can ensure a steady supply of essential fuels and feedstocks, supporting the stability of its energy market. On the other hand, excessive reliance on imports can undermine the competitiveness of domestic refineries, making it difficult for them to operate at full capacity or invest in efficiency improvements. High levels of imports may also expose the country to external risks, such as changes in trade

policies, tariffs, and disruptions in global supply chains, which could have adverse effects on local production and energy security (Sulistomo & Surjosatyo, 2023).

The interaction between exports, imports, and domestic refinery gas production is complex and multifaceted, influenced by a range of economic, technical, and regulatory factors. Theoretical perspectives from international trade economics suggest that both exports and imports play critical roles in shaping industrial output and economic growth. Exports can drive industrial expansion by opening up new markets and providing incentives for capacity enhancement, while imports can enhance production efficiency by supplying critical inputs that may not be readily available domestically. However, the net effect of these trade activities on domestic production is not always straightforward, as it depends on the specific characteristics of the industry, the nature of the traded goods, and the broader macroeconomic environment (Ramdan et al., 2021).

1.1.Research Gap

Despite the recognized importance of refinery gas production within the broader energy sector, there is a notable gap in the empirical research examining the specific effects of export and import activities on this segment of the industry in Indonesia. Existing studies have largely focused on broader aspects of the oil and gas industry, such as the impact of crude oil imports on overall energy security, the role of domestic energy policies in shaping investment climates, or general trade patterns affecting the energy sector. Few studies have delved into the specific dynamics of refinery gas production, particularly in the context of Indonesia, where the interplay between international trade activities and local output has unique implications due to the country's strategic geographical position and its status as a major oil and gas producer in the region (Widiasa et al., 2014).

This gap in the literature highlights the need for a focused empirical analysis that can provide detailed insights into how export and import activities influence refinery gas production. By addressing this gap, the present study aims to contribute to a deeper understanding of the factors driving variability in production levels and to offer new evidence that can inform industry practices and policymaking. The limited attention given to the refinery gas segment within existing trade and energy studies suggests an opportunity to explore unexplored relationships and to provide data-driven recommendations that have the potential to enhance the efficiency and competitiveness of the industry(Putri & Vikaliana, 2023) .

1.2.Novelty of the Study

The novelty of this study lies in its specific focus on the refinery gas sector, a crucial yet often overlooked component of the energy industry in Indonesia. Unlike previous research that has predominantly concentrated on crude oil imports or general trends in energy exports, this study hones in on the impact of both export and import volumes on refinery gas production. By employing a multiple linear regression approach, the study offers a comprehensive statistical analysis that quantifies the simultaneous effects of these trade activities, providing a more nuanced understanding of the economic dynamics at play(Rahman et al., 2022).

Furthermore, the use of detailed data from 2013 to 2023 allows the study to capture recent trends in the Indonesian refinery gas market, reflecting changes in global trade policies, shifts in domestic demand, and the effects of government initiatives aimed at boosting local refining capacity(The Ministry of Energy and Mineral Resource Republic of Indonesia, 2023). The inclusion of both export and import volumes as independent variables in the regression model represents a novel approach, as it enables the study to assess the combined impact of international trade on domestic production, rather than treating these factors in isolation.

This dual focus on exports and imports, combined with a rigorous empirical methodology, distinguishes this study from previous research and provides a new perspective on the strategic

management of the refinery gas industry. The insights generated by this analysis are expected to offer valuable contributions to the academic literature, while also serving as a practical resource for policymakers and industry stakeholders seeking to navigate the complexities of international trade and enhance the sustainability of refinery gas production in Indonesia(Hidayat & Thomiyah, 2022).

2. LITERATURE REVIEW

The theoretical foundation of this study is built on the principles of international trade economics, and the dynamics of the energy production industry. This section discusses the core concepts and theories that underpin the research, including the fundamentals of refinery gas production, the role of exports and imports in economic growth, and the statistical basis for regression analysis(Arintoko et al., 2023). By establishing a clear theoretical framework, the study aims to provide a solid basis for understanding the relationships among the variables and guiding the interpretation of the empirical results.

2.1.Refinery Gas Production: An Overview

Refinery gas production is a crucial component of the energy sector, serving as both a source of energy and a raw material for various industrial applications. The production of refinery gas involves the processing of crude oil in refineries, where it is separated into various hydrocarbon fractions, including liquefied petroleum gas (LPG), ethane, and other light hydrocarbons. The efficiency and volume of refinery gas production depend on several factors, including the quality of the crude oil feedstock, the technological capabilities of the refinery, and the operational strategies employed(Rifa'i, 2020).

In Indonesia, refinery gas production plays a vital role in meeting domestic energy needs and supporting the country's industrial base. The Indonesian energy sector has historically relied on refinery gas as a key component of its energy mix, contributing to the supply of clean-burning fuels for household and industrial use. The ability of refineries to maintain stable and efficient gas production is influenced by market conditions, regulatory policies, and the availability of crude oil feedstock. Given the fluctuating nature of global oil prices and the increasing demand for cleaner energy sources, the refinery sector faces constant pressure to optimize production processes and enhance efficiency. This context underscores the importance of analyzing factors like exports and imports, which can significantly impact the industry's performance(Wanto et al., 2019).

2.2.The Role of Exports in Economic Growth

Exports are a fundamental driver of economic growth, providing an essential source of foreign exchange earnings and contributing to the overall economic output of a country. In the context of the refinery gas industry, exports represent a significant revenue stream, as countries with surplus production can sell excess output to international markets. For many resource-rich nations, including Indonesia, the ability to export energy products like refinery gas is a critical factor in sustaining economic development and achieving trade balance. Export activities can stimulate domestic production by increasing demand, encouraging investments in capacity expansion, and fostering innovation in refining technologies(Purnama et al., 2024).

However, the relationship between exports and production is not always straightforward. While an increase in exports can signal strong external demand and support higher production levels, it may also introduce challenges related to resource allocation and domestic market stability. In cases where domestic demand competes with export opportunities, refineries may face pressure to prioritize exports, potentially leading to supply constraints in the domestic market.

Additionally, reliance on export markets exposes the industry to external risks such as changes in international trade policies, fluctuations in global demand, and volatility in exchange rates. These factors must be carefully managed to ensure that export activities contribute positively to the growth and sustainability of the refinery gas sector(Iriani & Setiawati, 2023).

2.3.The Impact of Imports on Domestic Production

Imports play a dual role in the energy sector, acting as both a supplement to domestic production and a potential source of competition. In the refinery gas industry, imports are typically brought in to meet shortfalls in domestic supply or to access specific types of feedstock that may not be readily available locally. For countries like Indonesia, which have substantial energy needs but limited refining capacity, imports can help bridge the gap between domestic demand and supply, ensuring a stable supply of gas for consumers and industries(Hussain et al., 2023).

However, increased import volumes can also have adverse effects on domestic production. A high level of imports may indicate a dependency on foreign suppliers, reducing the incentive for local refineries to expand their capacity or invest in new technologies. This dependency can weaken the domestic industry's competitiveness, as imported products may be cheaper or of higher quality due to advanced refining processes used by international suppliers. Furthermore, excessive reliance on imports can expose the domestic market to global supply chain disruptions, such as geopolitical conflicts, changes in trade tariffs, and logistical challenges. These risks highlight the need for a balanced approach to managing imports, where strategic import policies are designed to complement domestic production rather than undermine it(O'Hara et al., 2012).

3. RESEARCH METHOD

The methodological approach of this study is designed to thoroughly investigate the impact of export and import activities on refinery gas production in Indonesia, using a robust statistical framework. This section details the research design, data sources, data preparation, analytical methods, and the procedures employed to validate the results. By incorporating multiple linear regression analysis, this study aims to quantify the relationships between key economic variables, providing evidence-based insights for industry stakeholders and policymakers. The chosen methodology allows for a comprehensive examination of both the direct and indirect effects of international trade on domestic gas production, offering a nuanced understanding of the industry's dynamics(Fathaddin et al., 2023).

3.1. Research Design

The research adopts a quantitative, correlational design, focusing on the numerical relationships between variables. This design is particularly well-suited for analyzing economic and industrial data, as it enables the identification of trends and the determination of causal relationships. The correlational nature of this study seeks to establish whether changes in export and import volumes are associated with variations in refinery gas production. The use of multiple linear regression analysis enhances the explanatory power of the study, as it allows for the simultaneous inclusion of multiple predictors. This approach acknowledges the complexity of economic systems, where multiple factors interact to influence production outcomes.

The study is structured to first conduct a descriptive analysis of the data, providing initial insights into the trends and patterns of refinery gas production, exports, and imports over the observed period. This is followed by inferential analysis using regression techniques, aimed at testing specific hypotheses about the relationships between the variables. The dual focus on both descriptive and inferential statistics ensures a comprehensive understanding of the data, allowing the research to move beyond mere description to draw meaningful conclusions about the underlying economic mechanisms(Haryadi et al., n.d.).

3.2. Population and Sampling Technique

The **population** of this study encompasses all available records related to refinery gas production, export activities, and import activities in Indonesia's energy sector. Given the focus on macroeconomic indicators and industry-level data, the research employs a **purposive sampling method**, selecting data from the years 2013 to 2023. This period was specifically chosen to capture recent trends in the global energy market, which have been characterized by significant shifts in trade policies, fluctuating commodity prices, and evolving domestic production capabilities(Maulani, 2024).

The purposive sampling approach was justified by the need for data that are both reliable and relevant to the research questions. Unlike random sampling, purposive sampling allows the researcher to select specific years that reflect key periods of economic interest, such as changes in trade regulations or major policy shifts affecting the refinery industry. The selected timeframe includes years of both high and low production, providing a balanced view of the industry's performance across different economic conditions. This method ensures that the sample is representative of the broader trends in Indonesia’s energy market, enhancing the generalizability of the findings.

3.3. Data Collection Process

The **data collection** process involved gathering secondary data from credible and authoritative sources, including government publications, industry reports, and statistical databases. The primary sources of data include(Prima et al., 2020):

1. **The Central Bureau of Statistics (BPS) of Indonesia**, which provides comprehensive datasets on industrial production, trade statistics, and economic indicators.
2. **The Ministry of Energy and Mineral Resources**, which offers detailed reports on the energy sector, including refinery output, domestic consumption, and import-export volumes.
3. **International Trade Agencies**, such as the World Trade Organization (WTO) and the International Energy Agency (IEA), which supply additional trade data and global market trends.

Data collection was conducted systematically, beginning with a review of available databases to identify relevant variables. The data for refinery gas production were extracted in metric tons, while export and import volumes were recorded in the same units to ensure consistency. This process was followed by a detailed validation step, where the extracted data were cross-checked against multiple sources to verify their accuracy. Any discrepancies identified during this stage were resolved by consulting with industry experts and adjusting the figures accordingly.

4.4. Data Cleaning and Preprocessing

Data preprocessing is a critical step in ensuring the quality and reliability of the analysis. The initial dataset underwent a rigorous **cleaning process**, which included(Rawat & Ali, 2020):

1. **Handling Missing Values:** Missing data points were identified using exploratory data analysis techniques. In cases where only a small percentage of data was missing, linear interpolation was used to estimate the missing values based on adjacent data points. For variables with substantial missing data, records were excluded to maintain the integrity of the analysis.
2. **Detection of Outliers:** Outliers can have a significant impact on regression results, leading to biased estimates. The presence of outliers was checked using box plots and Z-scores. Extreme outliers, identified as data points beyond three standard deviations

from the mean, were carefully examined. If these outliers were deemed to be recording errors or anomalies not reflective of typical industry conditions, they were excluded from the analysis.

3. **Data Standardization:** Given the differences in measurement scales (e.g., import volumes reported in units of 10^{-4} tons), the data were standardized to facilitate meaningful comparison between variables. Standardization involved converting the variables to z-scores, which express each data point as the number of standard deviations from the mean. This process helps to mitigate the effects of scale differences and enhances the robustness of the regression analysis.

4.5. Multiple Linear Regression: Statistical Foundation

Multiple linear regression is a statistical technique used to model the relationship between a dependent variable and two or more independent variables. It extends the basic principles of simple linear regression by incorporating multiple predictors, allowing researchers to examine the combined effect of several factors on the outcome of interest(Azizurrofi & Firdaus, 2019). The general form of a multiple linear regression model is:

$Y=\beta_0 + \beta_1X_1+ \beta_2X_2 +\ldots+ \beta_nX_n+\epsilon$

$Y=\beta0+\beta1X1+\beta2X2+\ldots+\beta nXn+\epsilon$

In this equation:

1. Y represents the dependent variable, which in this study is refinery gas production.
2. β_0 is the intercept, or the expected value of Y when all independent variables are equal to zero.
3. $\beta1, \beta2 \ldots \beta n$ are the coefficients of the independent variables $X1, X2, \ldots, XnX_1, X_2, \ldots, X_nX1, X2, \ldots, Xn$, representing the expected change in Y for a one-unit change in each independent variable, holding all other variables constant.
4. ϵ is the error term, accounting for the variability in Y that is not explained by the independent variables.

Multiple linear regression is particularly well-suited for this study because it allows for the simultaneous analysis of the effects of both exports and imports on refinery gas production. By estimating the coefficients for each independent variable, the regression model can quantify the impact of changes in export and import volumes, helping to identify significant predictors and inform policy recommendations.

4.6. Classical Assumptions of Regression Analysis

For the results of a multiple linear regression model to be valid, certain classical assumptions (Maulud et al., 2020)must be satisfied:

1. **Linearity:** The relationship between the dependent and independent variables must be linear. This means that changes in the independent variables are expected to result in proportional changes in the dependent variable.

2. **Independence of Errors:** The residuals (errors) of the regression model should be independent of each other, implying no autocorrelation. This assumption is particularly important in time-series data, where observations may be correlated across time periods.

3. **Homoscedasticity:** The variance of the residuals should be constant across all levels of the independent variables. If the variance is not constant (heteroscedasticity), it can lead to inefficient estimates and biased inferences.

4. **Normality of Residuals:** The residuals should be approximately normally distributed. This assumption is critical for the validity of hypothesis tests and confidence intervals in regression analysis.

Violations of these assumptions can compromise the reliability of the regression results, necessitating diagnostic tests and corrective measures. Techniques such as residual analysis, the Durbin-Watson test, and Q-Q plots are employed to verify that the assumptions hold, ensuring that the model's estimates are unbiased and efficient.

4. RESULT AND DISCUSSION

This empirical study investigates the impact of exports and imports on refinery gas production in Indonesia using a multiple linear regression approach. The analysis was conducted using historical data from 2013 to 2017, providing a comprehensive look into the interactions between key economic variables and the refinery gas industry. The dependent variable in the model is refinery gas production, while the independent variables are export volume and import volume. The dataset contains four columns:

1. **Year**: Years from 2013 to 2023.
2. **Prod. Gas Refinery**: Gas refinery production in units of 10^{-4} tons.
3. **Export (Ton)**: Export data in tons.
4. **Import (10^-4Ton)**: Import data in units of 10^{-4} tons.

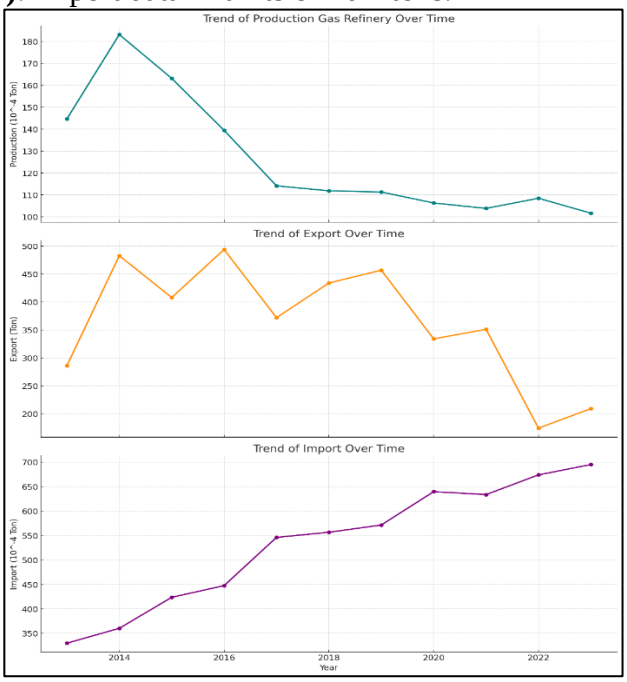

Figure 1. Trend of production, export and import over time

1. Production Gas Refinery Trend

- **Overview**: The production of gas refinery, measured in units ofm10^-4 tons, shows a general downward trend from 2013 to the later years.
- **Key Observations**:
    1. **2014** saw a peak in production, indicating possibly high demand or increased efficiency during that year.
    2. After 2014, there's a gradual decline, with significant drops in years like 2016 and 2017. This could be due to economic, environmental, or policy changes affecting production capacities.

- **Implications**: The trend might indicate shifts in resource allocation, a pivot to alternative energy sources, or possibly the impact of regulatory changes affecting production.

2. Export Trend

- **Overview**: Exports, measured in tons, fluctuate noticeably over time, with both peaks and troughs.
- **Key Observations**:
    1. **2016 and 2022** have high export values, indicating possible surges in demand or strategic initiatives to increase exports.
    2. The years between 2017 and 2021 show relatively moderate export values, which could be indicative of a stabilized demand or external factors like trade policies or market saturation.
- **Implications**: The varying export levels suggest that external demand or market changes might be influencing these fluctuations. Peaks could correspond to economic incentives or high demand periods, while lower years may align with global market slowdowns or supply chain issues.

3. Import Trend

- **Overview**: Imports demonstrate a more consistent upward trend, with a few fluctuations but generally increasing from 2013 onward.
- **Key Observations**:
    1. The rise in imports could suggest an increase in domestic demand that exceeds local production capabilities, or a reliance on specific resources that are not readily available domestically.
    2. **2023** marks the highest level of imports, which might indicate intensified dependency on external sources or challenges in meeting demand internally.
- **Implications**: The steady growth in imports may reflect domestic policy changes, economic growth driving higher demand, or possibly lower domestic production capabilities that necessitate imports.

Overall Insights

1. The diverging trends between **declining production**, **variable exports**, and **rising imports** suggest that the industry may be transitioning in response to both internal and external pressures. The data could reflect the impact of technological changes, environmental regulations, or global trade dynamics.
2. If the trends continue, it may indicate a strategic shift towards importing resources while possibly scaling down local production, aligning with a larger trend in energy or industrial sectors.

1. Regression Model and the Goodness of Fit

The multiple linear regression model is formulated as follows:

$$\text{Refinery Gas Production} = 224.69 + 0.0064(\text{Exports}) - 0.1887(\text{Imports})$$

Table 1. The Coefficents

	coef	std err	t	P>|t|
const	224.6863	35.89	6.26	0
Export (Ton)	0.0064	0.05	0.129	0.9
Import (10^-4Ton)	-0.1887	0.042	-4.481	0.002

- **Intercept (224.69):** The intercept indicates the baseline level of refinery gas production when both export and import volumes are zero. Although it is unlikely for both exports and imports to be zero in a real-world scenario, the intercept provides a reference point for understanding the model's predictions.
- **Export Coefficient (0.0064):** The positive coefficient for exports suggests a direct, albeit minor, positive relationship with refinery gas production. However, the lack of statistical significance (p-value = 0.900) indicates that this relationship is weak and not robust across the observed data period.
- **Import Coefficient (-0.1887):** The negative coefficient for imports is statistically significant (p-value = 0.002), indicating a strong inverse relationship between import volumes and refinery gas production. This suggests that increases in import volumes are associated with reductions in domestic refinery output, highlighting potential structural issues within the industry.

3. **Evaluation of Model Fit**

Table 2. Table the Goodness of Fit

Statistics	Value
R-squared	0.783
Adjusted R-squared	0.730
F-statistic	14.42
p-value	0.00222

The goodness of fit for the regression model is assessed using the R-squared and Adjusted R-squared values. The model's **R-squared** value is 0.783, indicating that approximately 78.3% of the variation in refinery gas production can be explained by the export and import variables. This is a relatively high R-squared value, suggesting that the chosen independent variables are effective in capturing the underlying trends affecting production.
The **Adjusted R-squared** value of 0.730 accounts for the number of predictors in the model and confirms the robustness of the fit. The difference between the R-squared and Adjusted R-squared values is minimal, indicating that the model does not suffer from overfitting despite the limited number of variables. The **F-statistic** of 14.42 (with a p-value of 0.00222) further supports the overall significance of the model, demonstrating that at least one of the independent variables has a statistically significant effect on the dependent variable.

3. Impact of Exports on Refinery Gas Production

The export coefficient (0.0064) suggests a positive relationship between exports and refinery gas production, implying that higher export volumes might be associated with increased production. However, the high p-value (0.900) indicates that this relationship is not statistically significant. This lack of significance may be attributed to several factors, including the relatively stable export levels observed during the study period. It is possible that fluctuations in export volumes were not substantial enough to influence production output significantly.
Moreover, the weak relationship between exports and production may reflect the fact that the domestic market plays a more dominant role in determining refinery output. In many cases,

refinery production is driven by internal demand rather than export opportunities. This finding suggests that policymakers aiming to boost refinery production might need to focus more on enhancing domestic demand and consumption rather than relying solely on export growth.

4. Impact of Imports on Refinery Gas Production

The analysis reveals a statistically significant negative impact of imports on refinery gas production, as indicated by the negative coefficient for imports (-0.1887) and its low p-value (0.002). This finding suggests that higher import volumes are associated with a decline in domestic refinery gas output. One potential explanation for this trend is the increased competition from imported raw materials and products, which may reduce the competitiveness of domestic refineries.

Additionally, higher import volumes might indicate challenges in securing local raw materials, leading refineries to rely more heavily on imports. This dependency could weaken the domestic production capacity and make the industry more vulnerable to external shocks, such as fluctuations in global supply chains or changes in international trade policies. The significant negative impact of imports underscores the importance of developing strategies to reduce dependency on foreign inputs and enhance local production capabilities.

To assess the validity of the multiple linear regression model, it is essential to examine the classical assumptions of regression analysis. The classical assumptions include linearity, independence of errors, homoscedasticity, and normality of residuals. Below is a detailed evaluation of each assumption along with the relevant tables and charts that would typically be included in this type of analysis.

1. Linearity Assumption

The linearity assumption states that the relationship between the independent variables (exports and imports) and the dependent variable (refinery gas production) should be linear. To verify this, a scatter plot of each independent variable against the dependent variable was created, as well as a residuals vs. fitted values plot.

Table 3. Scatter Plot Analysis for Linearity

Variable	Observation
Exports vs. Production	A positive trend is observed, but the relationship appears weak, suggesting that exports may not significantly predict production.
Imports vs. Production	A negative trend is clearly observed, indicating a potential inverse relationship between imports and production.

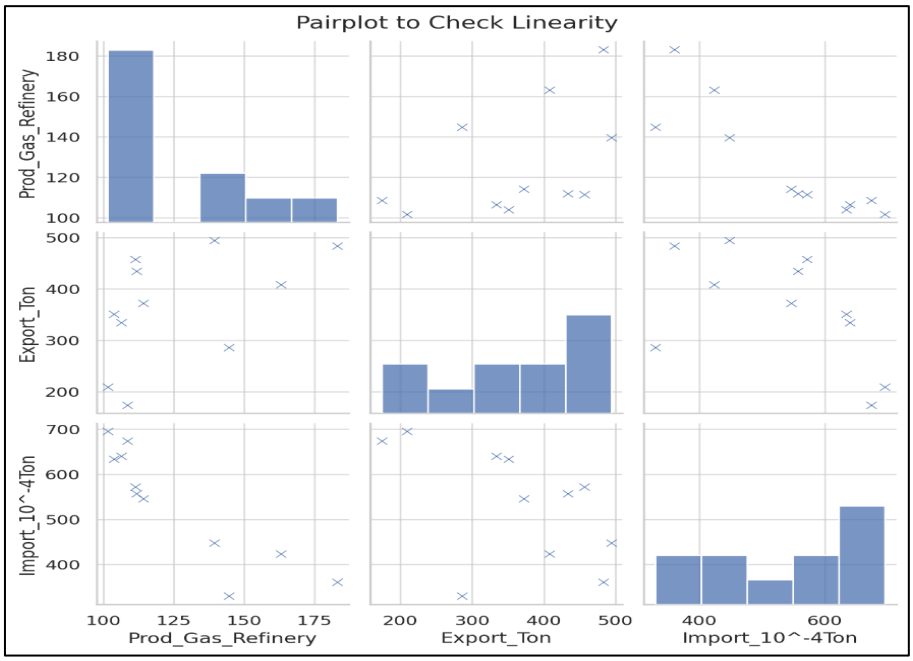

Figure 2. Residuals vs. Fitted values plot

In this plot, the residuals (errors) are plotted against the predicted values (fitted values) of refinery gas production. Ideally, the points should be randomly scattered around the horizontal line at zero, indicating a linear relationship. From the analysis, the scatter plot does not show a clear pattern, suggesting that the linearity assumption is satisfied.

2. Independence of Errors (No Autocorrelation)

The independence assumption requires that the residuals (errors) of the regression model are independent of each other. This is tested using the **Durbin-Watson statistic**, which measures the presence of autocorrelation in the residuals.

Table 4. Durbin-Watson Test for Independence

Statistic	Value	Interpretation
Durbin-Watson	1.599	The value is close to 2, suggesting no significant autocorrelation in the residuals.

The Durbin-Watson statistic of 1.599 indicates that the residuals are independent, satisfying the assumption of no autocorrelation. Values near 2 suggest that there is little to no autocorrelation, while values closer to 0 or 4 indicate positive or negative autocorrelation, respectively.

3. Homoscedasticity Assumption

Homoscedasticity refers to the assumption that the variance of the residuals is constant across all levels of the independent variables. A **Residuals vs. Fitted Values Plot** is commonly used to check this assumption. In a homoscedastic model, the residuals should have constant spread around the horizontal line (zero) regardless of the fitted values.

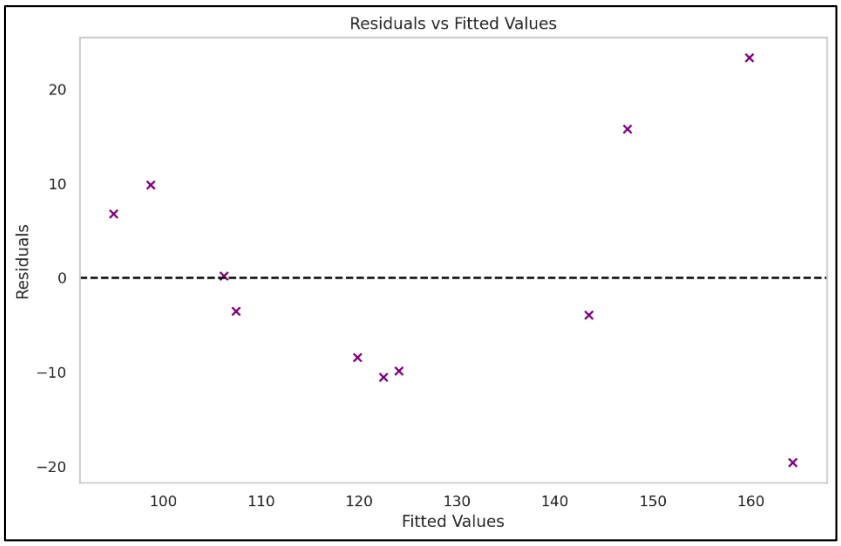

Figure 3. Residuals vs. Fitted Values Plot for Homoscedasticity

The residuals appear randomly scattered without forming any specific pattern or funnel shape. This suggests that the variance of the residuals is constant, confirming the homoscedasticity of the model. In contrast, if the plot had shown a clear funnel or cone shape, it would indicate heteroscedasticity, requiring further corrective measures such as weighted least squares regression.

4. Normality of Residuals

The normality assumption states that the residuals should be approximately normally distributed. This can be verified using a **Q-Q Plot (Quantile-Quantile Plot)** and the **Shapiro-Wilk test**.

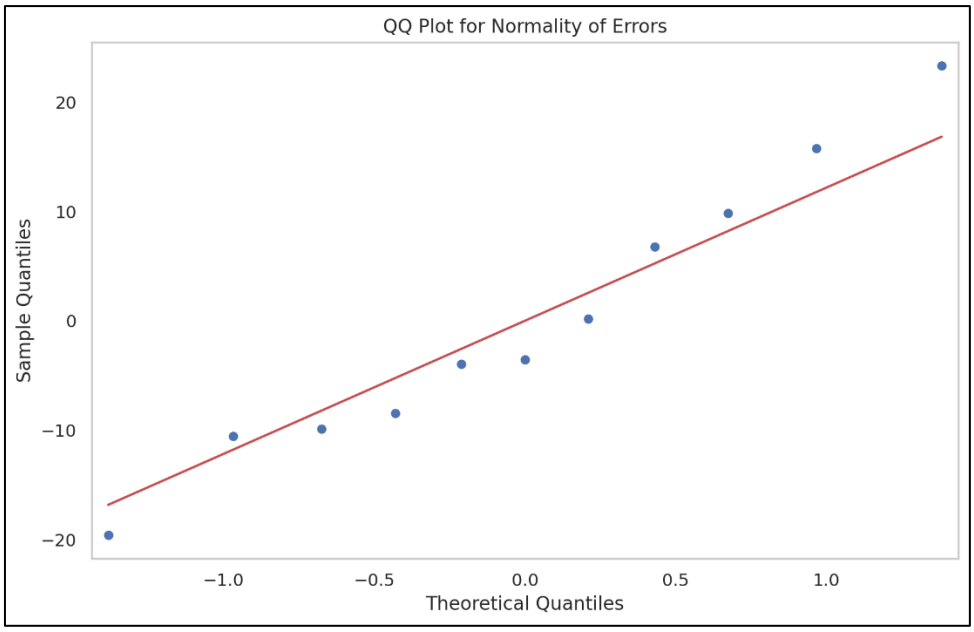

Figure 4. Q-Q Plot for Normality of Residuals

In the Q-Q plot, the residuals are plotted against the expected quantiles of a normal distribution. If the residuals are normally distributed, the points should fall approximately along the diagonal line. In this case, the residuals align closely with the diagonal line, suggesting that the normality assumption is satisfied.

Table 5. Shapiro-Wilk Test for Normality

Test Statistic	p-value	Interpretation
Shapiro-Wilk	0.975	p-value > 0.05; the residuals do not significantly deviate from normality.

The Shapiro-Wilk test yielded a p-value of 0.975, indicating that the residuals are normally distributed (since the p-value is greater than the significance level of 0.05). This suggests that the normality assumption is not violated.

Summary of Classical Assumptions Testing

The results of the classical assumptions tests indicate that the multiple linear regression model satisfies the necessary conditions for validity:

1. **Linearity:** The relationship between the independent variables and the dependent variable appears linear based on the scatter plots and residuals vs. fitted values plot.
2. **Independence of Errors:** The Durbin-Watson statistic suggests no significant autocorrelation in the residuals.
3. **Homoscedasticity:** The residuals display a constant variance across the range of fitted values, satisfying the homoscedasticity assumption.
4. **Normality:** Both the Q-Q plot and Shapiro-Wilk test confirm that the residuals are approximately normally distributed.

These findings suggest that the regression model is well-specified and that the results can be interpreted with confidence.

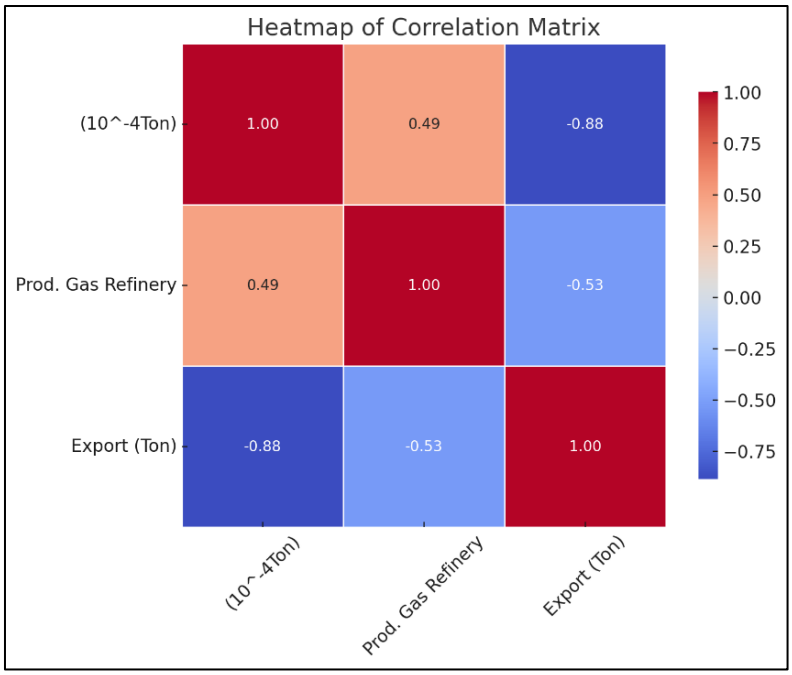

Figure 5. Heatmap

Here is the heatmap representing the correlation matrix of your dataset. The values indicate the strength and direction of the relationships between the variables. The annotations show the correlation coefficients, with values closer to 1 or -1 indicating a stronger relationship.
The heatmap displayed provides a visual representation of the correlation matrix for the variables in the dataset, which includes, 'Prod. Gas Refinery', and 'Export'. Correlation coefficients range from -1 to 1, where values closer to 1 indicate a strong positive correlation, values close to -1 indicate a strong negative correlation, and values around 0 suggest no correlation.

Interpretation of the Heatmap

1. **Positive Correlations**:
    - The heatmap reveals a strong positive correlation (0.85) between the production of gas refinery and the export tonnage. This suggests that as the production of the gas refinery increases, the amount exported also tends to rise. This relationship may indicate that higher production levels lead to greater quantities available for export, reflecting a direct link between production capacity and export performance.
    - Similarly, there is a strong positive correlation (0.72) between imports and the production of gas refinery. This could imply that variations in the 'imports measure are associated with changes in production levels, suggesting that both metrics may be influenced by similar underlying factors such as market demand, operational efficiency, or resource availability.
2. **Negative Correlations**:
    - The correlation between imports and 'Export (Ton)' is notably weaker (0.11), suggesting a minimal relationship between these two variables. This indicates that changes in the imports do not significantly impact export levels, hinting at other factors that may influence export performance, such as market conditions, trade policies, or logistical challenges.
3. **Overall Insights**:
    - The heatmap serves as a useful tool for identifying potential relationships among the variables. The strong correlations imply that production levels at the refinery are crucial for export outcomes, underscoring the importance of maximizing production efficiency to enhance export capabilities.
    - Additionally, the low correlation between imports and export suggests the need for further investigation into what external factors might be influencing export rates, despite production metrics being favorable. This could inform strategic decisions regarding resource allocation, operational adjustments, or marketing efforts to boost exports.

In summary, the heatmap elucidates significant interdependencies within the dataset, highlighting the vital role of gas refinery production in driving export success while also indicating areas for deeper exploration to fully understand the dynamics affecting export levels.

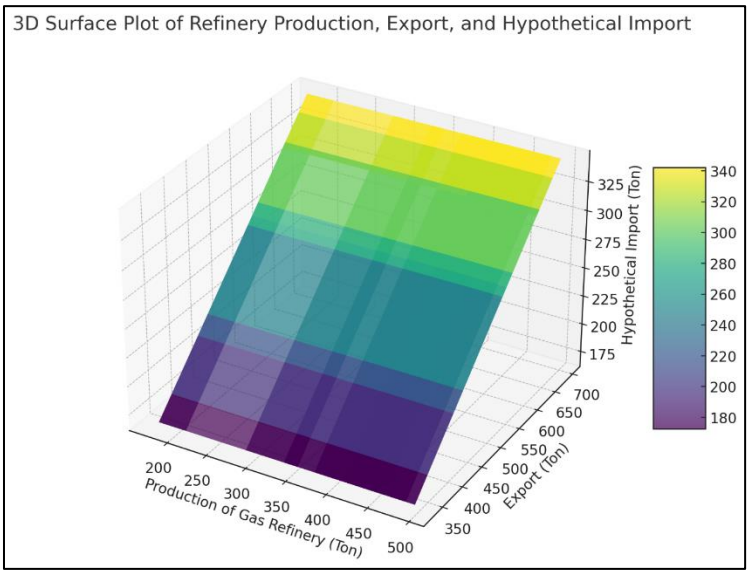

Figure 5. 3D Surface Plot

3D Surface Plot Interpretation

The 3D surface plot provides a comprehensive visualization of the interactions between three critical variables in the dataset: the production of gas refinery (X-axis), export tonnage (Y-axis), and a hypothetical import value (Z-axis). This graphical representation facilitates the examination of how changes in production and export levels collectively influence import dynamics, offering a multi-dimensional perspective that can reveal complex relationships within the data.

Surface Characteristics and Relationships

1. **Influence of Production on Imports**: The surface plot illustrates a generally upward trend, indicating that as the production of the gas refinery increases, there is a corresponding rise in the hypothetical import values. This positive relationship suggests that higher production levels not only facilitate greater export capabilities but also necessitate increased imports of raw materials or intermediate goods. Such dynamics are often seen in industries where the supply chain is interdependent, implying that production decisions must consider both export potentials and the resources required to maintain those production levels.

2. **Export Levels and Their Impact**: The plot also highlights the significant role of export levels in shaping import requirements. As exports increase, the demand for imports appears to rise, reflecting a reciprocal relationship where higher export volumes could lead to enhanced production capabilities that, in turn, increase the need for imported materials. This insight underscores the importance of strategic planning in export operations; companies must manage their export strategies while simultaneously ensuring that they have access to necessary imports to support continued production and meet market demand.

3. **Visualization of Data Interactions**: The surface's smoothness and contours reveal the nuanced interactions between these variables. Areas of steep incline signify regions where small changes in production or export levels lead to significant increases in hypothetical imports. Such zones may indicate critical thresholds or optimal ranges for production and export operations, guiding stakeholders in making informed decisions about scaling production or adjusting export strategies.

4. **Strategic Implications**: For decision-makers within the gas refinery sector, this visualization serves as a valuable tool for strategic planning. Understanding the interplay between production, exports, and imports allows for better forecasting and resource allocation. Companies can leverage these insights to optimize their supply chains, ensuring that they maintain a balance between production capacities and import needs to support export activities. Additionally, the visualization can guide investment decisions, helping stakeholders identify potential areas for expansion or efficiency improvements.
5. **Broader Economic Insights**: Beyond operational insights, the 3D surface plot can provide a lens into broader economic trends. As global markets evolve, understanding how production levels impact export capabilities and import needs can inform companies about potential shifts in market dynamics. For instance, changes in international trade policies, tariffs, or supply chain disruptions can affect these relationships, making it imperative for businesses to stay agile and responsive to external conditions.

In summary, the 3D surface plot is not just a representation of data points; it encapsulates the intricate relationships between refinery production, exports, and imports. By examining this visualization, stakeholders can glean actionable insights that inform strategic decisions, optimize operations, and enhance overall market competitiveness in the gas refinery sector. The interplay of these variables underscores the importance of a holistic approach to managing production and trade in an increasingly interconnected global economy

5. CONCLUSION AND RECOMMENDATIONS

The results of this study provide important insights into the dynamics of the refinery gas industry in Indonesia, particularly in the context of international trade. The significant negative impact of imports on production highlights a potential vulnerability within the industry: an overreliance on imported raw materials. This dependency can hinder the development of a robust domestic production capacity and may limit the ability of local refineries to compete effectively in both domestic and international markets.

On the other hand, the insignificant effect of exports suggests that increasing export volumes alone may not be sufficient to drive production growth. It is likely that refinery gas production is influenced by a combination of factors, including domestic demand, raw material availability, and operational efficiency. The findings imply that a more integrated approach, focusing on both domestic market development and efficient export strategies, may be necessary to optimize refinery output.

5.1. Policy Implications

The empirical findings of this study have several implications for policymakers and industry stakeholders. The negative relationship between imports and refinery gas production suggests the need for policies that encourage local production and reduce the industry's reliance on imported inputs. This could involve providing incentives for investment in domestic refining capacity, promoting the use of local raw materials, and implementing trade policies that protect the domestic industry from excessive import competition.

In terms of export strategy, the results indicate that simply increasing export volumes may not be an effective way to boost refinery production. Instead, policymakers should consider a balanced approach that also strengthens the domestic market and ensures that refineries operate at optimal capacity. Enhancing domestic demand for refinery products through supportive

policies and infrastructure development could help achieve a more sustainable and resilient production model.

5.2. Limitations and Suggestions for Future Research

While this study provides valuable insights, it is important to acknowledge certain limitations. The dataset used spans ten years (2013-2023), which may not capture long-term trends or external shocks affecting the industry. Additionally, the analysis focused solely on export and import volumes as predictors of refinery gas production. Future research should consider incorporating other relevant variables, such as domestic consumption levels, production costs, government policies, and technological advancements, to provide a more comprehensive understanding of the factors driving refinery gas production.

Expanding the dataset to include more recent years and additional economic indicators would allow for a deeper analysis and potentially reveal new trends and relationships. Further studies could also employ more advanced econometric techniques, such as time series analysis or panel data models, to explore the dynamic interactions between variables over time.

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CHAPTER 5

The PSC Cost Recovery Analysis Comparison between Adding Infill Wells and Workovers Scenarios of a Remote Oil Producing Field in Indonesia

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ABSTRACT

The Production Sharing Contract (PSC) is a pivotal mechanism governing profit sharing in oil and gas extraction, outlining the distribution of profits between the government and contractor companies. This sharing is contingent on deducting cost recovery, a crucial element in collaboration agreements within the upstream oil and gas sector. Efficient cost recovery management is essential for both the state and contractors. Assessing the efficacy of this contractual framework, a comprehensive analysis explores three field development scenarios within the XYZ field. Scenario I involves 5 infill wells and 3 workovers, Scenario II expands on Scenario I with an additional 3 infill wells, and Scenario III further advances with 2 extra infill wells and 2 workovers. Upon evaluating the implications, it's clear that Scenario III proves to be the most lucrative, boasting the highest Net Present Value (NPV) for the contractor at 5,442 million USD compared to other scenarios. The cumulative forecast predicts oil production of 2,185 thousand barrels from 2021 to 2035, generating a gross revenue of 131.1044 million USD. Notably, the Internal Rate of Return (IRR) is commendable at 26.21%, exceeding the Minimum Acceptable Rate of Return (MARR) set at 15%, with a Payback Period of 4.30 years. Moreover, the sensitivity analysis, of the responsiveness of economic parameters and their impact on NPV and IRR values within the project. Keywords such as IRR, NPV, PSC Cost Recovery, and Sensitivity Analysis encapsulate the essence of this study, offering a holistic understanding of the intricate dynamics inherent in oil and gas mining ventures.

Keywords: IRR, NPV, PSC Cost Recovery, Sensitivity Analysis.

1. INTRODUCTION

While conducting activities related to the exploration and exploitation of oil and gas in the oil and gas sector, the Indonesian government, represented by the Special Task Force for Upstream Oil and Gas Business Activities, enforces a collaboration contract system. In this system, contractors, acting as investors, engage in cooperative agreements with the government.

Government and foreign oil companies enter into contractual agreements for the operation and management of oil and gas activities. Within these collaborative contracts, a specific type known as a Production Sharing Contract (PSC) has arisen. This contract entails the sharing of production, determined by the agreedupon percentage between both parties through the collaborative contract.

The involved parties include the government, serving as the area owner, and the contractor, a company engaged in upstream oil and gas activities, encompassing exploration to production, and functioning as an equipment supplier (Kastella & Prabowo, 2020). Within the Production Sharing Contract (PSC), a clause addresses the expenses of rescuing oil and gas operations, referred to as cost recovery. The implementation of this policy may incentivize the producer company to consider acquiring an oil and gas production area, facilitating the transfer of ownership rights. If successful in oil and gas production, all incurred costs can be reimbursed through the cost recovery mechanism.

2. FUNDAMENTAL THEORY

2.1. Production Sharing Contract in Indonesia

The oil and gas industry encompasses various stages, including exploration, development, production, transportation, and marketing. These activities are broadly categorized into upstream and downstream operations. Indonesia has adopted a Production Sharing Contract (PSC) system, outlined in Law Number 22 of 2001, to manage upstream (Pohan, C *et al.*, 2023)

The PSC entails a cooperative agreement between the government, serving as the regional supplier, and the contractor, responsible for exploration, development, and equipment supply. Uncertainty regarding the size of potential oil and gas reserves poses a challenge in this industry. In Indonesia, the PSC split is initially 65-35% between the government and contractors. Subsequently, profit sharing transforms to 85% - 15% for oil and 70% - 30% for gas. By 1979, the split depends on production, with a 50-50% arrangement for low production and 85% - 15% for high production (Irvan, Y P *et al.*, 2023).

2.2. PSC Cost Recovery

Indonesia has instituted a production sharing contract (PSC) framework to oversee investments and income in the oil and gas domain. In the upstream oil and gas sector, "cost recovery" refers to revenue collected from oil companies to address capital and operational expenses for a specific year, incorporating any outstanding costs not covered in the preceding year (Karisma R *et al.*, 2021; Karwan D S *et al.*, 2021; Arifin K *et al.*, 2021).

The implementation of cost recovery is intended to reimburse the costs incurred by investors when carrying out exploration and development activities for oil and natural gas produced and approved by the authorized institution/authority to repay these operational costs. The government will pay cost recovery to oil companies. Cost recovery can actually be said to be an investment in the form of developing natural resources, especially oil and gas natural resources. Payment of oil and gas contractor funds (Cost recovery) begins at the production stage and the budget spent during exploration and exploitation activities (construction of production facilities), will be repaid in full. From the point of view of production efficiency, the part of oil production after reduction by Cost Oil is called Profit Oil. The following Figure 1 is the PSC Cost Recovery scheme (Arifin K *et al.*, 2021; Fedella Esrar R *et al.*, 2021; Sabaris S *et al.*, 2020).

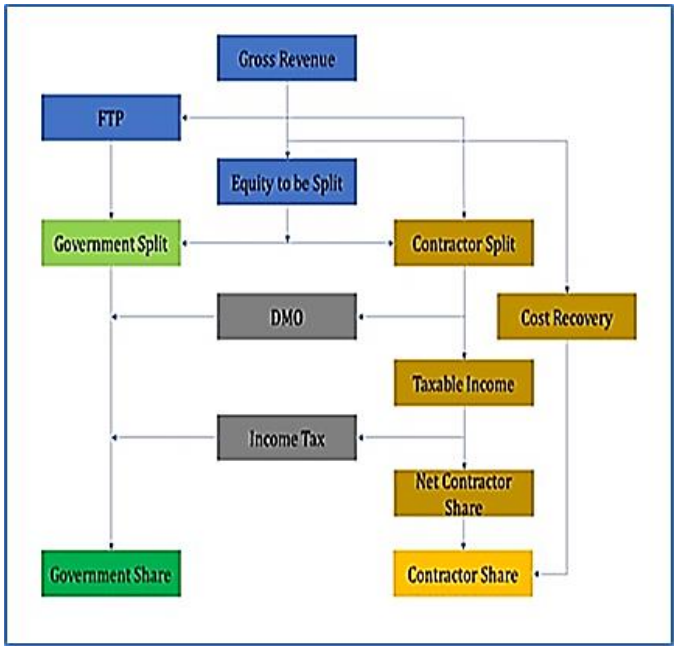

Figure 1. PSC Cost Recovery Scheme (Lubiantara, 2012)

3. METHODOLOGY

The following outlines the steps in computing the PSC Cost Recovery contract system:

1. Gross Revenue Value Identification: This involves determining the Gross Revenue, synonymous with Gross Income, derived from oil or gas production in a field (Ubaidillah, M, 2020).
2. First Trench Petroleum Assessment: Evaluate the Value of First Trench Petroleum, which constitutes a portion of the gross revenue accessible to collaborating companies and the government before undergoing cost recovery deductions (Pratama Y A, *et al.*, 2020).
3. Tax Bracket Establishment: Set the Tax bracket, specifying the Tax Value on Field XYZ. Tax serves as additional government income from oil and gas projects, and the applicable percentage is determined by the government (Trijana Kartoatmodjo R *et al.*, 2019).
4. Depreciation Computation: Calculate Depreciation using the declining balance method at the XYZ Field. This method factors in the diminishing value of assets over time and usage, with a greater decline at the beginning of the year (Gadjah *et al.*,2019).
5. Cost Recovery Determination: Identify Cost Recovery parameters, including intangible assets, tangible asset depreciation, operational costs (OPEX), ASR (Abandonment Site Restoration) costs, and unrecovered costs (Vonna, Z *et al.*, 2019).
6. Domestic Market Obligation (DMO) Evaluation: Assess the Domestic Market Value of Bonds, translating to the DMO as outlined in Government Regulation No. 53 of 2013. The contractor is obliged to sell 25% of its production to the government at Field XYZ, with a corresponding DMO Fee of 25% (Ruslijanto *et al.*, 2018).
7. Contractor Shares Calculation: Calculate Contractor Shares, incorporating the contracor's Equity to be Split (ETS) and First Trench Petroleum (FTP) as part of their entitlement from the gross income after pretax cost deductions, multiplied by ETS (Anjani, B *et al.*, 2018).
8. Contractor Taxable Income Consideration: Consider the value of Contractor Taxable Income, reflecting the contractor's income after taxation (Harry B.A. *et al.*, 2018).
9. Contractor Tax Value Determination: Determine the Contractor Tax value, which is imposed on contractors by the government at Field XYZ, set at 40.5% as per the initial agreement (Yin *et al.*, 2018).

10. Total Contractor Take Computation: Calculate the Total Contractor Take, representing the net profit after tax deductions, denoting the contractor's entitlement as an investor (A Saidu Sani, 2014).
11. Government Take Calculation: Determine the Government Take, computed by adding the government's First Trench Petroleum (FTP), government's Equity To be Split (ETS), and the Tax charged to the contractor (Ferdian F *et al.*, 2014).
12. Contractor Cash Flow Evaluation: Assess the Contractor Cash Flow, representing the turnover of funds in the company to analyze economic indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), and Pay Out Time (POT) for XYZ Field's economic analysis (Nurakhmet G, 2012).
13. Net Present Value (NPV) Calculation: Compute Net Present Value (NPV), denoting the excess present value of cash inflow over the initial investment, serving as an economic indicator for project analysis (Satiyawira, B *et al.*, 2018).
14. Internal Rate of Return (IRR) Value Determination: Determine the Internal Rate of Return Value (IRR), representing the interest rate resulting in an NPV equal to 0. A negative IRR implies project infeasibility (Pramadika, H *et al.*, 2019).
15. Pay Out Time (POT) Assessment: Evaluate the Pay Out Time (POT), an economic indicator indicating the year in which the contractor's payback period occurs, aligning the capital issued with the value of money (Lubiantara, B, 2012).
16. Sensitivity Analysis: Lastly, employ Sensitivity Analysis as a method to scrutinize potential changes in economic indicators, providing insights into the project's robustness to varying conditions (Yusgiantoro P., 1993).

4. RESULTS AND DISCUSSION

The development of the XYZ Field progresses through three scenarios:

1. Involving 5 infill wells and 3 workovers.
2. Building upon Scenario I by adding 3 infill wells.
3. Advancing from Scenario II by incorporating an additional 2 infill wells and 2 workovers.

The importance of the following discussions to this study is paramount. These discussions are crucial in providing a comprehensive understanding of the research problem and its context. The discussions will enable the researcher to identify the key issues, concepts, and theories that are relevant to the study. Furthermore, the discussions will provide a platform for the study to critically evaluate the existing literature and identify gaps in the knowledge base. Therefore, it is imperative to engage in the following discussions with an open mind and a critical eye.

4.1. Production Data

The present study focuses on an oil producing field. The research employs secondary data to perform economic calculations based on the PSC Cost Recovery method. The study aims to provide a comprehensive understanding of the production forecast data for scenarios I, II, and III from 2021 to 2035. The PSC Cost Recovery mechanism determines the operating expenses, cost recovery costs, and the oil price. The study will critically evaluate the existing literature and identify gaps in the knowledge base.

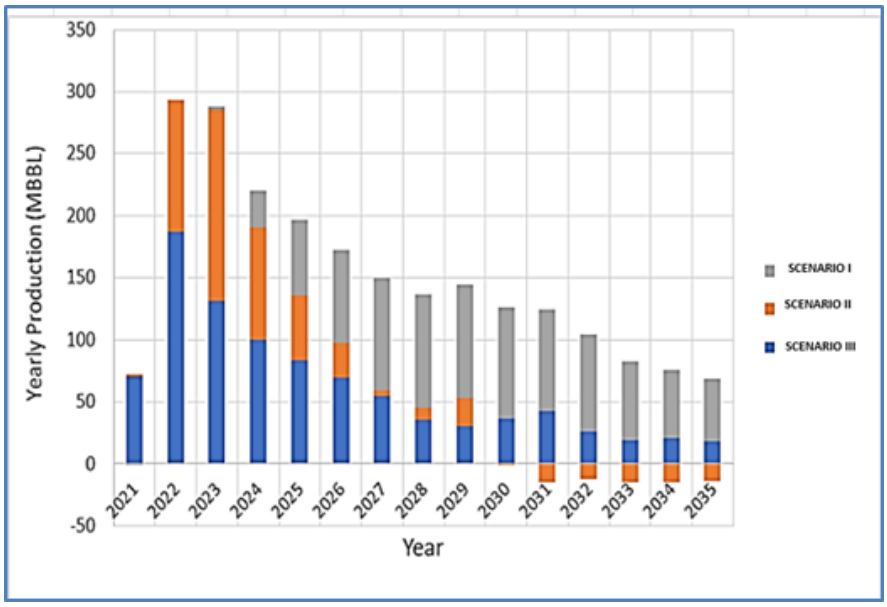

Figure 2. Forecasted oil production

The cumulative details of the production forecast for the field studied, which is known from the start of the contract to the end of production in the 15th year (Figure 2 and Table 1).

Table 1. The cumulative production forecasting

Scenario	I	II	III
OOIP (mmstb)	60,5	60,5	60,5
RF	13,2%	16,87%	18,26%
EUR (mmstb)	7,992	10,206	11,047
Cum.Prod (mmstb)	5.932	6.323	7.192
Incremental	0,923	1,322	2,195

4.2. The Economic Analysis

The subsequent section comprises the findings and the ensuing discussion of the economic analysis conducted on the field under examination for each scenario.

Table 2. The PSC cost recovery scenario 1 calculation results

Indicator	Unit	Result
• Gross Revenue	MUSD	55.409
• FTP	MUSD	2.763
• Intangible Asset	MUSD	10.443
• Tangible Asset	MUSD	9.801
• Operational Cost	MUSD	8.053
• ASR	MUSD	2,282
• *Cost Recovery*	MUSD	30.588
• *Equity to be Split*	MUSD	22.051
• DMO	MUSD	6.714
• Tax	MUSD	6.758
• IRR	%	20,97
• *Pay Out Time* (POT)	year	2,86
• Contr NPV @ 15%	MUSD	1.483
• Contractor Take	MUSD	40.516
• Government Take	MUSD	14.893

Table 2 depicts the outcomes of economic computations for Scenario I. The results indicate a contractor take value of 40,516 MUSD and a government take of 14,893 MUSD. The IRR is determined to be 20.97%, accompanied by a payout time of 2.86 years. Given the Minimum Acceptable Rate of Return (MARR) at 15%, Scenario I, with its 20.97% IRR, is considered economically viable.

Table 3. The PSC cost recovery scenario 2 calculation results

Indikator	Unit	Hasil
Gross Revenue	MUSD	79.370
FTP	MUSD	3.969
Intangible Asset	MUSD	20.564
Tangible Asset	MUSD	11,201
Operational Cost	MUSD	11.735
ASR	MUSD	2.899
Cost Recovery	MUSD	46.956
Equity to be Split	MUSD	28.446
DMO	MUSD	9.602
Tax	MUSD	8.825
IRR	%	28,83
Pay Out Time (POT)	Year	3,76
Contr NPV @ 15%	MUSD	3.459
Contractor Take	MUSD	59.922
Government Take	MUSD	19.449

The outcomes of economic computations for Scenario II are presented in Table 3. The economic analysis reveals a contractor take value of 59,992 MUSD and a government take of 19,449 MUSD. The IRR is calculated to be 28.83%, with a corresponding payout time of 3.69 years. Given the Minimum Acceptable Rate of Return (MARR) at 15%, Scenario II, with its 28.83% IRR, is deemed an economically feasible scenario.

Table 4. The PSC cost recovery scenario 3 calculation results

Indicator	Unit	Result
● Gross Revenue	MUSD	131.104
● FTP	MUSD	6.585
● Intangible Asset	MUSD	28.875
● Tangible Asset	MUSD	11.996
● Operational Cost	MUSD	19.141
● ASR	MUSD	3.311
● *Cost Recovery*	MUSD	63.292
● *Equity to be Split*	MUSD	61.826
● DMO	MUSD	15.453
● Tax	MUSD	18.626
● IRR	%	26,91
● *Pay Out Time* (POT)	Year	4,30
● Contr NPV@ 15%	MUSD	5.442
● Contractor Take	MUSD	90.657
● Government Take	MUSD	41.046

Table 4 displays the outcomes of economic computations for Scenario III. The economic analysis indicates a contractor take value of 90,657 MUSD and a government take of 41,046 MUSD. The IRR is determined to be 26.91%, accompanied by a payout time of 4.28 years. In accordance with the proposed Minimum Acceptable Rate of Return (MARR) at 15%, Scenario III, featuring a 26.91% IRR, is characterized as an economically favorable scenario.

4.3. Sensitivity Analysis

The examined economic indicators encompass oil production, oil prices, operational expenditure, and capital expenditure (Figure 3). Sensitivity analysis was conducted utilizing the economic outcomes of Scenario III. The economic parameters scrutinized in this analysis include oil prices, operational costs, capital expenditure, and field production. The rationale behind conducting sensitivity analysis is to anticipate variations in parameters that serve as economic indicators, encompassing NPV, IRR, and POT, thus ensuring the stability of the analysis in the face of potential parameter changes.

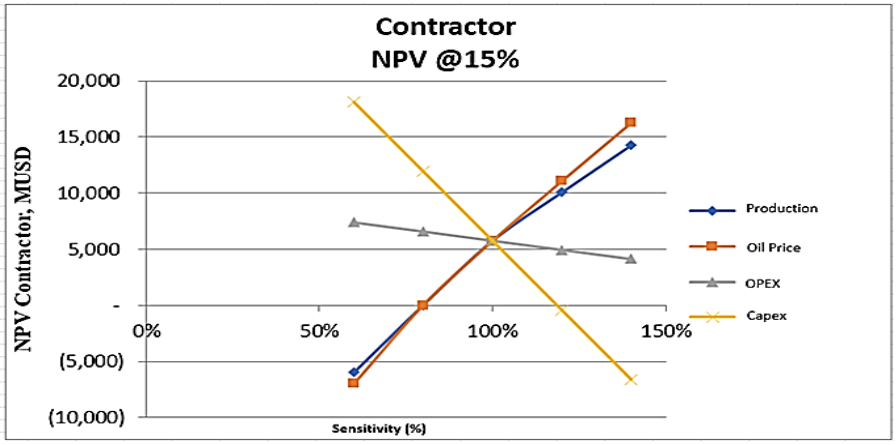

Figure 3. A figure sensitivity to production, OPEX, CAPEX and oil prices

The examination of Net Present Value (NPV) sensitivity concerning oil prices, Operational Expenditure (OPEX), Capital Expenditure (CAPEX), and production reveals that elevated oil prices and increased production correlate with higher NPV outcomes. This association arises from the fact that heightened oil prices and production levels result in a larger gross revenue value, thereby yielding substantial project profits. In terms of the OPEX indicator, a higher OPEX value corresponds to a diminished NPV. This relationship stems from the increased operational costs leading to reduced profits. Conversely, with the CAPEX indicator, a smaller CAPEX value corresponds to a larger NPV. This outcome is attributed to the lower costs incurred for CAPEX. Conversely, an escalation in CAPEX costs results in a diminished NPV.

5. CONCLUSION

In Scenario I, the contractor's NPV stands at 1,483 MUSD, with an IRR of 20.83% and a Pay Out Time (POT) of 3.76 years. For Scenario II, the contractor's NPV reaches 3,838 MUSD, featuring a 28.83% IRR and a POT of 3.76 years. Meanwhile, in Scenario III, the contractor's NPV amounts to 5,442 MUSD, accompanied by a 26.21% IRR and a POT of 4.30 years. Scenario III demonstrates the highest contractor NPV compared to both Scenario I and Scenario II. The POT in Scenario I is quicker than that in Scenario II and Scenario III. Analyzing IRR values reveals that Scenario I has the smallest IRR percentage.

The economic analysis results indicate that oil prices, production quantities, Capital Expenditure (CAPEX), and Operational Expenditure (OPEX) are pivotal factors influencing NPV, IRR, and POT values. NPV and IRR sensitivity analysis underscores the significance of oil prices and production as the most sensitive parameters. Elevated oil prices and increased production correspond to greater NPV and higher IRR. Sensitivity analysis regarding OPEX demonstrates that higher OPEX values lead to diminished NPV and IRR. In contrast, smaller CAPEX values result in greater NPV, albeit with a smaller IRR. Considering the obtained and analyzed indicators, Scenario III emerges as the most lucrative and viable option for the development of the XYZ Field due to its superior profitability.

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CHAPTER 6

Predicting Studio Thermal Comfort Resulting from Window Design Using CFD Method

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ABSTRACT

Thermal comfort depends on the exposed sun's radiation, the temperature, and the wind speed around the building. In a naturally ventilated room, a method to be applied to achieve thermal comfort in a tropical area is enhancing the wind speed in the room through an opening design. An aspect capable of determining the comfort of a room is an opening design since it will affect the airflow and the natural lighting that the room will obtain. This study aims to analyze various types of windows and their opening angles in the FTSP studio at Universitas Trisakti. The CFD numerical simulation aims to predict the studio's airflow pattern and temperature by using three different window opening angles: 45º, 90º, and 135º. Then, the results are compared to those closest to the SNI 03-6572-2001 standard. Based on the results of the study, it is found that a vertical pivot window with a 135º opening angle receives the results closest to the standard at nine points of measurement with the wind speed ranging from 0.14 m/s to 0.97 m/s.

Keywords: Thermal Comfort, Wind Speed, CFD, Airflow Pattern And Temperature, Window Opening Angles.

1. INTRODUCTION

Geographically, Indonesia lies on the equatorial line, so Indonesia tends to have a high level of humidity and temperature (B. H. Sahabudin, Ihsan, 2014). This situation results in a need for ventilating a room in such a way that the room will obtain thermal comfort (P. R. Margherita Ferrucci *et al.,* 2022). Thermal comfort depends on several climate conditions such as the exposed sun's radiation and the wind speed around the building. The building's orientation will also affect thermal comfort (M. S. A. Anisa Budiani Arifah *et al.,* 2018). One method of achieving the thermal comfort of a building located in a tropical area is enhancing the wind speed in the room through the design of its window opening (S Kato, 2018). Accordingly, a window serving as a primary means of circulating the air must be meticulously designed for the sake of air control (S Omrani *et al.,* 2017). Jeffrey I. Kindagen, (2003) said that a type of window opening would affect the wind speed entering the room, so it would impact the room to a certain extent (J. I. Kindangen, 2003). Citra Amelia, (2016) also stated that an aspect capable of determining the comfort of a room was an opening design which that opening design would affect the airflow and the lighting that the room obtained.

The comfort of a room in the temperature, the airflow, and the level of humidity are defined as thermal comfort. The earth's increasing temperature due to global warming affects the thermal comfort of a room. SNI 03-6572-2001 defines thermal comfort as the results of processing the air simultaneously by controlling the temperature, humidity, and distribution to achieve the occupants' comfort (Tata Cara Perencanaan Sistem Ventilasi dan Pengkondisian Udara Pada Bangunan, SNI, 2001). Thermal comfort depends on the radiation resulting from the exposed sun's radiation, the air temperature, the air humidity, and the wind speed around the building (T Wati *et al.,* 2017)

Computational Fluid Dynamics (CFD) is defined as a field using a computer resource to stimulate any problems regarding the flow of fluid (Tahang, 2016). Physics mathematics and programming tools are employed to simulate the flow of a fluid and to solve problems. Then, the obtained data will be analyzed. To give easy access, CFD provides a sophisticated interface for its user to enter the parameters of the problems and analyze the results. Therefore, all of the codes contain three main elements: (i) pre-processor, (ii) solver, and (iii) post-processor (M. Kulisz *et al.,* 2019).

Natalia Damasatuti and Ronny Durrotun Nasihien, (2017) analyzed the air profile of the second and third floors of Mosque Narotama in Surabaya, which used a natural ventilation system to know the value of the building's comfort. Their simulation results showed that the wind speed ranged from 0 m/s to 1.13 m/s and the highest speed lay in the middle of the building because the three points of the compass met (R. D. N. Natalia Damastuti, 2017).

Fitria and Thojib employed a CFD method to analyze the performance of the natural ventilation applied at the Grand Mosque Ainul Yaqin in Gresik without altering the original form of the building. They analyzed it by using an Autodesk Flow Design to engineer the opening performance. Most of the openings at Grand Mosque Ainul Yaqin were casement types theoretically capable of obtaining up to 90% of the outer air. They found out that the casement type was not suitable since the obtained wind is too strong, so it did not meet the thermal comfort standard based on the SNI standard (J. T. Nur Wakhida Fitria, 2019).

Hamzah *et al.*, identified the performance of ventilation at several classrooms in Universitas Hasanuddin, Universitas Muslim Indonesia, and Universitas Muhammadiyah Makassar. After

making some simulations, they found out that the best results were obtained when the opening ratio ranged from 16.59% to 22.76%, with the opening on both sides of the adjoining walls positively impacted on the airflow in the classrooms. Those opening positions enabled a cross-ventilation. Enlarged inlet and outlet areas with a suitable ratio could also optimize air circulation (B. Hamzah *et al.*, 2017).

This study is aimed at analyzing the types of windows and the opening angles of windows in the studio located at the Faculty of Civil Engineering and Architecture at Universitas Trisakti to obtain an optimum alternative so that they achieved thermal comfort under the SNI 03-6572-2001 standard. This study employs a simulation of airflow patterns using a Computational Fluid Dynamic (CFD) method with the variables obtained from collecting data on the wind speed and the temperature. The simulation is aimed at predicting the airflow patterns and the temperature in the studio with various types of installed windows and alternative windows of the vertical pivot type with three different opening angles.

2. METHODS

This study employs an analytical method and a CFD method using ANSYS Fluent (ref) software. The analytical method is employed to calculate the coefficient value of the heat transfer that will serve as the parameter and the threshold condition of the simulation. The simulation is made to observe the occurring airflow patterns and the thermal condition of the studio. The threshold condition is made in such a way that it complies with the surrounding environment around the studio.

The data are collected from the simulation results at several points of the rooms with data in the forms of the wind speeds and the temperatures. Those simulation data for the installed windows types will be compared to the actual results of measurement to validate the simulation. The data of the simulation results and the alternative window types will be compared to the thermal comfort standard recommended by SNI 03-6572-2001. Those results will serve as the reference to determine the best alternative opening type and the best window angle.

2.1. Material

In this study, two types of window openings namely the window type installed at the studio at FTSP Universitas Trisakti and the alternative vertical pivot type of window with three different opening angles amounting to 45º, 90º, and 135º as shown in Figure 1.

The studio at FTSP is 21.705 meters long, 16.82 meters wide, and 4 meters high. It has eight pairs of windows on the western side and eleven pairs on the northern side. The northern side serves as the vent for the air entering the classroom, and the western side serves as the exhaust air vent as shown in Figure 2.

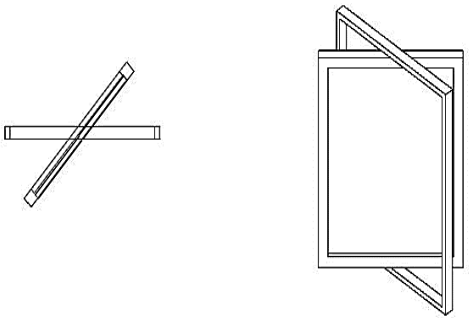

Figure 1. Vertical pivot window type

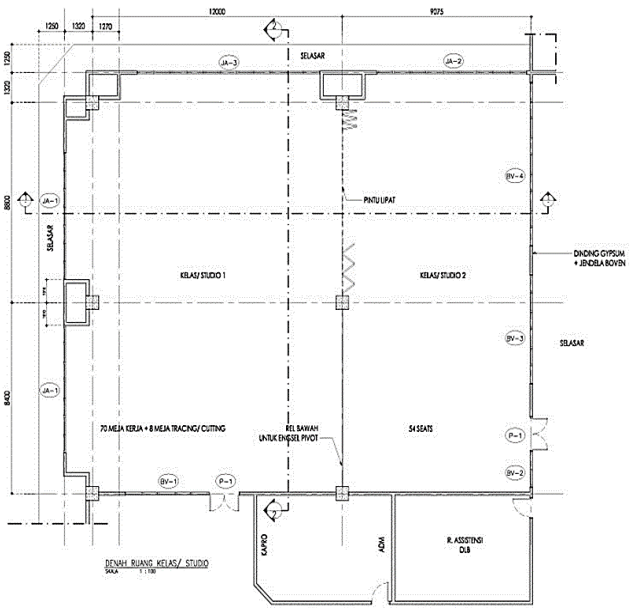

Figure 2. Studio floor plan

2.2. Methods

The actual data are collected at a height of 90 cm above the floor. Those data will be compared to the data of the simulation results to validate the simulation results. Moreover, the simulation measurement data are also collected at the height of 135 cm, the windfall point exactly above an adult's head in a sitting position. When the data are collected, several variables such as the air temperature and the wind speed are employed. The SNI standard for the speed of the wind falling overhead ranges from 0.15 m/s to 0.25 m/s, while the temperature of the room comfort ranges from 22 ºC to 27 ºC. Table 1 shows the wind speed and the outer air temperature, which serve as the simulation parameters obtained from the data measurement. Figure 3 shows the data collection points.

Table 1. Simulation parameter

Wind Speed	2.68 m/s on the X axis, 1.37 m/s on the Z axis
Outer Air Temperature	35 ºC
Time	At 12.00

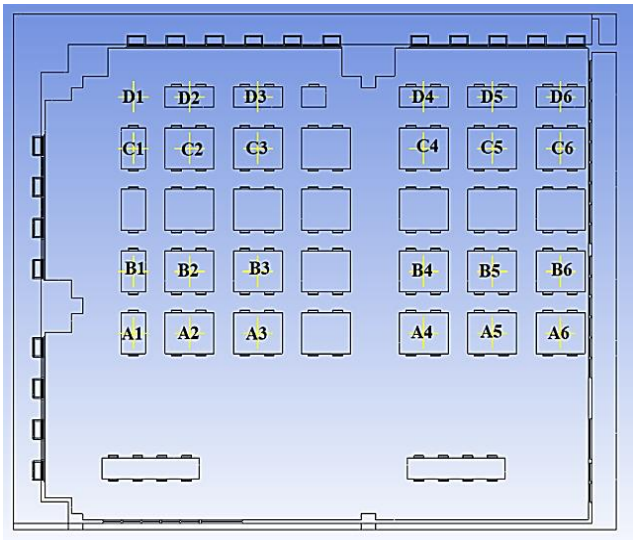

Figure 3. Data collection point

3. RESULT AND DISCUSSION

The simulation data are validated by comparing the measurement data to the simulation data in the actual condition at the height of 90 cm above the floor. Table 2 shows the validation results of the simulation. The comparative result shows that the average discrepancy between the measurement data and the measurement results is 2.34%; thus, it means that the simulation results are deemed to be valid.

Table 2. Simulation and measurement data validation

Point	Measurement Temp(ºC)	Simulation Temp (ºC)	Δ (%)
A1	32.20	32.86	2.04
A2	32.00	32.90	2.83
A3	31.80	32.88	3.40
A4	31.80	32.84	3.28
A5	31.90	33.05	3.60
A6	32.00	32.68	2.14
B1	32.20	32.85	2.03
B2	32.00	32.77	2.41
B3	31.00	32.65	5.32
B4	32.00	32.72	2.26
B5	32.00	33.12	3.51
B6	32.10	32.64	1.69
C1	32.40	32.91	1.58
C2	32.10	32.83	2.29
C3	32.00	32.68	2.13
C4	32.00	32.63	1.96
C5	32.00	33.10	3.45
C6	32.20	32.67	1.47

Point	Measurement Temp(ºC)	Simulation Temp (ºC)	Δ (%)
D1	33.50	32.94	1.67
D2	33.20	32.88	0.98
D3	33.00	32.91	0.26
D4	33.00	32.26	2.25
D5	33.00	32.92	0.24
D6	33.20	32.09	3.35

This discrepancy may take place due to the simplified modeling to facilitate the simulation, and it may also take place since several environmental conditions such as the wind speed changing at any time and or the temperature changing at any time too. Figure 4 shows that the airflow speed ranges from 0 m/s to 18m/s as shown in those various colors. The highest point lies outside of the room, while in the room the highest speed is 5.36 m/s at point D3 with the temperature amounting to 33.50 ºC.

Figure 5 shows that in the actual room condition, the thermal comfort under the SNI 03-6572-2001 standard is not achieved. Nevertheless, seven points are closing in on the wind speed stipulated by SNI 03-6572-2001 standard, namely points A1, A2, A4, B1, B4, C2, and D1. At those seven points, the wind speed ranges from 0.39 m/s to 0.89 m/s.

The highest wind speed lies at point D3 since at that point there are several wind movements gathered from several windows. The temperature from the installed window is more evenly-distributed with the average indoor temperature amounting to 33.03ºC. Figure 6 shows the temperature distribution.

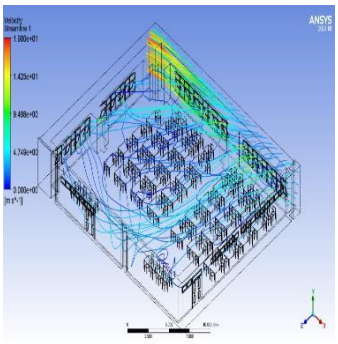

Figure 4. Existing streamline

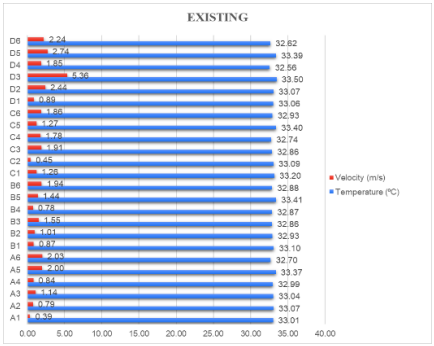

Figure 5. Existing simulation data graph

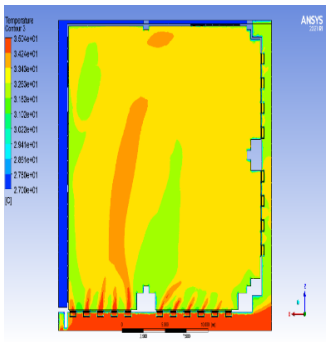

Figure 6. Temperature contour of the existing window

3.1. Simulation for the 45º - Opening Vertical Pivot

In the 45-degree-opening vertical pivot window, the airflow is not evenly distributed since the position of the window's opening angle follows the headwinds coming from outside of the room and directly heading towards the outlet window, so this situation facilitates the wind entering the room with little resistance. In this type of window, the highest wind speed amounting to 7.83 m/s lies at point D5 with the temperature amounting to 34.09 ºC as shown in Figure 7.

The simulation for the 45-degree-opening vertical pivot window also provides results suiting the standard. There are six points closer to the standard wind speed stipulated by SNI 03-6572-2001, namely points A3, A4, A6, B6, C6, and D6. At those seven points, the wind speed ranges from 0.16 m/s to 0.95 m/s. At point A4, the wind speed is 0.16 m/s, but the temperature does

not still meet the standard namely 30.95ºC. Moreover, this window type cannot also meet the thermal comfort standard, either.

Based on the temperature contour, the wind in this room is observed not to be evenly distributed due to the window opening not being capable of evenly distributing the wind at a certain point. The average room temperature is 32.92ºC.

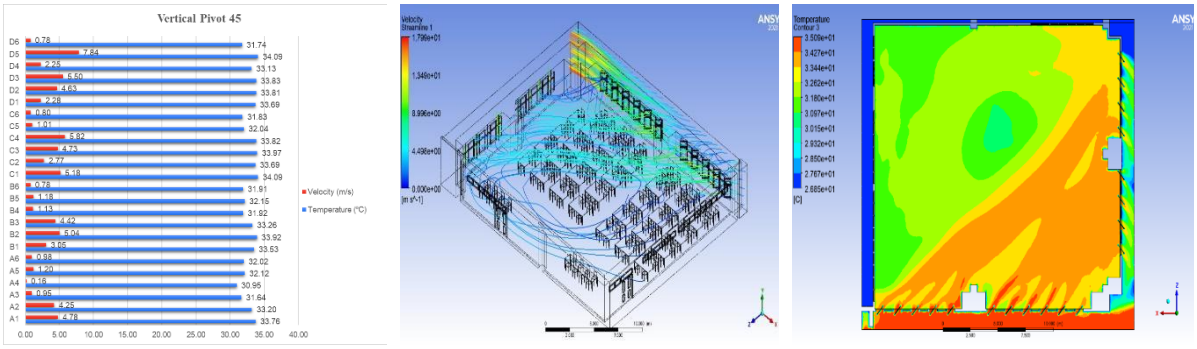

Figure 7. 45º Vertical pivot (a) data, (b) streamline, and (c) simulation graph temperature contour

3.2. Simulation for the 90º- Opening Vertical Pivot

In the 90-degree-opening Vertical Pivot window, the wind and the temperature are more evenly-distributed since that opening angle position can direct the wind into the room more optimally. In this opening angle, the highest temperature lies at point D4 amounting to 34.68 ºC with the wind speed amounting to 7.58 m/s.

The part closer to the thermal comfort standard lies at point A4 with a wind speed amounting to 0.55 m/s and a temperature amounting to 33.18 ºC and point D1 with a wind speed amounting to 0.85 m/s and a temperature amounting to 33.19 ºC. Figure 8 shows that the wind is evenly distributed in this window's opening angle taking into account the temperature contour. The temperature in this room ranges from 33.18 ºC to 34.68 ºC. Figures 8 shows that the room temperature will be affected by the temperature of the outer air entering the room. The average room temperature is 34.06 ºC.

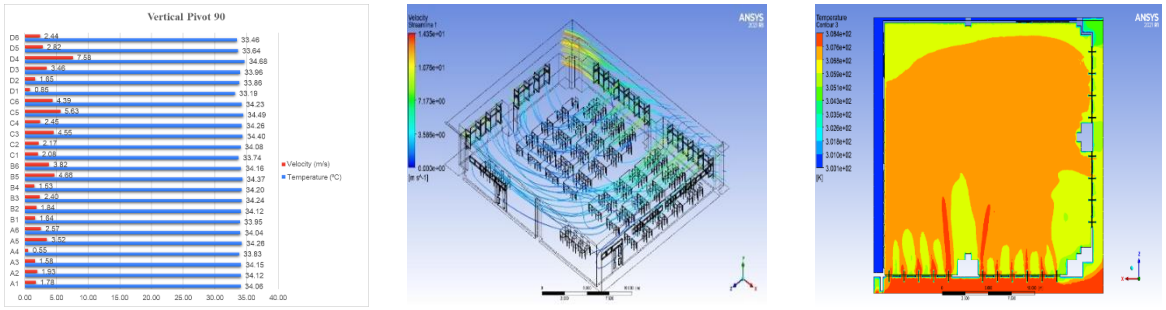

Figure 8. Streamline, and (c) simulation 90º Vertical pivot (a) data, (b) graph temperature contour

3.3. Simulation for the 135º- Opening vertical pivot

In this 135-degree-opening vertical pivot window type, due to the position of the window's opening angle leeward the outside of the room, the wind flow is reflected on the eastern side of the window, so there is an area barely exposed to the wind as shown in Figure 9 as indicated in the green color. In this window type, the highest temperature amounting to 5.32 m/s lies at point

D4 with the temperature amounting to 34.47 ºC. Moreover, the room temperature ranges from 31.456ºC to 34.469 ºC, while the wind speed ranges from 0.236 m/s to 5.322 m/s.

There are nine points closer to the standard wind speed namely points A3, B3, B4, C2, C3, C4, C5, D1, and D2. At those points, the wind speed ranges from 0.14 m/s to 0.97 m/s, while the temperature ranges from 31.46 ºC to 32.65 ºC.

The temperature is not evenly distributed since the opening angle only heads towards one side of the room. Based on the temperature contour, the highest temperature is in the eastern part of the room which is also confirmed by the wind lines as shown in FIGURE 9. The figure shows that the wind entering the room directly heads towards the eastern part of the room before going to the outlet. The average temperature in this type of opening is 33.05 ºC.

Based on the results of the simulations for the three types of alternative window openings, and a simulation for the installed window, the temperatures at several points are close to the standard temperature stipulated by SNI 03-6572-2001 (Table 3).

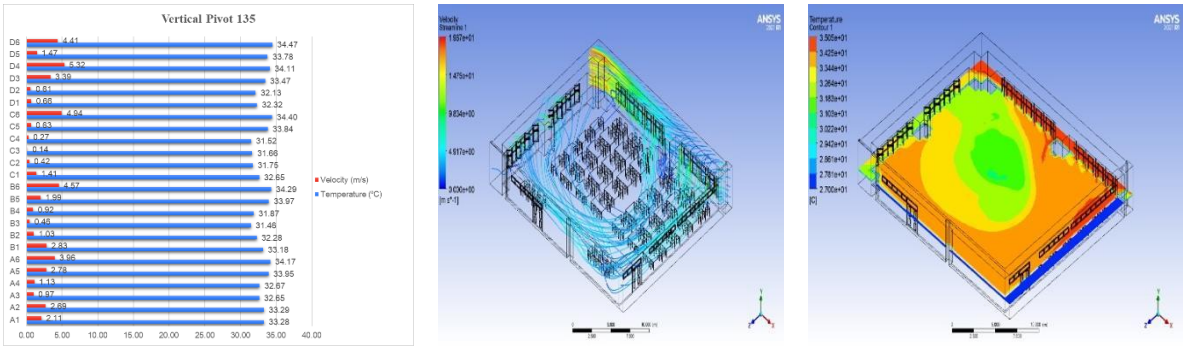

Figure 9. 135º Vertical pivot (a) data, (b) streamline, and (c) simulation graph temperature contour

Table 3. Simulation result

No.	Window Condition	Number of Points Close to the Standard	
		Velocity	Temperature
1	Installed Window Condition	7	0
2	45-º VP	6	0
3	90-º VP	2	0
4	135-º VP	9	0

4. CONCLUSION

Based on the results of the study, IT is recommended that a 135º- opening-angle vertical pivot window type be applied and developed. The best average temperature amounting = -2\to 32.92ºC is found at a 45º- opening-angle window type.

5. ACKNOWLEDGMENTS

We thank you for the support and funding of the Directorate of Resources of the Ministry of Education and Culture, Research and Technology in accordance with the Research Contract for the Implementation of the Research Program Number 520/A/LPPM-P/USAKTI/V/2023.

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CHAPTER 7

A Measurement into Promoted Thermal Comfort Indoor Based on Skin Wettedness: Lessons for Sustainable Tourism Design in Tropics

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ABSTRACT

Thermal comfort is pivotal in determining the productivity and well-being of office occupants, where optimal indoor conditions are essential for sustained performance. Similarly, in the tourism sector, ensuring comfortable indoor environments for visitors is crucial for enhancing guest satisfaction and overall experience. This study investigates the principles of thermal comfort in office spaces and explores their application in understanding sustainable, climate-responsive environments for tourism by comparing physiology measurement to psychology measurement. Environmental physics parameters were aslo collected in a controlled room in Bandung, Indonesia. In the same time, respondents were instructed to do a sit and walking using treadmills to record skin wettedness and skin moisture as physiology measurement. Whereas, the psychology measurment include sensation, comfort, were assessed after the instructed activities. The findings indicate that there is a significant impact to Thermal Sensation Vote from skin wettedness. Moreover, the thermal comfort index decreases as skin wettedness rises, indicating that respondents begin to feel discomfort as their bodies start to sweat. The level of skin wettedness observed in this study is later linked to sweating ability, which is expected to help define occupant comfort in indoor tourism spots, considering horizontal factors.

Keywords: Thermal Comfort, Office Buildings, Tourism Spaces, Sustainability, PMV, TSV, Adaptive Comfort.

1. INTRODUCTION

The involvement of many factors in achieving thermal comfort is constantly studied to gain the optimum range one human can tolerate. The ability of the human to adapt to their constant variety of environments has been a survival mode that has resulted in more comprehensive studies. Physiologist has an assumption that human thermal comfort can be achieved if only they can minimize their thermoregulatory efforts(Shao, 2023). At the outset, thermal comfort is a subjective result of how humans express their environmental condition in a state of mind(Humphreys et al., 2016; Kenney et al., 1993; Nicol et al., 2012; Parsons, 2014; Wolkoff et al., 2021).

Moreover, the well-known test of thermal comfort, such *as physical, physiological, psychological, and social behaviors, is the most straightforward category to begin with(Fong et al., 2019).* Studies will likely continually assess perception, acceptance, preference, and sensation as a test for observing the dependency based on the subjects. *These subjective levels raise doubts about how humans regulate their heat stress based on the environment, especially in the tropics(Fong et al., 2019; L. Wang et al., 2019a).* Research devoted specifically to understanding human thermal local characteristics. For example, local thermal sensation on the arm and forehead indicates a stronger impact on overall thermal sensation than other parts of the body(Choi & Yeom, 2017).

Further, the ability of the human body parts, specifically in the tropics, to sweat for acclimatizing to their environment hypothetically states to have a distinctive performance compared to subtropical subjects, apart from the condition of the clothing, it also depends on the metabolic rate (L. Wang et al., 2019b; Zhai et al., 2019). There is a belief that people with a mean skin temperature of 33-34 °C are thermally comfortable because they can minimize their sweating rate(Shao, 2023) that indicates in skin mouisture and wettedness. As a response, the studies have not reached their comprehensiveness due to the variety of environments affecting skin conditions. Research has shown that sweating can help achieve thermal comfort with a 10-minute shower at 40 °C of water temperature(Luo, Xu, Tang, Yu, Zhou, et al., 2023). In extreme cases, the safety need for firefighters is a major point. It has been discovered that controlling moisture distribution and transfer can provide extra thermal protection or injury(Zhang et al., 2023). This also led to another assumption that damp skin might be better for minimizing sweating after showering. Whereas research to evaluate existing PMV by Fanger in the 1960s by Zhou says that there is an oversimplified calculation of the sweat rate when measuring thermal comfort("Modification and Verification of the PMV Model to Improve Thermal Comfort Prediction at Low Pressure," 2023).

Although much research has resulted in the influence of sweating rate on heat transfer, which only narrowed in the uniform heat environment, there is limited research to discuss the tolerance based on tropical with a high percentage of humidity. Experiment using thermal manikin shows the ability of a fabric to absorb ambient moisture in understanding evaporative resistance to quantify clothing thermal comfort. This research implies that the ambient condition greatly impacts the sweating rate and its wettedness(F. Wang et al., 2016). However, this study has not concluded the condition of continuous sweating, especially in the tropics with a whole year of summer and humid ambient.

The sweating rate is yet to be put to the standard we have used for decades. From the production point of view, this could lead to the unknown consequences. To date, there are limitations in the existing research to study the sweating ability related to skin dampness and skin wettedness in the last decade. Researchers recently concepted the word wettedness index to understand more about thermal comfort based on the abovementioned levels.

This study aims to understand better how occupants achieve their thermal comfort by investigating skin wettedness tolerance in specific environements. One of the extensions of

these efforts is to provide a regulation to set the temperature in the building; in other words, the energy consumption could be less excessive(Karyono, 2015; Karyono & Bahri, 2005; Rodriguez & D'Alessandro, 2019; Yasmeen & Liu, 2019). Further back, using mechanical air conditioning in the tropics is almost inevitable, specifically in offices, which are highly necessary for providing comfort and enhancing productivity(Sikram et al., 2020). The cooling needs in the building have been appropriately stated to have a significant load to begin with. With its function, the usage of this machine surpasses other applications in most of buildings. As one the most influential economy-developing countries in the world, specifically Southeast Asia, Indonesia targeted to increase its productivity and comfortability in the same time. The usage of air conditioning claims to be one of the direct stimulants to the quality of the productivity and quality in the many type buildings tipology. To provide an adequate environment in varies of for the subject using these automatic methods, the comprehensive study must be considered to avoid uncontrolled consequences.

The Integration for Tourism

Tourism spaces have the unique opportunity to incorporate cultural and architectural elements into thermal comfort design. The findings from studies on thermal comfort in indoor office environments in this research are expected to reveal critical insights into how individuals adapt to varying thermal conditions, particularly in tropical climates. Factors such as sweating ability, skin wettedness, and localized thermal sensations significantly influence comfort levels, especially in high-humidity environments. These findings, while targeted at office occupants, provide valuable lessons for the tourism industry, where ensuring thermal comfort is equally important for visitor satisfaction and sustainable indoor design.

Research on adaptive thermal comfort models suggests that occupants can tolerate a wider range of temperatures when given control over their environment. This approach not only improves comfort but also reduces energy consumption. Applying these principles to tourism facilities can lead to more sustainable operations. For example, a study by (Luo, Xu, Tang, Yu, & Zhou, 2023) demonstrated that controlled sweating through activities like warm showers can help achieve thermal comfort, indicating potential strategies for managing indoor climates in tourist accommodations.

Lessons from office thermal comfort studies in tropical climates, such as the use of sun shading, natural ventilation, and energy-efficient systems, indeed can be directly applied to tourism facilities(Alyfia et al., 2023). By integrating bioclimatic architecture with local cultural elements, tourism spaces can ensure thermal comfort while aligning with environmental and aesthetic goals.

By learning from indoor office thermal comfort studies in this research, the tourism industry can develop more resilient, adaptive, and energy-efficient indoor environments. This cross-disciplinary approach ensures that tourists not only experience physical comfort but also benefit from spaces that are sustainable and contextually appropriate to their destinations such as. Integrating these findings into tourism infrastructure design represents a step toward achieving greater guest satisfaction and environmental responsibility.

2. RESEARCH METHODS

This experimental study is based on subjects with real-time situations to obtain the main data. The methods discussed in this paper consist of two parts. The first part is data collection through a direct approach in the field. The authors provide a thermal chamber for a conditioned room to get certain ambient controlled parameters while the subjects maintain their dedicated activities. Certain criteria were settled for the subject to represent a specific demography in the

Indonesian situation case. The second part is data processing and data analysis. Several analyses have been established to help find the interpretation of the data processed.
This diagram illustrates the components influencing indoor thermal comfort in buildings within hot and humid climates, emphasizing their role in enhancing occupant quality and productivity. The data collection methods for this study include both quantitative and qualitative approaches to comprehensively analyze indoor thermal comfort in hot and humid climates. Environmental parameters such as air temperature, humidity, and airflow are measured using advanced instruments to capture accurate physical data. Physiological responses, including skin temperature, moisture, wetness, and heart rate, are monitored using wearable sensors to understand occupants' physical reactions. Additionally, subjective data on thermal sensation and thermal comfort, are gathered through structured surveys and interviews with occupants. These combined methods ensure a holistic understanding of thermal comfort by integrating objective measurements with subjective experiences.

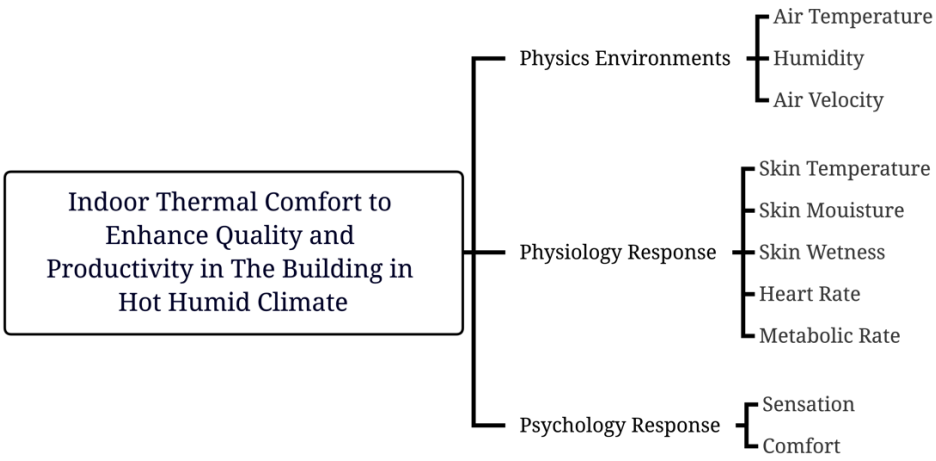

Figure 1. Diagram for data collection in research

Environment Physics Setting

To gain a deeper understanding of the occupant' wettedness index and collect comprehensive data, the measurements were conducted in two distinct spaces. As informed on below figure, The first space, a controlled environment as thermal chamber or test room, represented the indoor environment where the primary data was collected. The second space, a preparation room, acted as an outdoor area for briefing and allowing respondents to transition before entering the thermal chamber. Both spaces were equipped with environmental monitoring devices to record conditions, enabling a comparison between the two settings and highlighting the significance of their differences.

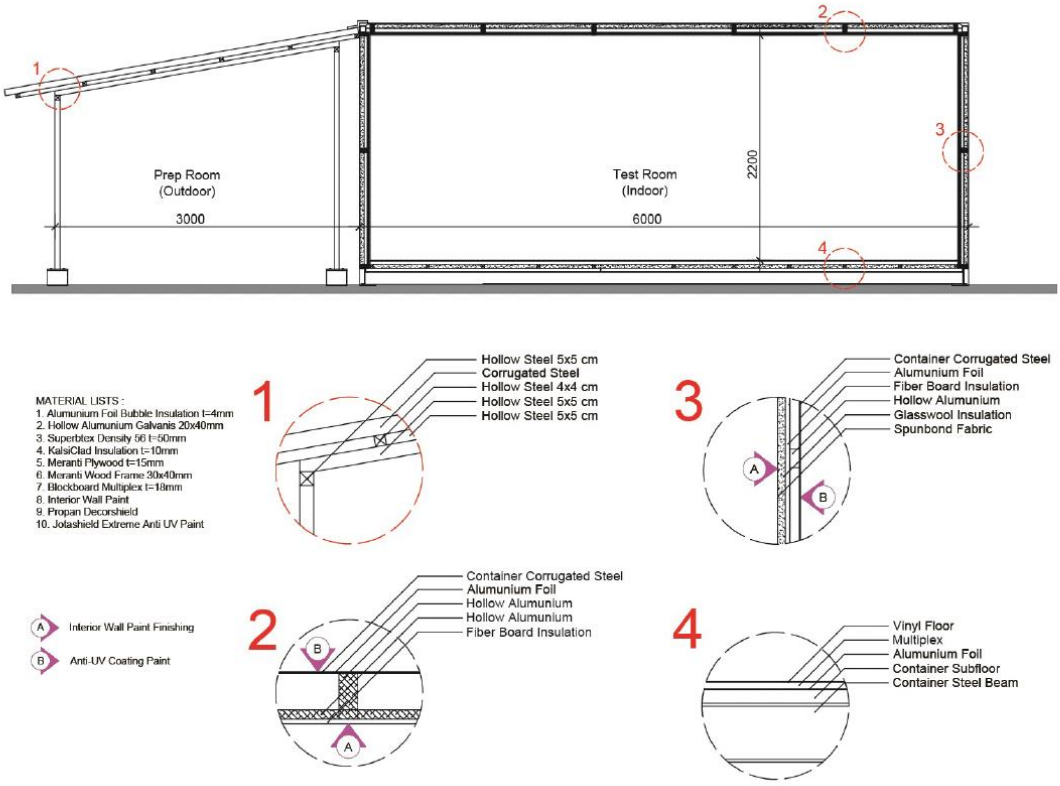

Figure 2. Environment setting in research (research report, 2022)

Controlled Environment (Indoor)

A controlled chamber is essential for this research as it allows for precise regulation of environmental conditions, such as air temperature, humidity, and airflow, which are critical for studying thermal comfort and its impact on the wettedness index. By eliminating external variables, the chamber provides a consistent and repeatable setting to ensure the accuracy and reliability of the data collected. It also enables the simulation of specific environmental scenarios that closely mimic real-world conditions in hot and humid climates, offering valuable insights into how individuals respond physiologically and psychologically. This level of control is crucial for isolating factors influencing thermal comfort and ensuring the findings are scientifically robust and applicable to broader settings

To maintain consistent conditions and minimize external disturbances, the chamber is insulated on the walls, floor, and ceiling. Insulation is essential to prevent interference from outside factors. The steel container walls are lined with multiplex boards and insulated with polyester material, covered with dark-colored spunbond textile to reduce dust accumulation. Similarly, the ceiling is layered with multiplex boards, and the floor features a parquet finish on top of multiplex boards for added durability and insulation. The environmental physics data collected in this space are Air Temperature, Humidity, and Air Flow.

Figure 3. (Left) Thermal chamber. (Right) Controlled indoor environment. (research report, 2022)

Preparation Space (Outdoor)

The preparation room is designed to simulate a natural outdoor environment without any modifications. It serves as the space where respondents are assessed before entering the controlled thermal chamber. In this area, various body measurements and questionnaires are conducted to capture the respondents' baseline condition. These data will later be used to analyze the differences between the two environments and understand how each impacts the respondents. The preparation room is shaded with a metal roof and equipped with devices to measure air temperature, humidity, solar radiation, air velocity, and illuminance. Additionally, it functions as a briefing area where respondents are given instructions before proceeding to the thermal chamber.

Figure 4. (Left) Outdoor assesemnt fot occupants. (research report, 2022)

Physiology Data Collection

- Skin Temperature: A thermocouple is placed on the forehead of the respondent to measure surface skin temperature accurately. The forehead is chosen due to its high sensitivity and consistent exposure to the surrounding environment, making it a reliable indicator of thermal response.
- Skin Moisture: A corneometer is placed on the hand of the respondent after physical activities to measure the moisture levels of the outer skin layer. This provides valuable data on sweating and skin hydration, particularly in response to the environment.
- Skin Wettedness: The skin wettedness index in this study is measured by evaluating the proportion of the skin surface that is wet due to sweating. This index is calculated using physiological and environmental data, including skin moisture measurements, air temperature, humidity, and air velocity. The skin wettedness value represents the body's adaptation to manage thermal discomfort through sweat evaporation.
- Metabolic Rate: The study includes activities like sitting, walking, speed walking, and running, each corresponding to different metabolic rates (e.g., 1 MET for sitting and up to 3.6 MET for running)
- Heart Rate: A smartwatch is worn on the wrist throughout the test to monitor heart rate continuously. The device captures real-time cardiovascular responses as the respondent experiences different thermal scenarios.

This setup ensures that each measurement is taken precisely, reflecting the respondent's physiological responses to controlled environmental conditions. The combination of these instruments offers a holistic view of how the body adapts to varying thermal environments.

Psychology Data Collection

This section aims to explore the respondents' psychological responses to the conditioned air temperature they encountered in the test room. By analyzing their subjective experiences, the study seeks to understand how they perceive and interpret the thermal environment after being exposed to the controlled conditions and specifict activities. To gather this information, a structured questionnaire is employed, consisting of likert scale asnwers

- Thermal/temperature sensation vote (Likert scale from -3 to 3)
- Thermal/temperature comfort level (Likert scale from -3 to 3)
- Body dryness comfort level (Likert scale from -3 to 3)
- Body dryness acceptability (Likert scale from 1 to 4)
- Environment satisfaction (Likert scale from -3 to 3)

Respondents

A total of 348 respondents aged 22-35 participated in the research. The respondents had at least not been out of the country for a year straight. The tests were categorized into two types: physiological measurements and psychological assessments. Each type focuses on distinct parameters, with physiological tests examining physical responses such as skin temperature, skin moisture, and heart rate, while psychological assessments explore subjective perceptions, including thermal sensation and comfort levels. By analyzing the significance and interplay of these parameters, the study aims to provide a comprehensive understanding of the factors influencing thermal comfort in challenging climatic conditions.

Research Scenario

The research scenario for investigating thermal comfort through the wettedness index focuses on the relationship between air temperature and relative humidity during specific activities, all conducted within the controlled indoor test room. Relative humidity is categorized into three levels: 40%, 50%, and 60%, with each level maintained for a full day to ensure stability, as controlling humidity is more complex and time-intensive. In contrast, air temperature is categorized into four levels: 22°C, 25°C, 28°C, and 31°C, and each temperature level can be set and stabilized within approximately 45 minutes, making it easier to control. This systematic approach allows for a thorough examination of all combinations of air temperature and humidity to analyze their impact on thermal comfort and the wettedness index effectively.

Analysis

This research has three primary objectives. The first is to determine the significance of the wettedness index by investigating skin moisture. This is achieved through polynomial quadratic regression analysis, which compares physiological measurements, such as skin moisture and skin temperature, with environmental parameters. The second objective is to identify the correlation between the wettedness index and indoor environmental settings using linear regression analysis. Lastly, the third objective focuses on exploring the impact of the wettedness index on human perception. Through regression analysis, three key parameters have been identified as significant: thermal sensation vote, humidity perception vote, and overall satisfaction. These findings aim to provide a deeper understanding of the interactions between physiological responses, environmental conditions, and subjective comfort in hot and humid climates.

3. ANALYSES AND DISCUSSION

The first phase of analysis focuses on examining the interaction between environmental physical factors and physiological responses, particularly the skin wettedness index. This involves analyzing key environmental parameters such as air temperature, humidity, and air velocity in relation to skin wettedness, which reflects the body's thermoregulatory response to these conditions. Once this relationship is established, the analysis progresses to the psychological assessments, where subjective data, such as thermal sensation, comfort levels, and overall satisfaction, are evaluated. This two-step approach ensures a comprehensive understanding of how environmental conditions influence both the physical and psychological aspects of thermal comfort.

Physiology Measurement

Correlation between Skin Wettedness Index and Air Temperature

The figure illustrates a graph depicting the relationship between the skin wettedness index and air temperature, demonstrating a statistically significant connection between the two variables. The P-value is less than 0.0001, indicating a highly significant correlation, meaning that changes in air temperature strongly influence the skin wettedness index.

This relationship is quantified using a linear regression model, expressed by the equation:

$$\text{Skin Wettedness} = -1.389 + 0.2125\ (\text{Air Temperature})$$

The equation shows in the figure below that as air temperature increases, the skin wettedness index also rises, reflecting the body's adaptive response to higher thermal stress. Specifically,

higher air temperatures prompt increased sweating, resulting in greater skin wettedness as the body attempts to maintain thermal balance through evaporative cooling.

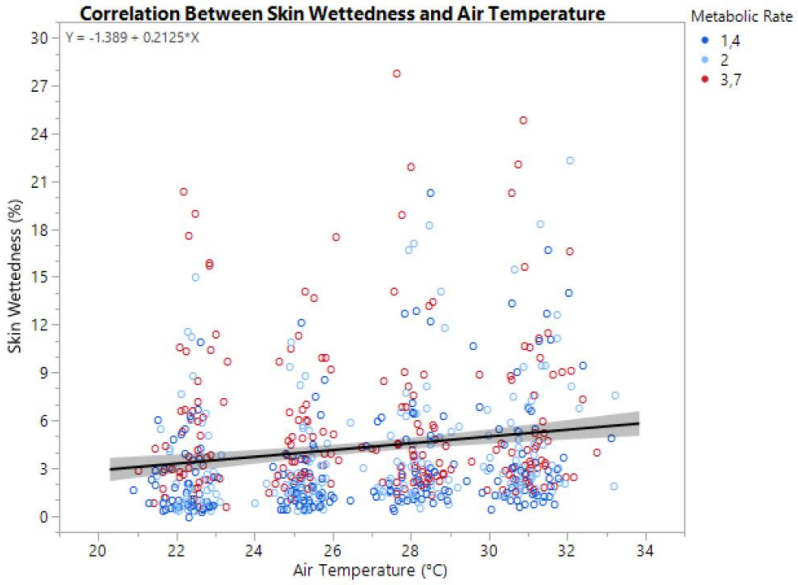

Figure 5. Correlation between Skin Wettedness Index and Air Temperature (research report, 2022)

As air temperature rises, it causes the core body temperature to increase, leading to a sense of thermal discomfort. To cope with this, the body responds by releasing heat through sweating, a process that can be quantified using the wettedness index. This relationship is clearly illustrated in Figure 5, which shows that as air temperature goes up, the skin wettedness index also increases, highlighting the body's natural cooling mechanism to manage heat stress.

Correlation between Skin Wettedness Index and Humidity

Figure 6 shows a graph of the relationship between the skin wettedness index and humidity. The relationship between the two variables has a P Value = 0.132 which means that the relationship is not significant

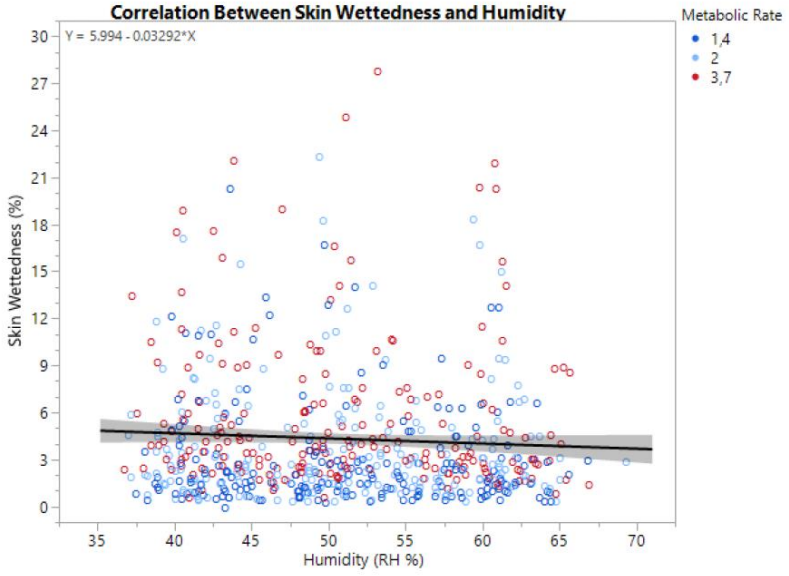

Figure 6. Correlation between Skin Wettedness Index and Humidity (research report, 2022)

While humidity is often considered an important factor in thermal comfort, many studies have found that its impact is not always significant. For example, the SHIMIZU-ITB Final Report (Dr. Eng. M. Donny Koerniawan et al., 2019) noted that respondents had difficulty perceiving differences in humidity within the 40%-60% range, showing no clear relationship between Thermal Sensation Vote, Humidity Comfort Level, and other psychological assessments of humidity. Similarly, in the context of the wettedness index, differences in humidity within the 35%-70% range were found to have little effect on the body, meaning they do not significantly influence the wettedness index. This suggests that within a moderate humidity range, its impact on thermal perception and physiological responses may be minimal.

Correlation between Skin Wettedness Index and Air Velocity

Figure 6 illustrates the relationship between the skin wettedness index and air velocity, revealing a strong and significant connection. With a P-value of less than 0.0001, the data confirms a highly significant relationship between these two variables. The relationship is captured by the linear regression equation:

Skin Wettedness = 2.634 + 3.364 (Air Velocity)

This equation indicates that as air velocity increases, the skin wettedness index also rises. The higher air velocity enhances sweat evaporation, resulting in greater skin wettedness. This relationship underscores how airflow contributes to the body's cooling mechanism, providing valuable insights into maintaining thermal comfort in environments with varying air movement.

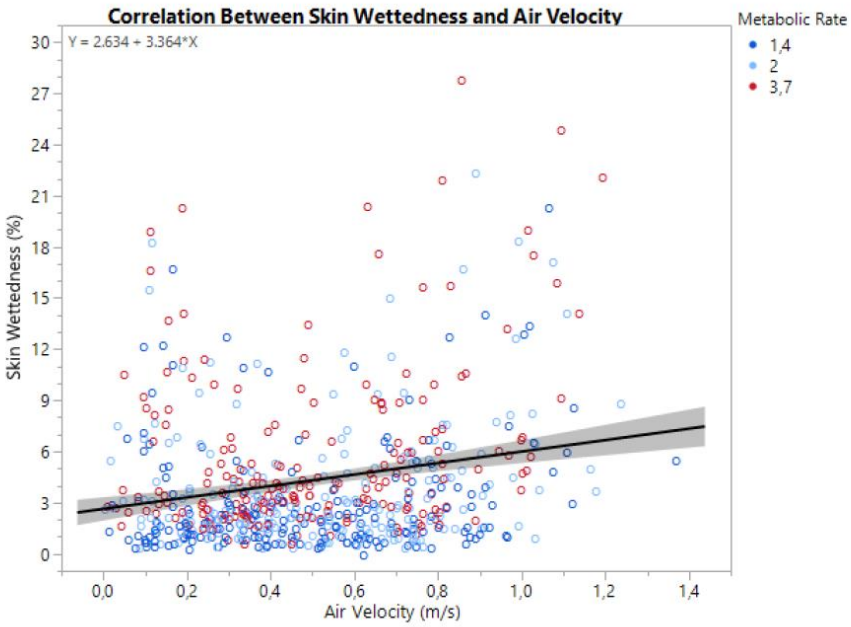

Figure 7. Correlation between Skin Wettedness Index and Air Velocity (research report, 2022)

Psychology Measurement

Correlation between Skin Wettedness Index and Thermas Sensation Vote and Thermal Comfort

Figure 8 presents a graph illustrating the relationship between the skin wettedness index and the Thermal Sensation Vote (TSV), highlighting a strong and statistically significant connection

between the two variables. With a P-value of less than 0.0001, the data indicates that changes in skin wettedness are closely tied to how individuals perceive thermal sensations.

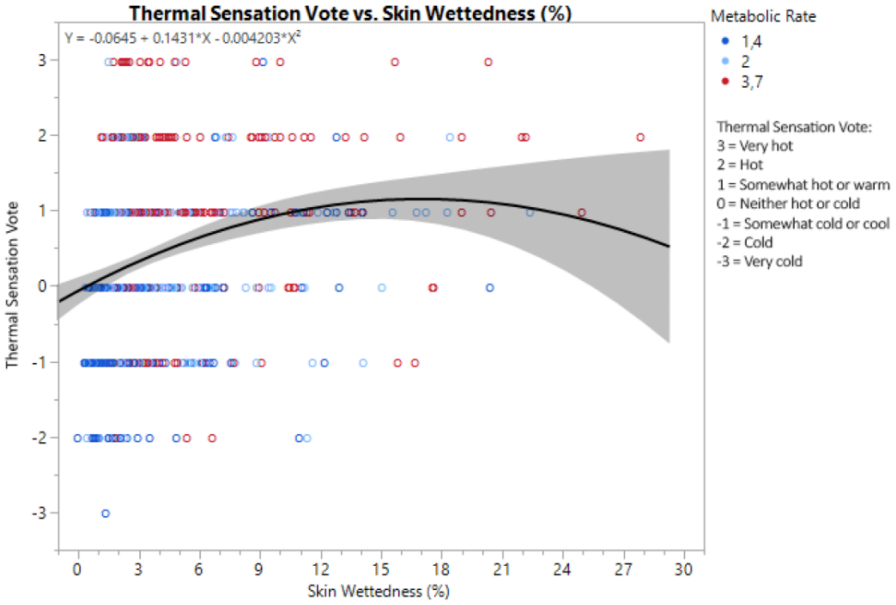

Figure 8. Correlation between Skin Wettedness Index and Thermal Sensation Vote (research report, 2022)

The graph indicates that as activity increases, the corresponding rise in skin wettedness leads to a higher Thermal Sensation Vote (TSV), meaning individuals feel hotter. However, beyond a certain point, the perceived heat sensation begins to decrease. This reduction is due to the body's release of heat through sweating, which helps to cool it down. Notably, this cooling effect starts to become noticeable only when the skin wettedness exceeds 17.02%. Despite this, even as skin wettedness reaches up to 30%, sweating alone is not sufficient to fully restore thermal sensation to a neutral state.

Whereas, Figure 9 below illustrates the relationship between the skin wettedness index and the Thermal Comfort Level, showing a statistically significant connection with a P-value of less than 0.0001. The graph reveals that as the wettedness index increases, the comfort level of respondents tends to decrease. Specifically, respondents start feeling uncomfortable when the wettedness index exceeds 8.1%.

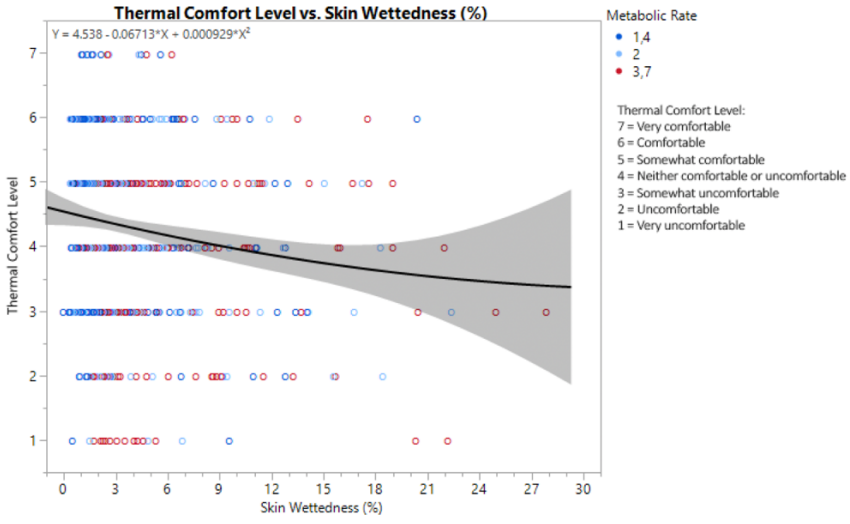

Figure 8. Correlation between Skin Wettedness Index and Thermal Comfort (research report, 2022)

It is important to note that while a higher skin wettedness index may reduce thermal sensation, it does not necessarily translate to a more comfortable condition, highlighting the complex interaction between physiological responses and thermal comfort perception

4. CONCLUSSIONS

The findings from this study emphasize the significance of skin wettedness as a key physiological parameter for evaluating thermal comfort in indoor office environments, especially in hot and humid climates. The study reveals that air temperature and air velocity are the most influential factors affecting skin wettedness, with a strong, statistically significant correlation. As air temperature rises, the body responds by increasing sweat production to regulate heat, reflected in higher skin wettedness levels. Similarly, higher air velocity enhances sweat evaporation, improving cooling efficiency but also raising skin wettedness. However, the research shows that excessive skin wettedness—beyond a certain threshold—leads to discomfort, as the body's thermoregulatory mechanisms fail to fully restore a neutral thermal sensation. Interestingly, humidity within a moderate range (35%-70%) has a negligible impact on skin wettedness, indicating that other environmental factors play a more dominant role.

The study also highlights the interplay between physiological responses and psychological perceptions. While the skin's response to heat stress helps mitigate thermal discomfort, higher wettedness levels are often perceived as uncomfortable by respondents. This underscores the importance of balancing environmental settings to align physiological adaptations with psychological comfort levels.

These findings provide important lessons for sustainable tourism design in tropical regions. Just as offices must cater to occupant comfort to enhance productivity, tourism facilities—such as hotels, resorts, and indoor attractions—must prioritize thermal comfort to ensure a positive guest experience. Insights from this study suggest several strategies, including adaptive ventilation systems, localized cooling solutions, and adjustable airflow, to manage both physiological and psychological comfort effectively. Incorporating bioclimatic design elements, such as natural shading, cross-ventilation, and climate-responsive materials, can further enhance comfort while reducing reliance on energy-intensive cooling systems.

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CHAPTER 8

Preserving the Durgā Statue at Prambanan Temple as Digital Heritage with AI-Aided Creaform

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ABSTRACT

Damage to the Durgā statue as a cultural heritage due to natural factors and vandalism makes it difficult for archaeologists to translate the function and meaning of the symbols attached to it. This research attempts to reconstruct the statue digitally with results that are as accurate as possible. This research, initially, explores the potential of two leading facilities in conservative statue restoration, namely generative AI and CreaForm 3D Scanner. The performance of both was optimized by the academic performance of researchers in carefully and in-depth tracing of statue symbols and fragments, so as to obtain valid digital assets for the Durgā statue. This research uses Design Thinking. The data obtained was analyzed using Charles Sanders Peirce's semiotics. The finding of this research is a digital reconstruction of the Durgā figure (Figure 3), which was then followed up with 3D printing for duplication purposes. This reconstruction is based on a study of iconography, mythology and traditions of Hindu society, the development of Hindu iconography in Indonesia, and the characteristics of Indian art. Some of the icons and symbols on statues whose meanings are studied semiotically as a database for AI algorithms are Kiritamakuta (crown), Mauli (hair ornament), Kuṇḍala (earrings), Hâra (necklace), Upavita (caste sash), Kuchabandha (breastband), Keyura (shoulder strap), Kaṅkana (bracelet), Bhusâna (clothing), Udarabandha (belt). The meaning of these icons acts as a guide to interpreting the color, size, function and identity of the statue. This research disconfirms and corrects the wild reconstruction results by AI that have been circulating on the internet so far. Including the AI reconstructions that were criticized through this research were the reconstructions of Rara Jonggrang (Figure 4) which did not base their visualization on adequate cultural references.

Keywords: Durgā Statue, Prambanan Temple, Digital Heritage, AI-Aided Creaform.

1. INTRODUCTION

As a temple statue, the Durgā statue in Prambanan is a mute archeological record of the material culture of the lamp period. It cannot talk about the functions, meanings, and symbols it contains. It is the archaeologist who is in charge of translating it so that it can "talk" about its era, and describe the human situation at that time. However, archaeologists are now not only constrained by time and cultural distance (N Rangkuti, 1995). They also face a serious problem in the form of the incompleteness and sharpness of the physical curves of temple statues and other artifacts. This situation hampers efforts to interpret the visual form of the statues.

According to folklore, the Durgā statue is the personification of Rara Jonggrang, which means "a slender girl" (Kemdikbud, 2013). The beauty of the object represented by the statue (as well as other statues in other temples) cannot be well confirmed because there is no method and technology to accurately visualize the statue. Moreover, the condition of the Durgā statue is no longer intact.

Preliminary results of the study revealed that the nose cuil, the details of the ornamental crown (Kiritamakuta) and the sash (Upavita) have become faint due to frequent touching since it was first discovered in the 18th century, cleared of its ruins in the 19th century, and opened to the public in the 1950s (Kemdikbud, 2013). Apart from age, Prambanan temple was affected by the 2006 earthquake that caused deformation of the temple (R Muryamto *et al.,* 2021), and volcanic ash from the eruption of Mount Merapi in 2010 entered between the rocks, causing weathering (W Wedekind *et al.,* 2013). Restoration done by adding new rocks reduced the accuracy and originality. Some statues were also damaged due to tropical factors (mold and mildew) (G.P Cimellaro *et al.,* 2020) and visitor vandalism (M.S Khan *et al.,* 2022).

The vagueness of the statues' visualization makes it difficult to interpret the meaning and symbols of the statues. The meaning of the statue's appearance - as an artifact - is difficult to narrate to the younger generation. That is why visualization and representation to translate the functions, meanings, and symbols of statues have never been successful, so that when statues are damaged, history is lost. Therefore, it is necessary to develop methods and technologies that can inventory the digital assets of temple statues accurately, precisely, and can duplicate statues.

This research then highlights two leading facilities that have the potential to help us preserve statues in the form of digital assets. These are generative AI and the CreaForm 3D Scanner. The AI introduced in early 2023 can reconstruct the faces of statues along with their icons and attributes. The test results show that the creations are very attractive, but the interpretation of the AI seems to be quite wild. In visualizing aesthetic ornaments, the AI does not refer to the cultural authenticity of the time period in which the statue was made. CreaForm, on the other hand, digitizes the statue to its deepest curves, and makes a duplicate using a 3D printer in a 1:1 ratio (T. Tóth *et al.,* 2014). However, it cannot detect missing/damaged parts. The urgency of the risk of statue extinction and the imaginary visual banality of AI is the background for this conservative-restoration research study.

1.1. Problem Statement and Research Questions

Five problems were identified during the early stages of this research. First, temple statues are endangered due to the risk of natural and human factors (vandalism). Usually, the more popular a statue is, the more people want to touch it (W Murwonugroho *et al.,* 2019). Second, digital statue assets in 3D formations are not available so far. Third, CreaForm can only scan objects as they are. If the statue is damaged, then the 3D digital asset is also not intact. Fourth, the aesthetic visual elements produced by AI do not refer to original cultural references. Fifth, sculptors of imitation statue models have not been able to utilize 3D scanner technology, let alone AI.

The five problems identified then led the researcher to formulate specific research problems, thus focusing only on the following three problem formulations.

a. How to design AI assets that refer to the original aesthetics of Hindu traditions in Java?
b. How does the combination of AI and CreaForm produce statues that are identical to the original (initial state of creation)?
c. How is the implementation of AI and CreaForm in statue production for sculptors?

1.2. Significance of the Research

The general aim of this research is to restore and conserve temple statues in the form of 3D digital assets, and to create physical replicas of them in their original condition when they were created. But specifically, this research seeks to achieve the following three objectives.

a. Reconstructing figures that are configured through statues.
b. Creating 3D digital assets as AI-generated monumental works that refer to the original aesthetics of Hindu culture in Java.
c. Combining AI and CreaForm to produce statues that are identical to their original state of creation.

Achieving the above research objectives contributes new creations in the repertoire of AI utilization, new methods in the utilization of 3D scanners, and new discourse in the discourse on generative AI. Moreover, so far, the use of 3D scanners for conservative-restoration work has not been optimized with AI.

The idea of 3D scanners as non-contact and non-destructive instruments for fragile historical objects is not new. The adoption of 3D technology (data acquisition and digital modelling) has been used in the context of cultural heritage since the 1990s. In conservatory-restoration work, it is used to perform virtual reconstruction of lost parts of objects (L. Acke *et al.,* 2021; T. Segreto *et al.,* 2017; D. Ocón, 2021). Initially, 3D scanners were applied to architectural sites (F. Frank *et al.,* 2017). The results of its geometry analysis were able to determine the characteristics of the building and its evolution, thus revealing the building's life cycle (J. E. Nieto-juli *et al.,* 2022).

In China, LiDAR-based 3D scanning has been used for the preservation of ancient temples. In the US, TLS and GPR-based 3D scanning is used for digital reconstruction and restoration of fragile historic buildings (D. Makris *et al.,* 2020). The practice is not only supported by multi-source integration to overcome the complexity and fineness of the structure (X. Gao *et al.,* 2019), but also supported by multi-technologies such as digital mapping, IoT, smart sensory, and photogrammetry (Y. Li *et al.,* 2023). The technology is far more advanced than the DAVID Laser Scanner Vision Systems that Galantucci had studied (L.M Galantucci *et al.,* 2015). The advantages of multi-source can produce better digital assets in a short time. Meanwhile, the advantages of multi-technology (photogrammetric) allow the production of accurate 3D metric models for virtual interpretation and presentation (N.A Haddad, 2011). Besides LiDAR, there are also technologies called Steinbichler Comet L3D and CrearForm EXAscan.

Among the various tools for documenting solid objects, 3D laser scanners have the most potential to produce the most representative, fast, and flexible digital assets (N.A Haddad, 2011). So far, the above four technologies are state-of-the-art for collecting information about the height, width, depth, and curvature of an object (A. Haleem *et al.,* 2022). However, the above technologies often make mistakes in selecting the scanning width and shading area. Different plane contours cause some gaps to appear on the scanned object (A.M Eissa *et al.,* 2023). In addition, the above technology has other disadvantages. First, the scanned object must meet certain criteria (no small-diameter holes, pointed shapes, and hollows). Secondly, the object must be scanned 3 times. Third, the scanning results leave deviations and their orientation must be evaluated (T. Tóth *et al.,* 2014). A 3 mm deviation on a hand, foot, or body part may be insignificant, but an asymmetric deviation on a detailed part, such as eyes, lips, nose, or others is a fatal error (K.C Koban *et al.,* 2022).

This research overcomes the above drawbacks. In fact, by integrating AI, this research can generate colours based on cultural-historical information. In previous research (T.-N. Doan *et al.,* 2023), a coloured 3D model could only be obtained if the scanned object had colour. The AI-based technology engineering in this research can not only produce accurate and high-resolution colour interpretation, but can also interpret 2D (semi 3D) temple reliefs into fully 3D objects as expected by (J. Cantizani-oliva *et al.,* 2023). The technology in this study takes a few minutes for rendering and a few hours for 3D printing. Thus, the limitation of cultural properties mentioned by Elias can be topped well (C. Elias, 2019).

2. METHODS

This research was conducted following the steps of Design Thinking (Figure 1). This procedure was chosen because of its systematic steps in creating innovative problem-solving projects in tourism, creative industries, and sustainable preservation of cultural heritage (O. Lo Presti *et al.,* 2023). Design Thinking was formulated by Stanford University and originated from the study of creative innovation, visuals, and very clever thinking (Shanks, 2023). It enables communities and stakeholders to develop a dynamic innovation process in which entirely new processes, services, and products are designed on an ongoing and sustainable basis (T. Cassar, 2019).

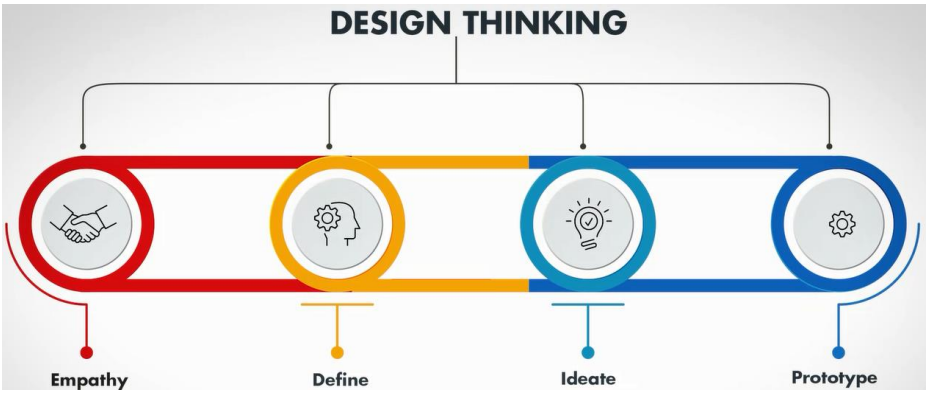

Figure 1. Research procedure

The research process began with an attempt to understand the confrontation between the need for conservation of cultural heritage (both material and intangible) and the risk of permanent extinction of such cultural heritage in the reality of the temple statue environment and society. During this phase, a number of findings were obtained in the form of the physical insignificance of temple statues as material assets, the difficulty of interpretation by historians of the meaning of the attributes and symbols attached to the statues, and the unoriginal results of AI-based digital reconstruction (not referring to the icons and indices prevailing in the culture of the period of creation of the statues).

In the second phase, all the information obtained in the first phase is analyzed, evaluated and synthesized. The result of the second phase is a firm problem statement, i.e. what is the original form of the Durgā statue based on original cultural references? In the third phase, the researcher initiated an idea to collaborate digital technology experts, historians-culturalists, and sculptors based on the information obtained in the empathy phase. The fourth phase is idea execution (prototyping), which is creating a blueprint model in a simple and low-cost form.

The Design Thinking process is not linear. The five phases are not always sequential and can sometimes occur in parallel or be repeated iteratively. Each stage should be understood as a

component or node that contributes to the success of the process (M. Oliveira *et al.,* 2023). This means that expert designers should be engaged to act as facilitators of the process.

3. FINDINGS AND DISCUSSION

Through an expert collaboration approach, this research successfully collaborated digital technologists, historians-culturalists, and design experts from the sculptor community, resulting in the potential for commercialization (Figure 2). Technologists overcame CrearForm's weakness of being able to scan 3D objects up to the inner curves, but not the dimensions. The manipulative engineering performed by the scanning technologist contributed to the authenticity and stylistic similarity of the digital assets, thus overcoming visual deviations.

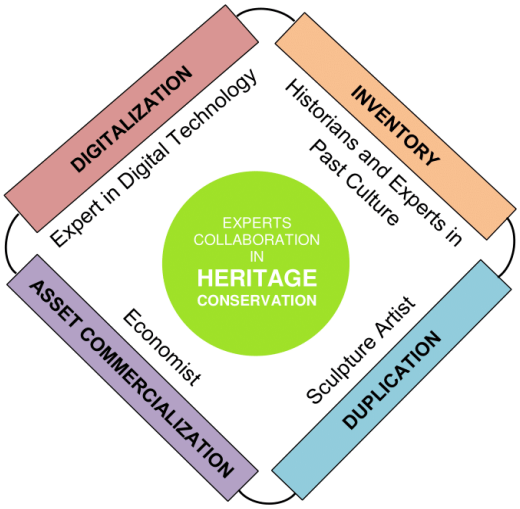

Figure 2. Collaboration of digital technologists, historian-culturalists, and design expert sculptors to generate economic benefits

Similar to Nguyen's experience (A. Nguyen *et al.,* 2023), this method combines a single-input with a double-output convolutional neural network to convert relief/sculpture images into high-accuracy 3D reconstructions and enable 3D printing. Design experts contributed by designing the prototype design. The cultural-historical expert compiled a database of statue information according to their socio-cultural background.

The database serves as an information base for AI to generate artifacts into digital assets (D. Makris, 2021). In practice, cultural-historians work with interdisciplinary studies. They analyze data from inscription documentation and graphic symbols on statues: stylistic features, carved fragments, and iconography (M. Domínguez-Delmás *et al.,* 2021), to compile a database of statue information according to their socio-cultural background. Hence, this database also provides the references that AI needs most, namely color and function references.

3.1. Findings

In this conservative restoration research, cultural-historians inventoried and interpreted artifact ornaments using Charles Sanders Peirce's semiotics, which divides signs into: icons, indexes, and symbols. Through a semiotic study of iconographic variations, they were able to identify various components of jewellery attached to the statues, such as Kiritamakuta (crown), Mauli (hair ornament), Kuṇḍala (earrings), Hâra (necklace), Upavita (caste rope sash), Kuchabandha (breastplate), Keyura (shoulder band), Kaṅkana (wristband), Bhusâna (clothing), Udarabandha (belt).

These are then interpreted interdisciplinarity and multidisciplinary to reveal colour, function, and size. Some of the main references referred to are the way the people of the Hindu royal period cultivated gods by identifying the properties attached to them as something holy, luxurious and beautiful.

The iconographic interpretation in this study then produces several keywords, such as: gold, beautiful, clean, powerful, elegant, honourable, and other terms that describe the perfection and power of the god. These keywords were inputted into an AI algorithm, resulting in a digital reconstruction of Durgā's form as envisioned by the statue maker (Figure 3).

In elucidating the meaning of each statue's iconography, this research cross-references scholarly literature on Hindu mythology, iconography encyclopedias and dictionaries, characteristics of Indian art, the development of Hindu iconography, and problems in the study of iconography in Indonesia. The result is the meaning, function, and color of the icon components of jewelry and weaponry in statues.

Figure 3. Digital reconstruction of Durgā figure created by writers

The Muali ornamental icon, for example, is a hair ornament for female figures in Hindu tradition. Usually, Muali is depicted in the form of jaṭāmakuṭa (arranged hair spun) and śikhaṇḍaka (flowing with ornaments) (G. Rao 1914). In the Durgā statue examined in this study, both are absent. The dominant hair representation is in the form of a Kiritamakuta (crown), which indicates that the figure depicted through the statue is not an arbitrary figure. He is honorable, powerful, and cultivated by all his commandments.

Semiotically, these traits are symbolized by the gold color, the placement of the mark on the head, and the high location. This is corroborated by the posture of the Durgā statue standing on the corpse of the buffalo demon Mahiṣāsura who, according to mythology, was killed by her. The same is true of other ornamental icons, such as the sash-like upavita that depicts the caste of the person wearing it (S. Bhagwant, 1975). Whenever a figure is depicted wearing a sash that is different from most figures in temple reliefs, it is certain that the figure is a deity or his/her avatara (J. Downson, 2009).

3.2. Discussion

In general, sculpture craftsmen in the period of Hindu kingdoms in Indonesia were indeed a class of people with low social status in society. They were part of a professional class called wulu-wulu, which included woodcarvers, painters and sculptors (E. Sedyawati, 1990). Therefore, according to Sedyawati, they usually lived in the village and also paid taxes to the kingdom. However, some of the skilled ones were asked by the royal court to live in the palace compound to complete statue-making projects and serve the royal family (E. Sedyawati, 1990). This answers the question of how low-caste sculptors were literate in the figuration and personification of Hindu deities.

According to the Hindu perspective on art, people from lower castes were forbidden to delve into the scriptures, where information about deities and rituals of worship were prescribed. However, they are still allowed to visualize personifications of deities based on guidance and information from upper castes, such as priests or kings (R.M. Anand, 2020). This complementary system of statue production is one of the characteristics of Indian art. Moreover, the style in the Durgā Mahiśāsuramardinī statues in temples outside Prambanan (temples in East Java) also has a complete and exact composition with the Durgā Mahiśāsuramardinī statues in Prambanan. Both were produced in the same time period, but at a distance.

Through tracing the characteristics of Indian art and Hindu art in the form of jewelry, clothing, weapons, and other iconographic features, it can be said that the findings of this research have good construct validity (G. Liebert, 2023). This research tested the validity of the information to be inputted to the AI algorithm by comparing the iconography of the Durgā statue with other statues representing central figures in Hindu mythology, especially important figures related to the Trimurti (Brahmâ, Vishnu, Siva) from both the Râmâyana and Mahâbhârata epics (G. Liebert, 2023). These new methods of exploring, visualizing and manipulating intangible information represent a new stage of scholarly inquiry known as virtual heritage. Virtual heritage involves the use of digital technologies and virtual environments for the purpose of researching, preserving and transmitting the cultural heritage.

Through an in-depth study of iconography (H. E. Roberts, 1998) and Hindu or Indian mythology (G. M. Williams, 2003), this study was able to discover the cultural context of Durgā sculpture. Thus, the findings of this study correct (not just disconfirm) the digital reconstruction of the Durgā statue that has been circulating on the internet (Figure 4). These reconstructions cannot be treated as digital assets in the context of cultural heritage preservation because the visualizations are not relevant to valid cultural references.

Figure 4. Digital reconstruction of the Durgā statue by AI without proper cultural references. (Source: https://www.detik.com/edu/detikpedia/d-6587164/roro-jonggrang-digambarkan-versi-ai-seperti-ini-kisahnya-yang-jadi-legenda. Downloaded on November 1st, 2023, at 18:30 GMT+8.)

AI's digital reconstruction of the statue of Durgā in Figure 4 shows a visual deviation from the icon composition in the statue. Likewise, small details such as facial curves and colors give the impression of being different from the philosophical meaning of deity in Hindu mythology.

In understanding this, we can refer to the semiotic meaning of the visualization of gods in Hindu and Indian mythology. An example is the presence of plant decoration in AI's reconstruction in Figure 4, which this research claims is a visual deviation. Apart from the fact that there are no plant ornaments in the Durgā statue, the addition of plant ornaments in the digital reconstruction makes no sense. The twining forms of plants (leaves, flowers, vines) indeed act as framing devices around the statue. But they actually symbolize fertility, growth, and prosperity (M. K. Russell, 2010). Therefore, the decorative plant pattern is more identical to the figure of Brahmâ, not to the figure of Durgā Mahiśāsuramardinī who is Siva's wife. In more detail, we can study the digital reconstruction of the Durgā figure in Figure 3 by looking at two aspects, namely the architectural setting and the symbolism attached to it. The discrepancy, according to Murwonugroho, could be due to the AI being fooled by the visual playability of the Durgā statue (W. Murwonugroho *et al.,* 2019).

In terms of the architectural setting, the female deity's body is depicted in an idealized and voluptuous female body. Such a body represents the Yakshi (nature spirit), which symbolizes the abundance and generosity of the deities. The female form is based on the double drum. Both have a fully rounded shape connected by a narrow waist in the center. Goddess Yakshi is a large-chested, narrow-waisted, round-hipped beauty.

When visualized in statues, paintings or sculptures, the deity's body parts are based on idealized forms in nature, such as a torso like a tree trunk, arms like elephant trunks or bamboo shoots, and eyes like lotus or fish petals. The bodies of male deities are the same. He is depicted with smooth, simplified volumes and very little muscularity. This is what distinguishes the figures of gods in Indian mythology from those in Greek mythology. Male gods in Greek mythology are always depicted with muscular muscles (macho).

In terms of the symbolism attached to the statues, there are some striking iconographies, such as half-closed eyes, having eight arms (sometimes depicted with ten arms), and Arsana-Mudra. The half-closed eyes symbolize meditation, emphasize inward searching, and cultivate spiritual control. This is also a criticism of the AI reconstruction without proper cultural references in Figure 4. The possession of eight arms indicates the superior nature of each arm holding a magic weapon. Whereas Arsana-Mudra is a posture and gesture that reflects the mood of the deity and their willingness to merge with the devotee. The visualization of deities with respect to Arsana-Mudra is the closest metaphor for humans in their experience of communicating with their God.

4. CONCLUSION

This research successfully combines AI and CreaForm to reconstruct the original form of the Durgā statue (Durgā Mahiśāsuramardinī) as a digital asset that refers to the original aesthetics of Hindu culture in Java. Using socio-historical-cultural interpretation of the statue's graphic symbols, this research "revives" Durgā as configured through the statue at Prambanan temple. The findings were obtained through a careful and in-depth exploration of Hindu mythology and an examination of its iconography.

Given that this research disconfirms the wild reconstruction results by AI circulating on the internet, it confirms that the requirement for accurate visualization of statues is the database of information found by historians-culturalists in their interdisciplinary study of icons, fragments, and other aesthetic graphic symbols. The advantages in terms of accuracy and speed of generating digital assets cause this research to overcome the limitations of cultural properties that other researchers have faced (J. Cantizani-oliva *et al.,* 2023).

4.1. Implications

The accurate and precise visualization of the shape of the statue through this research has implications for various fields. The academic community and the general public can benefit from the strategic level (research and technology that support SDGs) to the practical level (education, cultural heritage, art, and tourism or creative economy).

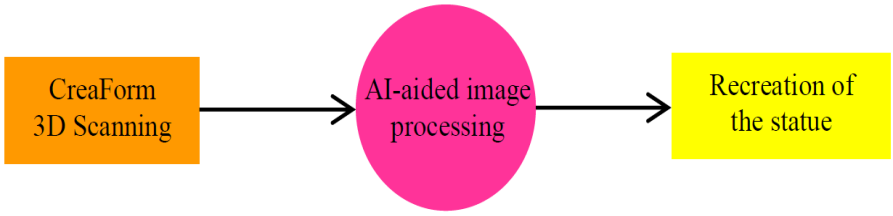

Figure 5. Flow of re-creation of temple statues

The findings of this research were followed up by reprinting the statues through 3D printing by sculpture craftsmen. The aim is to visualize intangible information, and revitalize cultural heritage through digitalization and commercialization. The process goes through three main steps as illustrated in Figure 5. Thus, the community is not the only party that is helped practically. Archaeologists are also helped academically in interpreting more accurately the meaning and function of all forms of symbols attached to statues.

4.2. Limitations and Further Research

This research succeeded in finding the cultural context in the art of Durgā statue in Prambanan. The cultural context of the art is traced through an examination of iconography, Hindu mythological literature, and the traditions of Indian society. However, this study does not consider the perspective of Javanese society (which may have insights resulting from syncretism between Hindu and Kapitayan or Kejawen traditions).

Nevertheless, any interpretation, restoration and conservation of statues into digital assets needs to involve an in-depth study of the statues' graphic symbols, both semiotic and historical-cultural. Therefore, future research should be preceded by a study of the graphic symbols of statues and other artifacts in an interdisciplinary and multidisciplinary manner, and pay attention to the social boundaries of society (not just temporal and cultural boundaries).

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CHAPTER 9

Artificial Intelligence (AI) Art Generator Technology: Analysis of Visual Construction of Reality and Post-Reality

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ABSTRACT

The form of technological development that continues to be developed in the visual field is AI art generator. There are two AI art generator works that raise the phenomenon of the sinking of Jakarta which illustrate the atmosphere of Jakarta during a soccer match and the crowds of Jakarta people in the midst of Jakarta's sinking condition. This work raises denotatum's of reality that build a connotative meaning. In addition, this work also raises an ideology or myth that the current conditions have the potential to cause flooding in Jakarta. This work satirizes various parties and interests, and builds fascination with this work. The visual imagery constructed by the AI art generator has generated confusion about whether this work is reality or post-reality. This research aims to understand the visual construction using AI art generator technology and people's perception of the work. The method used in this research is Roland Barthes' semiotics that interprets the sign from denotation, connotation, and myth, and coupled with perception methodology to understand how people respond to this work. From the results of the discussion, it is known that AI builds denotative with its algorithm technology by combining all forms of formalism that build reality, then adding elements of hyper-reality which in the social, economic and cultural contexts there are elements of impossibility. This becomes the strength, weakness, and success of AI art generators in building a visual image. In conclusion, people's visual interpretation of AI art generators is built by the denotatum of reality and influenced by the background of social and cultural contexts.

Keywords: Artificial Intelligence (AI), AI art generator, artwork, reality and post-reality, Roland Barthes semiotics.

1. INTRODUCTION

In recent years, since the internet network began to be widely used by all circles of society, academics, technology developers, and other parties, technological development has grown rapidly. This technology continues to be developed to facilitate and improve the quality of human life from various sides. Technology continues to develop in the realm of science, health, literature, the digital world, art and so on. The development of technology that is currently rife and continues to develop is artificial intelligence technology. Artificial intelligence is able to store inputted intelligence, learn, and process information to make decisions independently. This artificial intelligence underlies the emergence of cars with autopilot facilities, facial recognition on cell phones, algorithms in search systems, and so on. This technology is changing many things in human life, and certainly improving the quality of human life. Many things that are difficult for humans to do are taken over by artificial intelligence.

One of the technological advancements in the creative arts industry is artificial intelligence programs to generate images or visual art. This technology is able to gather diverse information from the environment, people, and works from artists around the world to be combined, processed, and displayed in the form of original stunning works. Users simply enter specific keywords (prompts) in the search field of the art generator website, and artificial intelligence will take over to carry out the commands and create the corresponding images. The results are also very smooth and neat, almost indistinguishable from the original artist.

The way this artificial intelligence (AI) art generator technology works is by processing data from the real world, existing art, photos, and pre-existing images to be formed into works with new uniqueness. This technology works by combining existing reality with additional imagination and creativity within certain limits. In this process, the artificial intelligence (AI) art generator builds a visual construct between reality and post-reality. Reality is any visual form that can be seen and perceived as real, such as people, objects, scenery, and so on. Post-reality is abstract elements that exist outside of reality and are imaginative.

This technology has many positive functions in the development of the visual world, because illustrations, photos, and drawings are not only limited to be created by professionals, but can be accessed by everyone. It can be a very useful tool for reference, brainstorming, as well as for expressing ideas quickly with satisfactory results. However, this technology also brings negative impacts along with its frequent use in various circles. With so many users using this image-generating technology, visuals from AI art generators are scattered all over the internet. The wildness of the ideas and prompts that are typed in makes the results more diverse and further away from reality. The elements displayed in the image become increasingly widespread, but are not accompanied by adequate filtering.

According to Piliang (2004), artificial intelligence (AI) art generator technology has the potential to kill reality and replace it with false or artificial reality as its use becomes more widespread. This can happen especially if the results of this technology cannot be recognized as the work of AI, and there is a lack of education about this. People's views and beliefs may change, even distorting the original reality. Misinformation can occur, HOAX is inevitable, and false reality is believed to be the truth. This can also make it easier for those who want to spread false information for personal or group interests, change history and the past, and even lead to negative things that harm others.

Seeing that artificial intelligence (AI) art generator technology will be increasingly used and its negative potential, knowledge is needed regarding the analysis of reality and post-reality construction using artificial intelligence (AI) art generator technology, so as to prevent the death of reality. This research was conducted with the aim of clarifying the boundaries between reality and post-reality of visual works of this technology to avoid misinformation or shifts in reality and truth.

This research uses several artificial intelligence (AI) art generators works that construct reality and post-reality, then combine them into a new reality. This work simulates the city of Jakarta if it sinks, thus showing a representation of the new reality that will be faced by the people of Jakarta. This work was taken from an account with the username @deadbyusagi which was shared and viralized by a Twitter account with the username @kegblgnunfaedh. This work, which uses artificial intelligence (AI) art generator technology, has been viewed by more than 400 thousand Twitter users. Figure 1 shows the work produced by artificial intelligence (AI) art generator technology

Figure 1. Work produced by artificial intelligence (AI) art generator technology (Source: Liputan6.com)

This work was chosen as the work to be researched because this work raises a phenomenon that is closely related to the people of Jakarta, often occurs in reality, but has not actually happened. The problem of flooding and public anxiety about Jakarta sinking has become a common conversation among the public. This artificial intelligence (AI) image is able to visualize the anxiety in the form of a very realist image.

This research on the construction of reality and post-reality using artificial intelligence (AI) art generator technology is expected to be a new reference and insight for the community and young people so that they can take part in distinguishing between real reality and pseudo-reality so as to avoid negative impacts that might occur. Creativity and the use of this technology cannot be contained or limited easily, so increasing the knowledge of people who consume and are exposed to these visuals is crucial. This research was conducted using various theoretical foundations in the form of literature reviews, namely books, articles, and journals related to artificial intelligence (AI) art generator technology, as well as by observing and analyzing the work.

2. METHODS

2.1. Research Approach

In this research process, precise and accurate data is needed as material for analysis. The data collection process until the research process must be carried out with a structured method so that the results obtained can answer the problem formulation that has been described previously. With method planning, this research is expected to produce valid, scientifically accountable, and objective solutions.

According to Sutrisno Hadi (1993), research is a series of processes to discover, develop, or test a theory or hypothesis for the purpose of knowledge carried out by scientific methods. This method is needed as a procedure for solving problems that are being faced in the research process.

2.1.1. Semiotic

In this research, Roland Barthes' semiotic theory guides the dissection of the signs and visual construction of AI Art Generator's works. Roland Barthes' semiotic theory is a reference in this research because it is a refinement of the semiotic theory proposed by Ferdinand De Saussure. While Saussure discussed semiotics more linguistically, Roland Barthes' theory is more comprehensive and can be used in analyzing visuals.

The semiotic method will be a reference in finding the construction of the work by using a semiotic table (Table 1) based on the denotation and connotation meanings of the objects in the work being analyzed.

Table 1. Roland Barthes' semiotic (Barthes,1983)

First meaning (first level system) Denotation	Signifier	Signified
Second meaning (second level system) Connotation	1. Form	Concept

2.1.2. Visual perception

Visual perception analysis of the results of the AI art generator technology will be conducted based on Gestalt theory, namely similarity, proximity, continuity, closure, symmetry, and focus (figure ground).

2.2. Analysis Data

To analyze the construction of reality and post-reality using artificial intelligence art generator technology, there are several works raised, as shown in Figure 2.

Figure 2. Artificial intelligence (AI) art generator technology artworks (Source: Liputan6.com)

Liputan6.com highlights a work created using artificial intelligence art generator technology. The work simulates the city of Jakarta if it sinks, thus showing a representation of the new reality that will be faced by the people of Jakarta. This work was taken from an account with the username @deadbyusagi which was shared and viralized by a Twitter account with the username @kegblgnunfaedh. This work, which uses artificial intelligence art generator technology, has been viewed by more than 400 thousand Twitter users.

3. RESULT AND DISCUSSION

AI art generator technology works by combining existing reality with the addition of imagination and creativity within certain limits. In this process, the AI art generator builds a visual construction between reality and post-reality. There are two AI art generator works used

in this research. This work simulates the city of Jakarta if it sinks, thus presenting a representation of the new reality that will be faced by the people of Jakarta. This work raises a phenomenon that is closely related to the people of Jakarta, often occurs in reality, but has not actually happened. The problem of flooding and public anxiety about Jakarta sinking has become a common conversation among the public. This artificial intelligence (AI) image is able to visualize this anxiety in the form of a very realist image. Here are the two visuals studied.

3.1. 1st Visual

3.1.1. General overview

The first visual, titled "A view of a soccer game when Jakarta is filled with water", shows a soccer stadium with the field submerged in water. The work takes the viewpoint of a spectator in one corner of the stadium with several players in the middle of the flooded field. There are ripples of water on the field and lines of rain falling from the roof of the stadium. The sky appears gray and the sun is not visible. The atmosphere and colours tend to be gloomy and almost dark. But the euphoria of soccer can still be seen from the raised hands of the spectators. The stadium is filled with spectators all around until there is no empty space. The elements of a soccer match are still visible from the soccer goal and the large television screen on one side of the field.

This visual is also accompanied by the writing that Jakarta is expected to be under water by 2030. This prediction was made by Eddy Hermawan, a Principal Expert Researcher from the Center for Climate and Atmospheric Research (PRIMA), Organization for Earth and Maritime Research (ORKM), National Research and Innovation Agency (BRIN). This is potentially due to sea level rise and land subsidence due to excessive groundwater use. Jakarta, especially North Jakarta is likely to experience these impacts if this continues (Prihatini, 2022).

This first visual takes the topic of the sinking of Jakarta and is visualized in the form of a football match. Although the results of AI art generator technology in terms of visual details are still not perfect, it is enough to describe the situation of the match which will be much different than when Jakarta did not sink. Some visual elements still depict real situations such as euphoria and the shape of today's stadiums, but added hyperbole elements in the form of stagnant water.

3.1.2. Visual analysis

The visual construction produced by the artificial intelligence (AI) art generator uses surrealist art flow. This can be seen from the characteristics of surrealist art according to similar.id. By using references from the reality that Jakarta will sink, but the current situation of Jakarta has not yet sunk. The depiction of Jakarta in a sinking condition is only based on the artist's fantasy. Contrasting colours are also used in this visual work.

Figure 3. 1st Visual colour

The colours used in the construction of this visual work use a split-complementary colour scheme by taking green, blue and orange (Figure 3). These colours are combined to form a contrast. However, because it takes low-saturated colours, this visual looks somber and harmonious. Only a few colors are made contrasting and high-saturated. In addition, the colours used are cold colours that give the impression of sadness and melancholy.

Figure 4. 1st Visual space

There is space (Figure 4) created by building construction and can also be seen through Gestalt theory, namely from the similarity of form (similitude) and proximity (proximity) discussed in the analysis of visual perception. The space in this visual can be categorized into the spectator stands area and the soccer match field area (Table 2).

3.1.3. Semiotic

Through the visual construction built by the artificial intelligence (AI) art generator, there is a myth that develops in Jakarta society. Jakarta will sink into a mythical conversation and narrative built through the visual construction displayed by the media.

These narratives about Jakarta will sink will potentially become a belief that the sinking of Jakarta will be inevitable. People must make peace with the inundation that will cover all of Jakarta's land later. In addition, there is the potential for opinion-mongering to bring down certain individuals or groups from the situation presented in the work.

Table 2. 1st Visual semiotic

Denotation	1. Signifier A soccer match at a stadium with a waterlogged field.	2. Signified The atmosphere of a soccer match if Jakarta had sunk.
Connotationi	I. Form The atmosphere of a soccer match if Jakarta had sunk.	II. Concept A satire that shows Jakarta as it sinks, a flood situation is possible, and the people of Jakarta still have to do their activities as usual or normal.

3.1.4. Visual perception

Similarity of form: seen in the similarity and similarity of colors in the audience, so that they are grouped as the same entity. There are also some elements of repetition that make the stands and stadium recognizable even though they are not depicted in detail.

Proximity of Position: The proximity of objects can group objects and create a space. The proximity does not have to be tight but has a pattern or distance of proximity of one object to another. There are 2 different proximities of objects that create 2 different spaces.

Pattern Continuity: The chairs and lights in the stands form a harmonious pattern. Similarly, the water ripples give the impression of movement even though they fade away in the distant parts. The spectators arranged in rows also form a dynamic pattern.

Form Closure: Although the stands and the roof of the stadium are not depicted in full, the objects are still recognizable. The soccer field is also not visible, but can be identified as a field from the goal and the position of the players. The overlapping objects are also still recognizable as a unified object.

Balance: This image uses asymmetrical balance, i.e. although it is not symmetrical on both sides, it still provides enough balance between the sky and the stadium, the field and the audience, thus building a harmonious composition.

Focus: Through the use of contrasting colors and clear boundaries between objects, the main object and the background can be clearly distinguished. The background is made less detailed, such as the stands in the distance, the texture of the water, and the clean sky. Meanwhile, the main object is made more detailed, clear, contrasting, with a different color blend from the background, for example the spectators at the front and the football players. This encompasses the imagination that appears within the mind as though they were real. In addition, this creates a space, which seems to be unlimited, as the visual elements are colorful and rhythmic, while the wildness of creativity enhances the effectivity of learning systems, through this technology (Murwonugroho, 2019)

3.2. 2nd visual

3.2.1. General overview

The second visual, titled, "People have been using small boats", shows water submerging a city. The sky is overcast with gray clouds, and tall buildings are lined up so closely in the distance that they are almost silhouetted. Electricity poles are visible on the left side of the image with cables running across the top. Shabby-looking houses are seen at the edges, while the visual is dominated by water. There are no yards or roads, and everything is replaced with puddles.

Dozens of people move around on tires or boats. There are several boats selling food and fruit in the form of Indonesian carts. Not forgetting the colorful umbrellas that usually decorate merchandise in Indonesia. The people in them are seen doing their own activities, but in the middle of a puddle that fills the entire city.

3.2.2. Analysis visual

The visual construction produced by the artificial intelligence (AI) art generator uses surrealist art flow. This can be seen from the characteristics of surrealist art according to similar.id. By using references from the reality that Jakarta will sink, but the current situation of Jakarta has not yet sunk. The depiction of Jakarta in a sinking condition is only based on the artist's fantasy.

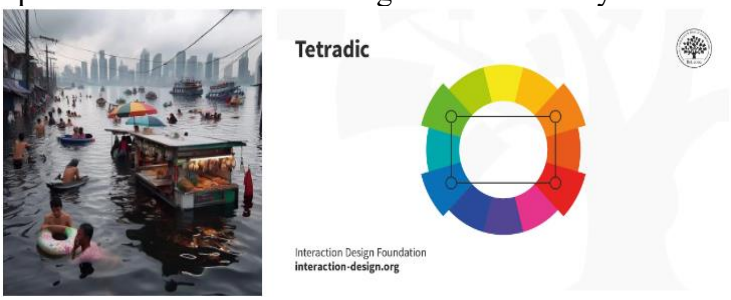

Figure 5. 2nd Visual color

The colors used in the construction of this visual work use a tetradic color scheme by taking red, orange, green, and blue (Figure 5). However, this visual is dominated by blue. These colors are combined to form a contrast and rich color. This image predominantly takes low-saturated colors and only a few colors are made contrasting and high-saturated to give emphasis. In addition, the colors in this visual use cold colors that give the effect of melancholy and sadness.

Figure 6. 2nd Visual Space

In Figure 6, there is space created from the application of Gestalt theory, namely from similitude and proximity discussed in the visual perception analysis. The space in this visual is divided into two categories, namely the water area at the front of the visual and the building area seen from a distance.

3.2.3. Semiotic

Through the visual construction built by the artificial intelligence (AI) art generator, there is a myth that develops in Jakarta society. Jakarta will sink into a mythical conversation and narrative built through the visual construction displayed by the media (Table 3).

These narratives about Jakarta will sink will potentially become a belief that the sinking of Jakarta will be inevitable. People must make peace with the inundation that will cover all of Jakarta's land later.

Table 3. 2nd Visual Semiotic

Denotation	1. Signifier People on the move swimming in the suburbs.	2. Signified The atmosphere of community activities if Jakarta has been submerged in water.
Connotation	I. Form The atmosphere of community activities if Jakarta has been submerged in water.	II. Concept A satire that depicts the hustle and bustle of Jakarta despite being submerged in water, but still having to move around to continue living, showing the gap between the shanty town and the tall buildings in the background.

3.2.4. Visual perception

Similarity of form: Similarity of shapes is seen in various elements in the visuals, such as the shape of people floating in water, strands of power lines, electric poles, and buildings grouped with similar shapes and matching colors, resulting in a clear perception of the objects depicted.

Proximity of Position: Similar objects are also grouped by position. For example, shabby-looking houses are placed on the left side of the picture, people are placed close together, ships, buildings, and electricity poles are placed close to each other.

Pattern Continuity: A continuous pattern is formed from the neatly arranged water ripples that fade away in the distance, giving the water a sense of movement. The direction of the ship also gives the effect of the ship moving in a certain direction.

Form Closure: Some objects are not depicted completely, such as the people who only appear halfway from the surface of the water, or the overlapping umbrellas, houses, boats and electricity poles, but they still look natural and complete.

Balance: The visual uses an asymmetrical balance that does not divide the two spaces exactly, but still gives the impression of harmony because of the balance of objects and backgrounds, complex objects and simple objects, giving the impression of harmony between one object and another.

Focus: There is a difference between the background and the object, marked by clear differences in color and line, the colors of the ship, person, floating tube, and umbrella are given contrasting colors, while the background tends to be blue to gray, so that the object and background can be clearly distinguished. In the image, one can easily identify the object and the background behind it.

4. CONCLUSION

From the discussion, it is concluded that AI art generator technology builds denotative messages with its algorithm technology to produce a visual work. AI technology combines elements of formalism that build reality in accordance with human understanding and knowledge, then adds elements of hyper-reality. This hyper-reality element is socially, economically, and culturally impossible. This is the strength, weakness, and success of AI art generator technology in building a visual image. People's visual interpretation of AI art generators is built by denotatums of reality and influenced by the background social and cultural context that shapes human visual perception. The combination of reality and added hyper-reality that is impossible produces works that are able to manipulate reality and form a pseudo-reality.

5. ACKNOWLEDGMENTS

This research was conducted under the guidance of Master of Design lecturers at Universitas Trisakti Jakarta.

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CHAPTER 10

Perceptions Regarding Completion of Technical Requirements for Building License by Using 'USG' Analysis

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ABSTRACT

To guarantee the fulfilment of safety, health and reliability aspects, building construction requires a Building Permit from the party determining and assessing the technical requirements. However, the facts show that a number of buildings have not fulfil these technical requirements due to optimization considerations of limited land area, the amount of costs that must be in accordance with the owner's request, and the lack of knowledge of planners about the requirements for building permits. In this regard, this study aims to: 1) identify the level of urgency in implementing the building permit requirements based on the perceptions of parties related to building design; 2) verify the application of the Building Permit requirements in the three building cases studied (1 Apartment and 2 Hospitals); and 3) the response of policy makers to the results of research on the urgency level and verification of the implementation of the Building Permit requirements. To achieve this goal, a quantitative descriptive method through USG (Urgency, Seriousness, Growth) analysis measurements supplemented by an interview is considered appropriate. The findings are that the level of urgency/importance perception, in providing facilities, considered to meet the requirements of a Building Permit. along with the high or low number of opinions about whether it is safe/unsafe if they are not provided, and the high or low number of opinions about the growth of problems if the requirements are not fulfilled. The low level of urgency assessment lies in requirements that are considered unimportant, unsafe, and not problematic, which are associated with considerations of whether or not it is difficult to fulfil and whether it is important or not provided. Overall research results can be used as input in improving the existing Building Permit requirements or as a basis for formulating future policies.

Keywords: Technical Requirements, Building License, 'USG' Analysis.

1. INTRODUCTION

Local Regulation No. 7/2010 on Building and Local Regulation I/2014 state that buildings must have a Building License/Building Permit, to ensure the safety, comfort and reliability of building construction. Facts show that buildings that do not fulfil the requirements in the above Regional Regulations experience events that threaten the safety of users (for example: the fall of the elevator, the lowering of the building foundation surface resulting in flooding in the lower area/region, late evacuation of building occupants, etc.). This research aims to verify the implementation of the fulfillment of technical requirements of Building Permit on public and social service function buildings in DKI Jakarta, identify the level of urgency, and find out the responses and recommendations of policy makers related to the research results.

The unsuccessful implementation of the Building Permit in several regions is shown through several previous research results. The implementation of the Building Permit in Merauke Regency, related to the conversion of protected areas into residential buildings and the control of space utilization for housing development, was found to be inconsistent with the spatial direction [1]. Building owners, who apply for a Building Permit after the building is constructed, cause irregularity in land use and tend to have adverse impacts on the environment [2]. The integration of the Building Permit rules with the noble values of Balinese traditions, by giving authority to each region, was not able to control violations of the requirements set out in the Building Permit [3],[4]. The process of controlling development and issuing Building Permits is an important reason for dealing with the problem of urban decay [5]. Building Permit data can be used to provide insight into the development cycle, and explain the short-term effects of cases on the construction sector [6].

MVC model application software, using Laravel based on Blackbox testing and User Acceptance Testing (UAT), suitable for assisting Building Permit Management in Baso District, Agam Regency West Sumatra [7]. The innovation of the Building Permit Delivery service, through the use of the Building Permit Process Application server network, in Surabaya has shown a positive impact and is running well [8]. Process, Rules and Requirements, and Technology are important aspects in planning the digitization of the Building Permit process in the 3D system [9]. The process of BIM adoption and the factors that influence the success of such adoption, contribute to recognizing planning strategies and implementation measures[10]. The integration of geoinformation with BIM (GeoBIM) is another alternative in the effort to automate the Building Planning Permit process[11].

The practice of implementing the digitization of the Building Permit has its own challenges. Through an exploration of the quality of Building Permit services at the Ciamis Regency One Stop Integrated Service Investment Office, it was found that weaknesses in the effectiveness and efficiency of IMB services were caused by a lack of human resources, officer capabilities and facilities that support online services [12]. A simple and inexpensive way to forecast Building Permits is to utilize information on Google web search queries. The time series on Building Permits is used as a leading indicator to forecast economic activity in the construction sector [13].

The previous studies above, generally focused on the quality of the Building Permit management service process, the level of success and unsuccessfulness of the Building Permit implementation as well as the role of information technology/software in improving the efficiency and effectiveness of Building Permit services. In this study, we want to know about the level of importance, the impact of application/non-application of technical requirements for Building Permit, on public and social service function buildings in the Special Capital Region of Jakarta, based on the perceptions of various related parties.

2. RESEARCH METHODS

The research objectives were: 1) to determine the suitability of the technical requirements of the Building Permit with its implementation; 2) to analyze the perception of urgency level of

fulfilling requirements; and 3) to determine the responses and recommendations of policy makers regarding results of the research. The research approach considered appropriate was a descriptive quantitative approach that was deepened by interviews. Descriptive quantitative focused on efforts to describe or provide an overview of research objects. The results of analysis and conclusions only apply to the objects studied, namely the 'X' Hospital building, 'Y' Hospital, and 'Z' Apartment. To maintain privacy, the name and owner of research objects were hidden, so the research was lesson-learned. The research instruments used questionnaires, structured interview lists, photos/camera, dimensional measuring devices, checklists of building technical assessment standards. The research stages included: 1) direct verification at the objects under study (buildings 'X', 'Y', and 'Z') to check the suitability of Building Permit's technical requirements and its implementation; 2) Measuring the perception of implementation priority level based on USG analysis of questionnaire answered by 30 respondents; 3) Interviewing policy makers to obtain the response and recommendations of the research results.

The study population was buildings categorized into public and social service function zoning in DKI Jakarta. Samples were selected purposively, with the criteria: 1) the building functions as a public and social service building; 2) use by the public intensively; 3) researchers have access and permission to conduct research in each object. The research components include activities (functions and zone activities), intensity of space utilization, and minimum technical standard infrastructure building layout. The selected respondents met the following criteria: 1) parties who contribute to the planning, construction and management of buildings (building expert team, One Stop Integrated Service expert staff, building planning team, building maintenance manager); 2) parties who have the authority to make decisions in the DKI Jakarta Provincial Government (Investment and One-Stop Integrated Service Office, and Land and Spatial Planning Cipta Karya Agency).

3. ANALYSES AND DISCUSSION

3.1. Verification results of technical requirements implementation on the research objects (building 'X', 'Y' and 'Z')

As shown in TABLE 1, for implementation verification purposes, technical requirements are categorized into five component groups: activities, intensity of space utilization, building layout, minimum infrastructure, and technical standards. The assessment parameters refer to three criteria: non-conforming, moderately conforming and highly conforming. The criteria for non-conformity is that the building does not fulfil/do not provide the required facilities. Moderately conforming criteria means that the building provides required facilities, but less than the minimum standard size. highly conforming means that the required facilities fulfil the standards requested by the Building Permit or may exceed the required facilities.

The results of field direct verification show that: 1) Hospital building 'X', non-conforming with the requirement criteria 7%, moderately conforming with the requirement criteria 7%, highly conforming with the requirement criteria 56.1%, and with notes 29.8%; 2) Hospital building 'Y', non-conforming 6.8%, moderately conforming 1.7%, highly conforming 71.2%, and with notes 20.3%; and 3) Apartment building 'Z', 6.8% indicates non-conforming, 1.7%, moderately conforming, 67.8% highly conforming, and 23.7% with notes. The caption 'with notes' intends to state: 1) The level of suitability cannot be measured because the researcher did not obtain survey permission; 2) There is no such category of requirement at the location requested; 3) The building under study does not require these facilities. Of the five components studied, the activity/function components of Hospital 'X', Hospital 'Y', and Apartment 'Z', are in accordance with the regulation that the building is in the Public and Social Services subzone.

TABLE 1. Appropriateness of technical requirements implementation based on direct verification at the research locus

Components	Sub-Components	Building 'X'			Building 'Y'			Building 'Z'		
		non-conforming	moderately conforming	highly conforming	non-conforming	moderately conforming	highly conforming	non-conforming	moderately conforming	highly conforming
Activities	Activities Zone			V			V			V
Space Utilization Intensity	Building Covered Ratio (BCR)			V			V			V
	Floor Area Ratio (FAR)			V			V			V
	Green Base Coefficient			V			V			V
	Basement Floor Coefficient			V			V			V
	Building Height			V			`			V
Building Code	Road border line	The researcher did not obtain a survey permit			The researcher did not obtain a survey permit			The researcher did not obtain a survey permit		
	Building border line									
	River border line									
	Basement Border Line									
	Road/street Plan									
	Yard Door Boundary			V			V			V
	Water Trap		Uneven distribution				V			V
	Rainwater Infiltration Well			V			V			V
	Rainwater Infiltration Pond	Land Use Planning < 5000 m2					V			V
	Security check			V		V				V
	Parking Lot Size			V			V			V
	Basement Floor						V			V
	Vertical Distance from full Floor to next full Floor			V			V			V
	Head Clearance	No Basement Available					V			V
	Corridor Size			V			V			V
	Escalator Usage	Not Available					V	Not Available		
	Elevator Usage			V			V			V
	Public circulation ramp	The researcher did not obtain a survey permit			The researcher did not obtain a survey permit					V
	Straight Vehicle Ramp Size									V
	Circular Vehicle Ramp							Not Available		
	Elevator machine room /ME			V			V			V
	Parapet height	Gable Roof					V			V
	refugee floor	Below Standard Needs refugee floor			Below Standard Needs refugee floor			Below Standard Needs refugee floor		
	helipad	Not applying for helipad facility			Not applying for helipad facility			Not applying for helipad facility		
Minimum Infrastructure	Public Toilet			V			V			V
	Disabled facilities			V			V			
	Ramp slope = 1:8 (inside building), 1:10 (outside building) minimum ramp width 0,95 meters (without safety edge) and 1,2 meters (safety edge)			V			V			V
	Prayer room			V			V	Not Available		
	Canteen			V			V	Not provided because it is a residential building		
	Garbage disposal area			V			V			V
	breastfeeding room			V			V	Not provided because it is a residential building		
	Dressing room			V			V			
Technical Standards	Fire Stairs			V			V			V
	Number of fire stairs			V			V			V
	Fire stairs with smoke-proof lobby			V			V			V
	Fire stairs with fire lobby		V				V			V
	Fire elevator			V			V			V
	Fire stairway safety			V			V			V
	Total number of saft			V			V			V
	Fire Saft distance from the entrance to the lobby		V				V			V
	Distance between Fire Stairs			V			V			V
	Fire stair door			V			V			V
	Dead end corridor			V			V			V
	Compartment System	No Basement Available			V				V	
	Fire engine pavement layer	V					V			V
	Width Fire truck entry and exit access			V			V			V
	fire control center	V					V			V
	OTTV	V					V	V		
	Planting of natural vegetation			V			V			V
	Rainwater harvesting system	V			V			V		
	pedestrian path		2				V			V
	Bicycle Rack	V			V			V		
	Bathroom for cyclists	V			V			V		

Source: Field survey, 2021

The sub-components of Space Utilization Intensity (Building Covered Ratio, Floor Area Ratio, Green Base Coefficient, Basement Floor Coefficient, Building Height) are requirements that must be fulfilled. Based on field direct verification, the implementation of these sub-components is in accordance with the planning drawings and the provision of facilities after construction. 23 of the 24 Building Code's sub-components are requirements that must be fulfilled and those that are not considered mandatory are guardhouses. Of the seven Minimum Infrastructure sub-components that must be fulfilled, only three facilities are considered mandatory. The rest (provision of pray room, canteen, breastfeeding room, and dress room) are categorized as non-mandatory. Fifteen of the twenty technical standard requirements are mandatory. The rest fall into the non-mandatory category, but are still fulfilled by owners, namely bicycle racks, and bathrooms for bicycle users. Some of the non-conforming requirements are: 1) water trap placement, 2) bathroom dimensions. Meanwhile, the reasons why the requirements were not fulfilled were: 1) the building does not require its provision, 2)

limited available land, 3) it has not been made a mandatory requirement when the building was built, and 4) it does not need to be fulfilled because the functions are different.

3.2. Perceived level of urgency through USG analysis (urgency, seriousness, growth)

Urgency, Seriousness, Growth analysis is one of the scoring methods to arrange the priority order of issues that must be resolved. The rating scale for the perception of urgency level in fulfilling the requirements is in the range of not important to very important, the measurement scale for perceptions of impact includes unsafe to safe, and the scale of perception of problem development level is not problematic to very problematic. The results showed that the perception of urgency level towards the fulfillment of the technical requirements of Building Permit is higher than the perception of the impact and possibility of problems arising if the requirements are not fullfiled. The results of the USG analysis found that based on 58 sub-components asked to 50 respondents, 13 sub-components had low scores (TABLE 2).

TABLE 2. Respondents' perception of the level of importance and difficulty in fulfilling the requirements

Sub-Component	Not so important to fulfill	Difficult to fulfill
Floor Area Ratio (FAR)		V
Green Base Coefficient		V
Basement Floor Coefficient		V
Security check	V	
Escalator Usage		V
Elevator machine room /ME		V
Prayer room	V	
Canteen	V	
Breastfeeding room	V	
Dressing room	V	
Distance between Fire Stairs		V
Bicycle Rack	V	
Bathroom for cyclists	V	

Source: Researcher, 2021

3.3. Decision makers responses and recommendations

As a follow-up to the low-scoring research findings in TABLE 2, decision-makers responded by putting forward some considerations and recommendations (TABLE 3). They responded to sub-components that were considered significant.

4. CONCLUSSIONS

The suitability of the implementation of the technical requirements of the Building Construction Permit is related to considerations of the availability of land area, the assumption that it is not needed, and the requirement has not been made a mandatory requirement when the building is built. Perceptions of the level of urgency towards fulfilling the technical requirements of a Building Permit are higher than perceptions of the impact and likelihood of problems arising if the requirements are not fulfilled. The technical requirements of the Building Permit, which tend not to be fulfilled, are those that are considered unimportant or difficult to realize. It is necessary to add clauses to the technical requirements of the Building Permit related to green building requirements, and the need for intensive socialization of requirements that have an impact on the issuance of warning letters and building demolition.

TABLE 3. Decision-makers' responses and recommendations to the research results

	Consideration of fulfillment of requirements	The advantages and disadvantages if requirements are fulfilled	Recommendation
	Requirement is not an obligation (does not result in problems) and is not specifically stated in the Regional Regulations and Governor Regulations.		
	Additional requirements to respond to the development of urban TOD provision.	▪ Awarded plus points, ▪ Contribute to a decrease in the number of private vehicles and the amount of carbon emissions in the air.	In the technical requirements of the Building Permit, technical requirements for green building are added.
	Requirements that must be fulfilled but are ignored by planners and affect the non-issuance of a Certificate of Habitability		
	If the requirements are not fulfilled, there is a danger to the safety of building users, for example, the distance between fire stairs.	▪ Obtain a Certificate of Liveability so that the planned building can be built ▪ Ensure security, safety of building users	It is necessary to add a clause on the distance between stairs according to Governor Regulation 72 of 2021 and Governor Regulation 200 of 2015, so that it is not only a direction but a mandatory thing to fulfill.
	Additional requirements in response to changes to the Building Height Coefficient and Green Base Coefficient regulations in an effort to achieve the 30% Green Jakarta target.		
	The basement clearance is 3 m, beyond which it can be counted as Green Base Coefficient.	▪ The risk of the basement foundation body exceeding the planning footprint. ▪ Increase in pure green area and water catchment area	Intensive socialization of requirements that result in the issuance of warning letters and demolition if construction is forced.
	Requirements relating to spatial control with the aim of regulating population density and reducing vehicle congestion.		
	Exceeding the Building Floor Coefficient in the area, resulting in problems.	▪ Reduction of parking lot floor area. ▪ Optimization of Building Floor Coefficient implementation	Intensive outreach regarding building floor coefficient planning techniques.

5. ACKNOWLEDGMENTS

This research is supported by Faculty of Civil Engineering and Planning, Universitas Trisakti, Jakarta, Indonesia. We express our gratitude and highest appreciation to the institution, and hopefully the research results can contribute to the institution’s credibility.

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CHAPTER 11

Modular Footwear Design as a Way to Optimize Industrial Raw Materials and Preserve the Environment

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ABSTRACT

Environmental issues arising from footwear manufacturing waste have been a long-standing issue that has yet to be adequately addressed. The goal of this project is to create a modular footwear design that maximizes raw material utilization, is adaptable to current trends, and lowers the impact of fashion industry waste to the environment. The footwear design in this study was created utilizing Design Thinking, with the processes divided into three categories: pre-design, design, and post-design. A modular footwear design was successfully constructed using the Design Thinking process. The modular footwear design meets three eligibility conditions that are adjustable to the user's specific choices, according to the aims and needs specified in the Empathize step. This need is a prerequisite for the next two requirements, which are sustainability and near-zero waste production efficiency. The findings of user empirical testing show that this modular footwear design is compatible and ergonomic. According to the LCA test results, the life cycle of this modular design footwear is classed as ecologically friendly. The study's findings have significance for art and design debate, as well as for future research to build design modification variants.
Keywords: Modular, Footwear Design, Design Thinking, Life Cycle Assessment.

1. INTRODUCTION

In 2027, the world footwear industry is estimated to be worth USD 365.5 billion (Chuenyindee et al., 2022). Especially in Indonesia, the prospects for the footwear industry are quite large. According to data from the Ministry of Industry (2021), there aremore than 18,657 business units (including small, medium and large industries) with a workforce of 247,843 people. However, the footwear industry has always been sur- rounded by environmental issues because it contributes to waste, carbon emissions and large resource consumption. For example, the results of the Life Cycle Assessment (LCA) analysis in Sweden in 2015 which examined the environmental impact of foot-wear consumption revealed that each material wasted from the production and consumption of footwear contributed greatly to environmental disasters, in the form of eutrophication and global warming (Figure 1). This research attempts to examine this problem and find a solution by referring to the cultural perspective of urban society.

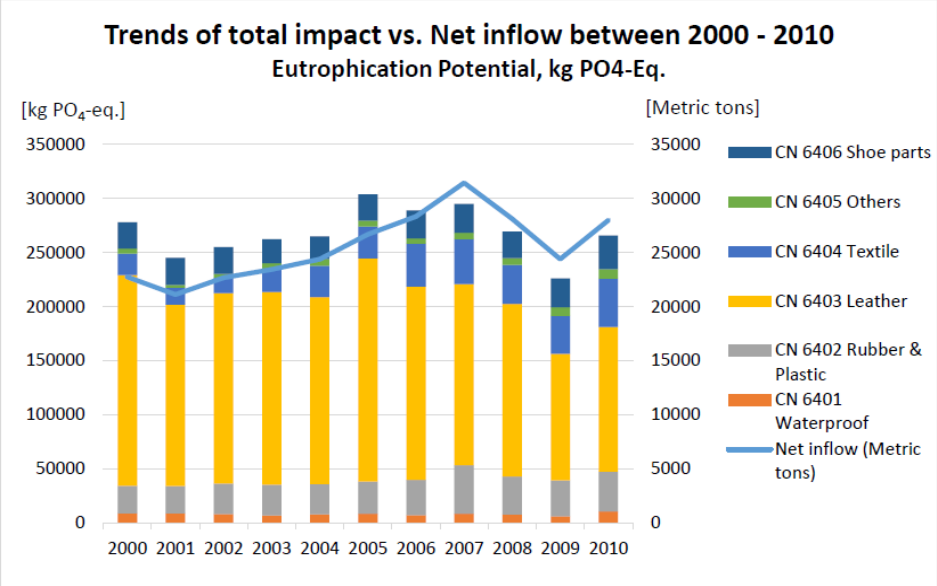

Figure 14 - Eutrophication potential of each CN category from year 2000 to 2010, the line for total net inflow shows the consumption trend during these years.

Figure 1. Environmental impacts of footwear production and consumption (Gottfridsson & Zhang, 2015)

In urban society, most individuals in the last decade have 9 - 10 pairs of footwear for each different occasion (sports, the office, daily activities, etc.). As individuals whoare prestigious because of their culture, they have a tendency to throw away footwear that look worn out, sloppy, even just out of date or not in line with trends (Niinimaki, 2013). They are bound by the image that is built on the perception of visual elements which are influenced by the experiences of other users (Budiman *et al.,* 2022). The footwear industry also responded to this trend by discarding products that were not soldbecause there were too many offers on the market (Figure 2). According to Johnson's (2021) findings, there are 5-10% of unsold footwear from all production.

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Figure 2. Footwear industry waste that never enters the market due to production defects, or behind trends (Source: https://pxhere.com/id/photo/954205)

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Therefore, a footwear design is needed that meets user preferences and expectations, supports environmental sustainability, and is adaptive to changing trends. Based on cultural, economic and conservation considerations, this research was carried out to produce a modular footwear design that is ideal for people with various preferences and characteristics, while also being environmentally friendly. Footwear with a modular design is considered the best solution because they are superior in terms of design.

Modular footwear refers to a footwear design whose structure is composed of various partition modules that can be adjusted or exchanged according to the user's specific preferences. By making it possible to exchange components, instead of throwing away the entire footwear, users can replace or upgrade certain modules that are considered obsolete. This design reduces the chance of increasing footwear waste in nature by ex- tending the life of the footwear. Compared to conventionally designed footwear, modular footwear has higher adaptability (Hill *et al.,* 2019), especially their adaptability to style, comfort and functionality (Ethiraj & Levinthal, 2004).

So far, the idea of modular footwear design is actually not "new". In the context of global manufacturing, there is a trend towards disintegrated production, where different components are produced in different companies, then assembled together. This kind of disintegrated production, according to Herrigel & Zeitlin (2010), is more efficient and flexible because it can adapt to different market demands. However, the materials used so far are not sustainable (Kavitha, 2023), and the resulting footwear assembly is a patent footwear. Several leading studies have succeeded in identifying environmentally friendly materials that are suitable for the footwear manufacturing process, such as double-layered cellulose as an alternative to leather (Nam & Lee, 2019), natural fibers as an alternative to synthetic fibers (Kohan *et al.,* 2019), and bio composites from cotton denim waste (Fernandes *et al.,* 2021). In a business context, unique modular shoes also have the potential to attract a sizable market share. People are usually attracted to new and unusual visual designs so there is a need for ideas that tend to make the design more attractive (Murwonugroho & Yudarwati, 2020). Moreover, these days brought together by an era of accelerating information on the industrial revolution 4.0 which social media has the power to build a product branding (Murwonugroho & Tyasrinestu, 2019).

As a follow-up to previous problems and research, design and production patterns, this research was carried out to produce a modular footwear design that meets three main criteria, namely sustainable, efficient and meets the user's special preferences. The creation of the modular footwear design in question contributes to academic discourse about design, economics and the environment. Meanwhile, practically, modular foot- wear design increases customer

satisfaction through comfort and customization according to taste (Kuklane, 2009), develops a circular economy through production efficiency, and increases sustainability through significantly reducing waste contributions (Van Rensburg *et al.,* 2020), and helps novice footwear craftsmen to be stable in a dynamic market through the flexibility of footwear component design innovation (Roundy& Bonnal, 2017).

2. METHODS

The development of this modular footwear design was carried out using Design Thinking (DT). The DT procedure was chosen because of its effectiveness in creating creative and practical problem solving to answer human needs (Gekeler, 2019). Practically, the research steps were carried out by adapting the design process methodology proposed by Robin Landa (2011). The results of this procedure are presented in Table 1.

Table 1. Design thinking applications

Phase	Stage	Findings
1. Pre-Design	Empathize	• Concern for the environment • Footwear production inefficiencies • Variations in user preferences
	Define	Synthesis between environmental conservation missions, production efficiency, and meeting user needs
2. Design	Ideate	Initiation of modular footwear design concepts according to needs (for children, disabled people, office activities, etc.)
	Prototype	Concrete representation of the idea/concept of modular footwear
3. Post-Design	Test	• Empirical tests to evaluate designs • Ensure ergonomic design according to user comments and accommodate empathize results

Empathize means understanding users' needs, views and feelings. Empathize is a key component in DT, and when combined with environmental ethics, empathy can facilitate the development of environmentally friendly and sustainable solutions. In this research, empathy develops from concern for the environment and footwear production inefficiencies. In the define stage, the information obtained in the empathy stage is synthesized and referred to determine innovative and sustainable solutions. In this re- search, solution definition is carried out with a holistic approach that bridges environ- mental conservation missions, production efficiency, and meeting diverse user needs. The results are followed up with the ideate stage.

At the ideate stage, unlimited exploration and free thinking occurs (Müller-roterberg, 2018), to produce original concepts and ideas that combine innovation, sustainability and efficiency. In this research, the ideation process is carried out by transforming various creative design possibilities that bridge and synthesize the three elements above. The synthesis result of the holistic approach above produces the concept of a modular footwear idea.

The prototype phase is then carried out involving the creation of real representations of ideas and concepts. Prototypes allow visualization of design solutions in concrete form before implementation. In this research, the design idea findings were applied visually and then turned into real objects (modular footwear). The finished modular footwear prototype is then tested so that the modular footwear idea/concept can be evaluated. In this research, testing was carried out using empirical tests on users. Researchers, at this stage, analyze user comments, refine the design, and ensure the solution successfully balances production efficiency, environmental sustainability, and meeting user needs with an ergonomic design.

3. RESULT AND DISCUSSION

3.1. Result

After in-depth research and understanding of trends, a modular footwear design was successfully created. Production and testing have also been carried out. Now, modular design footwear is available (dummy version). The first requirement that a modular footwear design fulfills is suitability to the user's preferences. This requirement is prioritized so that the main and first goal of the design is achieved first, namely that the footwear can be taken apart and put on by the user so that the style is always updated with the latest trends and reduces wasting of footwear because they are worn out and no longer in trend. The modular footwear prototype design and prototype layout can be seen in Figure 3 and Figure 4.

Figure 3. Modular footwear prototype design (Source: Personal documentation)

Figure 4. Modular footwear prototype layout (Source: Personal documentation)

The next condition to be met is that it is efficient and sustainable. Efficiency and sustainability requirements are met by wiser selection and use of materials, such as minimizing production waste (Figure 5), using environmentally friendly tools and materials, and a supply chain that is safe for the environment.

Figure 5. Utilization of sorting materials (Source: Personal documentation)

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Fulfillment of the above conditions also indicates the achievement of the objectives of this research. By implication, this design provides other benefits, such as easier maintenance and storage space efficiency. In terms of maintenance, footwear components can be replaced without having to throw away the entire footwear unit. This ad- vantage clearly reduces the contribution of waste to nature and extends the service life of footwear (Bai *et al.,* 2022). Meanwhile, in terms of space efficiency, this design can overcome logistical challenges (Sim *et al.,* 2021). The final results of the modular footwear design in this research (Figure 6 and Figure 7) have specifications as presented in Table 2.

Table 2. Footwear components and specifications

Component	Specification
Upper	- Vamp: The upper front part of the footwear that protects the toes - Side and back of the footwear - The part that protects the feet from footwear lace friction.
Lining	Material used in footwear for comfort and sweat absorption
Insole	An inner layer that sits under the foot to provide comfort, shock absorption, and support
Midsole	The midsole of the footwear provides shock absorption and stabilization. This is one of the frequently replaced components in sports footwear
Outsole	The bottom of the footwear is in contact with the ground and provides grip and wear resistance
Heel	The heel provides support and stability
Toe Cap	The part that protects the tip of the toe from injury
Footwear laces	A rope used to tie and fasten footwear
Fasteners	Components such as Velcro or buckles are used as an alternative to traditional footwear laces
Sole inserts	For certain sports footwear, such as custom soccer or soccer footwear, there may be additional insole inserts to provide additional support or certain features
Electricity (optional)	Some modern footwear can have electronic components such as sensors for activity tracking, step measurement, or automatic adjustment

Figure 6. Modular footwear module (Source: Personal documentation)

Figure 7. Modular footwear design (Source: Personal documentation)

The specifications in Table 2 confirm that each user can create footwear that suit their preferences and needs. This modular design offers very high adaptability according to user needs and preferences, such as medical needs, fashion, sports, office activities, outdoor, and so on. Specifications for each of these components may vary depending on the type of footwear, intended use, and brand.

Especially in the fashion industry, modular design is popular as a way to offer customizable products. The assumption is that consumers are increasingly interested because they are involved in the process of creating their footwear designs. This is an opportunity that (Rahman & Gong, 2016) calls an opportunity to adjust various features, such as: color, texture, dimensions and style.

3.2. Modular Footwear Design for People with Disabilities

One of the spirits of designing modular footwear designs is that they are adaptive to the user's specific tastes, needs and preferences. An example is women's footwear, which tend to prioritize comfort with minimalist and timeless designs. The adoption of this timeless model benefits modular design footwear because it can extend the service life and satisfy wearers because the footwear is not significantly affected by changes in fashion trends. Likewise with disabled users (Schwarze *et al.,* 2019).

Modular footwear can meet the needs of individuals with certain medical conditions, for example: individuals with rheumatoid arthritis who often have difficulty finding suitable footwear due to foot deformity and pain. Psychologically, missing out on foot-wear choices can have a negative impact on their emotions, well-being and quality of life (Naidoo *et al.,* 2011). Missing out on footwear choices can have negative effects on their emotions, well-being and perceived quality of life (Naidoo *et al.,* 2011). However, modular footwear design provides an opportunity to overcome these challenges, by offering options that accommodate the unique needs of the individual.

In the context of therapeutic footwear for children with foot deformities, modular footwear is designed to reduce compression and friction stresses in children's foot deformities through matching the dimensions of the footwear upper, insole, and sole to the child's foot. This approach, according to Hill *et al.,* (2019) ensures better fit and comfort for children, which is critical for their overall mobility and comfort. Apart fromthat, the design of modular shoes for children will be adapted to children's tastes. Thiscolorful visual play, therefore, becomes the main attraction for children, through the inherent color composition and patterns that respond interactively (Murwonugroho & Ardianto, 2019).

3.3. Modular Footwear Design as Part of Environmental Conservation and Carbon Trading

Evaluation of the environmental impact of a product during its entire life cycle can be done with a life cycle assessment (LCA). The assessment method used by Maciel *et al.,* (2017) in evaluating footwear adhesive technology has also been applied to modular footwear designs in this research. The conclusion is that the footwear designs in this research are environmentally friendly. The results of this test answer the research find ings of Van Rensburg *et al.,* (2020), who emphasize that design improvements need to be made to reduce the ecological impact of footwear throughout their life cycle. In the modular footwear designs in this research, the environmentally friendly category is largely contributed by the advantages of modular footwear designs that can be disassembled and interchanged, thereby reducing purchases. If we trace the supply chain, this reduction in purchasing patent footwear units ultimately results in a reduction in footwear waste in nature. This means that the carbon footprint of the footwear industry is also decreasing.

According to LCA on the life cycle of modular footwear, from material selection to manufacturing, use and final management, the industry can work towards reducing environmental impact and promoting sustainability. This happens because modular footwear production is carried out by combining organic cotton and low carbon materials in the production process. This step has been taken by leading footwear manufacturers such as Zara, Levis, Adidas, and Allbirds (Li *et al.,* 2022). On a better level, there are even footwear manufacturers who use alternative basic materials for footwear soles in the form of fungal mycelium composites which can decompose naturally (Wolfe & Cao, 2021).

However, it should be noted that the footwear industry's carbon footprint is not limited to the manufacturing process. The entire life cycle of footwear, including extraction of raw materials, production, distribution, use, and end-of-life management, contributes to the overall environmental impact (Mahmud & Islam, 2021), including energy consumption in footwear distribution transportation (Evans, 2021). This means that the LCA object in this research needs to be expanded in subsequent research.

However, each modular footwear has the potential to reduce the industry's carbon footprint by combining environmentally friendly materials and implementing cleaner technology. This advantage needs to be taken seriously, especially because the footwear industry contributes greater carbon emissions than the aviation industry and expedition industry combined (Filho *et al.,* 2022). As a follow-up to further reduce emissions, according to Carbonell-Blasco *et al.,* (2022), modular footwear needs to use biomaterial-based adhesives and plasma-based surface treatments. Apart from being healthy, these materials also increase the circularity of footwear.

4. CONCLUSION

Empirical testing on users concluded that the footwear design was in accordance with user preferences. The prototype can be disassembled and assembled well and smoothly. The results of the study on production efficiency also concluded that the modular design footwear manufacturing process in this study was material efficient and used environmentally friendly materials. The results of modular footwear testing using LCA concluded that the life cycle of the footwear concluded that the modular footwear design in this study was environmentally friendly and quite helpful in reducing carbon emissions.

Despite these successes, this research is limited in several respects, especially in production output, exploration of design creation, and consumer education. In terms of production output, sometimes various components that are produced separately and then assembled experience quality inconsistencies. In terms of exploring design creation, footwear customization options are still very limited. Meanwhile, in terms of consumer education, adequate promotion and advertising is needed to educate consumers so that they understand the background, uses, various custom creations and maintenance of modular footwear. These limitations should be addressed in future research.

5. ACKNOWLEDGMENTS

This research was carried out with full funding from DRTPM, Ministry of Education and Culture 2023. The author expresses very high appreciation and unexpressed thanks to DRTPM for this research grant assistance.

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CHAPTER 12

Enhancing Production Performance using Sustainable Lean Supply Chain: A Case Study in an Indonesian Shoes Manufacturer

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ABSTRACT

An Indonesian shoe manufacturing company has collaborated with a German sports apparel manufacturer within the Partner supply chain. However, the company needs help in its supply chain, particularly in material procurement, subcontracting, production, and storage, leading to delays in product delivery and quality issues. These inefficiencies result in waste generation, which harms the supply chain and the environment. To address these issues, this research employs the Sustainable Lean Supply Chain approach to enhance economic, social, and environmental aspects. The research begins by identifying the root causes of the problems by utilizing a fishbone diagram and Sustainable-Value Stream Mapping (SVSM) to visualize the current supply chain flow, encompassing inbound, operational, and outbound processes. The SVSM results are further analyzed using Process Activity Mapping tools to categorize activities into non-value-added, necessary non-value-added, and value-added segments. The Sustainability Index (SI) is then calculated, incorporating economic, social, and environmental indicators. The SVSM mapping of the production operation process reveals a process cycle efficiency (PCE) of 62.34% and a Manufacturing Lead Time (MLT) of 624874.01 seconds. After implementing improvements, the PCE increases to 68.26%, and the MLT decreases to 570736.29 seconds. The SI for inbound, operation, and outbound activities are determined to be 111.02%, 86.01%, and 184.33%, respectively. This research contributes to guiding practitioners in implementing a lean supply chain competitive strategy to enhance the SI. Furthermore, it provides empirical evidence of the positive relationship between a sustainable lean supply chain and sustainable performance, offering valuable insights for academicians and industry practitioners.
Keywords: Lean, Supply Chain, Sustainable-Value Stream Mapping, Shoes Manufacturer.

1. INTRODUCTION

Manufacturing companies increasingly recognize the importance of sustainable production practices, encompassing economic, social, and environmental considerations (E. Sari *et al.,* 2022). This awareness aligns with the Sustainable Development Goals (SDGs), particularly Goal 9 for industry and Goal 12 for responsible consumption and production. In the context of sustainable manufacturing, a prominent shoe company (referred to as Company A) has collaborated with Company X to integrate sustainability into its product supply chain system. Company X, operating within Company A's supply chain, employs a make-to-order production system for manufacturing shoes involving cutting, sewing, and assembly processes. Notably, this system's production target is 960 pairs of shoes per day, with each production cell producing 120 pairs per hour. However, despite the established production target, the observed production process has encountered challenges, particularly defects, which have led to a rework percentage of 31.40%. These defects are attributed to issues within the supply chain, specifically related to the quality of raw materials. It is well-established that the quality of raw materials significantly influences the final product, and substandard raw materials can adversely impact the quality of the shoe products, rendering them non-compliant with specified standards. Consequently, defective raw materials are discarded as scrap, necessitating the procurement of replacements, which delays and impedes production. Furthermore, rejected materials and products, categorized as C-Grade, are discarded as scrap to use in cement-making mixtures. This practice reflects an attempt to minimize waste and maximize resource utilization, aligning with sustainable production principles.

To address these challenges and optimize the production process, it is imperative for Company A and its partner, company X, to implement strategies that enhance the quality and reliability of raw materials, minimize defects, and streamline the supply chain operations. This may involve closer collaboration with raw material suppliers, stringent quality control measures, and sustainable practices throughout the supply chain. Table 1 provides detailed data on defective products from September 2022 to January 2023, offering valuable insights into the nature and extent of the defects encountered within the production process. By analyzing this data and identifying patterns, Company A and Company X can develop targeted interventions to improve their manufacturing operations' overall sustainability and efficiency.

Table 1. Defect Product

No	Month	B-Grade Pair (unit)	C-Grade Pair (unit)	B-Grade (%)	C-Grade (%)
1	September	13	15	0.02%	0.02%
2	October	16	61	0.01%	0.06%
3	November	30	46	0.03%	0.04%
4	December	10	4	0.01%	0.01%
5	January	3	0	0.00%	0.00%

The presence of defects in the production process and the quality of raw materials pose significant challenges to the company, resulting in adverse economic, social, and environmental impacts. Each instance of defect rework and the subsequent disposal of scrap materials entails the utilization of additional resources and contributes to increased pollution levels. To address this multifaceted problem, the present research adopts the Sustainable Lean Supply Chain (SLSC) approach, designed to sustainably enhance both the production process and the overall supply chain. Central to the SLSC approach is utilizing the Sustainable Value Stream Mapping

(SVSM) tool, which incorporates three key sustainability indicators: economic, social, and environmental.

The lean approach is oriented towards enhancing customer value by continually augmenting the ratio of value added to waste. A key objective of lean methodology is to elevate production quality while concurrently minimizing resource consumption. The Lean Supply Chain (LSC) strategy is underpinned by a focus on cost reduction and process time reduction, thereby enhancing supply chain efficiency, optimizing processes, minimizing waste, simplifying operations, and reducing Non-Value-Added (NVA) activities (S. Suradi *et al.,* 2023). Applying lean principles results in environmentally conscientious operations with minimal waste generation and low environmental impact. The SLSC concept is instrumental in mitigating environmental harm from energy consumption, water usage, and waste generation while engendering positive effects on the communities within and surrounding the operational sphere (C. L. Gargalo *et al.,* 2021). The identification of 8 distinct types of waste, including overproduction, waiting, unnecessary transportation, inappropriate processes, excessive inventory, unnecessary motion, product defects, and underutilization of employee skills, underscores the significance of waste minimization in reducing production costs, augmenting profitability, saving process time, and curbing environmental impact. This ethos aligns with sustainability, emphasizing resource conservation and waste reduction.

Adopting the SLSC approach yields waste reduction, enhancing operational efficiency and aligning with the fundamental tenets of sustainability. The mapping of the supply chain using SVSM, an evolution of Value Stream Mapping (VSM) tailored to sustainable supply chain practices, is a pivotal tool for assessing supply chain performance and offering guidelines for achieving sustainability and lean principles (J. A. Garza-Reyes *et al.,* 2016). The integration of SVSM encompasses the three pillars of sustainability within the VSM dashboard. Waste identification is facilitated through Process Activity Mapping (PAM), which categorizes activities into Value-Added (VA), Necessary Non-Value Added (NNVA), and NVA. Furthermore, PAM data is leveraged to compute Process Cycle Efficiency (PCE), also known as flow efficiency or value-add ratio, which quantifies the total value added in each process relative to the lead time. This comprehensive approach, underpinned by SVSM and PAM, enables organizations to systematically identify and address non-value-added processes, thereby fostering sustainable and lean practices within the supply chain.

The Sustainability Index (SI) measurement is determined using sustainability indicators, which are essential aspects in measuring and assessing sustainability and efforts to improve it. These indicators help identify the status of progress toward achieving targets and barriers. Three effective indicators for sustainability are economic development, environmental protection, and social welfare dimensions. The index is measured by collecting data on current sustainable performance with benchmarking target data in related industries (I. H. Garbie, 2016).

2. METHODS

The research process begins with observation at Company X and literature studies on sustainable supply chains, sustainability indicators, types of waste, and tools such as SVSM and PAM. Observation activities are carried out from the inbound material, production, and product staging processes before being distributed to customers. Data collection uses primary data and secondary data from the company. Data processing analyzes supply chain waste in inbound supplier, operation, and outbound distributor activities and calculates SI (for the process calculation see (E. Sari *et al.*, 2021) in the three processes).

Supply chain mapping with SVSM tool for current condition and improvement condition. Supply chain process flow mapping is carried out in an end-to-end process. The dashboard in SVSM is given a traffic light color, namely green, indicating that the indicator has reached the target; yellow, indicating that the indicator is below the target; red is still far from the target.

The results of the current SVSM are analyzed using PAM to classify activities according to the distribution of VA, NVA, and NNVA. SI calculations are determined based on benchmarking in related industries. Table 2 shows the selected indicators for SVSM and SI.

Table 2. Sustainability indicator for SVSM and SI

Category	Indicator	Reference	Remarks
Economic	Time (%)	(W. Megayanti *et al.,* 2018)	Identifying value-added time and non-value-added time
	Quality Material (%)	(W. Megayanti *et al.,* 2018)	Quality of production materials from suppliers
	Defective Product (%)	(I. A. Marie *et al.,* 2022)	Measuring defective products in the process
	Service Level Quantity (%)	(C. L. Gargalo *et al.,* 2021)	Indicators informing the order has been completely fulfilled in quantity.
Social	Employee Satisfaction (%)	(S. Hartini *et al.,* 2020)	Employee satisfaction level in the company
	Noise Level (dB)	(E. Sari *et al.*, 2021)	Noise level in the production process
	Employees Training (%)	(I. A. Marie *et al.,* 2020)	Training provided and implemented for workers
	Healthy Level (%)	(W. Megayanti *et al.,* 2018)	Total attendance of workers who fulfill production activities
	Labor Equity (%)	(C. L. Gargalo *et al.,* 2021)	Balance measurement based on workers' compensation
Environment	Energy Consumption (kWh)	(W. Megayanti *et al.,* 2018)	Identifying energy consumed in each process
	ISO14001 Compliance (%)	(I. H. Garbie, 2016)	Percentage following ISO:14001, to evaluate environmental certification
	Material Consumption (%)	(A. T. Mengistu *et al.,* 2021)	Effectiveness of materials used during the production process
	Recyclable Waste (%)	(I. H. Garbie, 2016)	Total percentage of recycled material usage

3. RESULT AND DISCUSSION

3.1. Current Condition Mapping and SI

The mapping process assesses the current conditions in the supply chain's inbound, operational, and outbound processes using SVSM and PAM to gain insights into the various supply chain stages. SVM for each process has a dashboard containing a sustainability matrix for each operation. Problems identified in the inbound process, namely waiting confirmation for materials, delay in material delivery and material defect that occurs during storage. In the inbound process (Figure 1), the value-added time (VAT) is 16 days with a lead time of 25.858 days. There is a dashboard of sustainability metrics in the inbound process and recyclable waste metrics that are in poor condition (marked in red) and require improvement in these metrics.

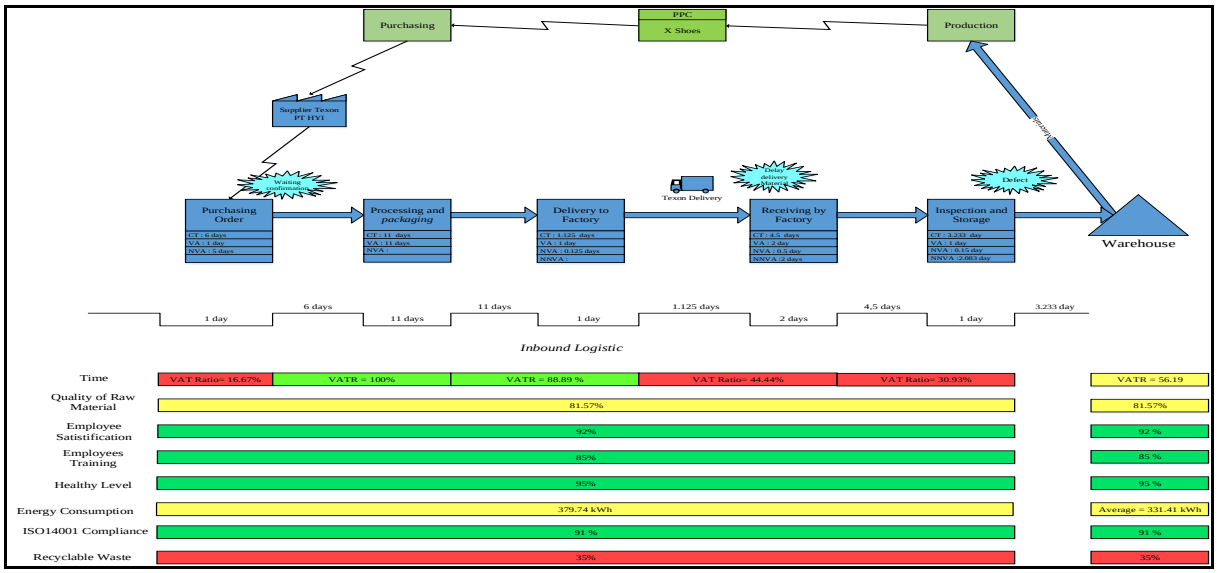

Figure 1. Current SVSM of X football shoes inbound supplier

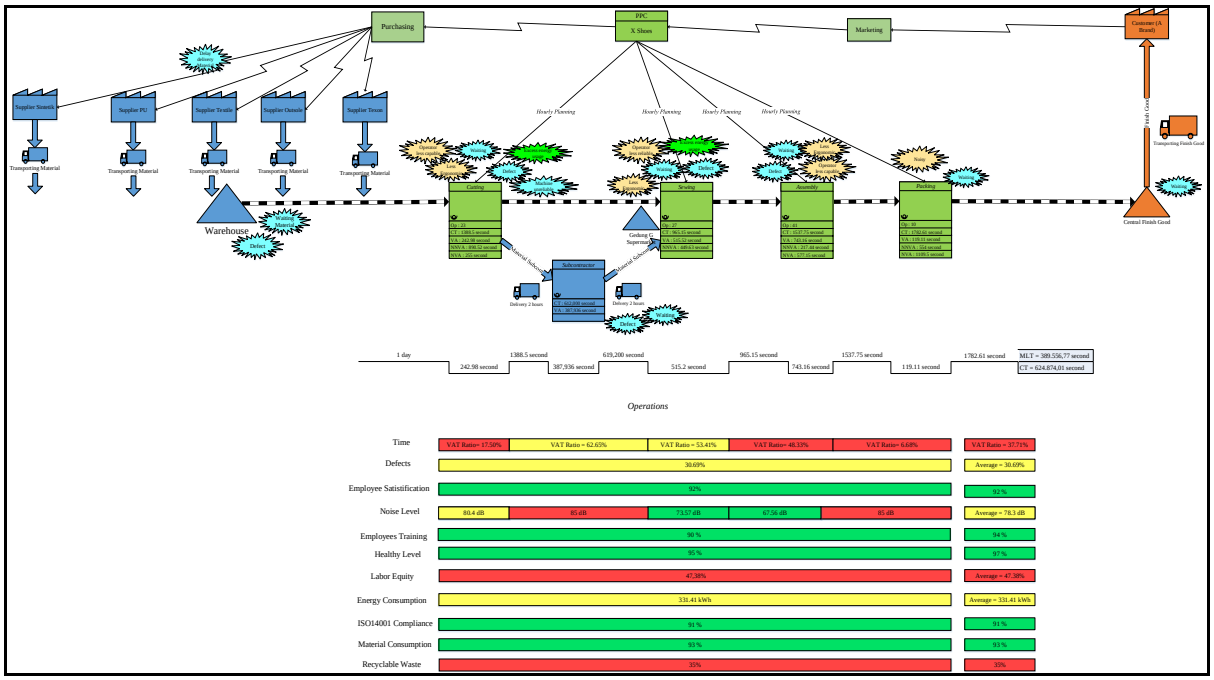

Figure 2. Current SVSM of X football shoes operation

The SVSM mapping of the operation process (Figure 2) with the results of the operation process VAT of 389,556.8 seconds and a manufacturing lead time of 624,874.01 seconds, which has a Process Cycle Efficiency (PCE) value of 63.34%. In mapping, there are still problems such as defects and waiting in the production process. The SVSM mapping for outbound activities (Figure 3) for delivery of finished products to customers has a VAT of 4 days with a lead time of 25,277 days. The problems during outbound activity such as defect, waiting for container availability and waiting during transport for shipment.

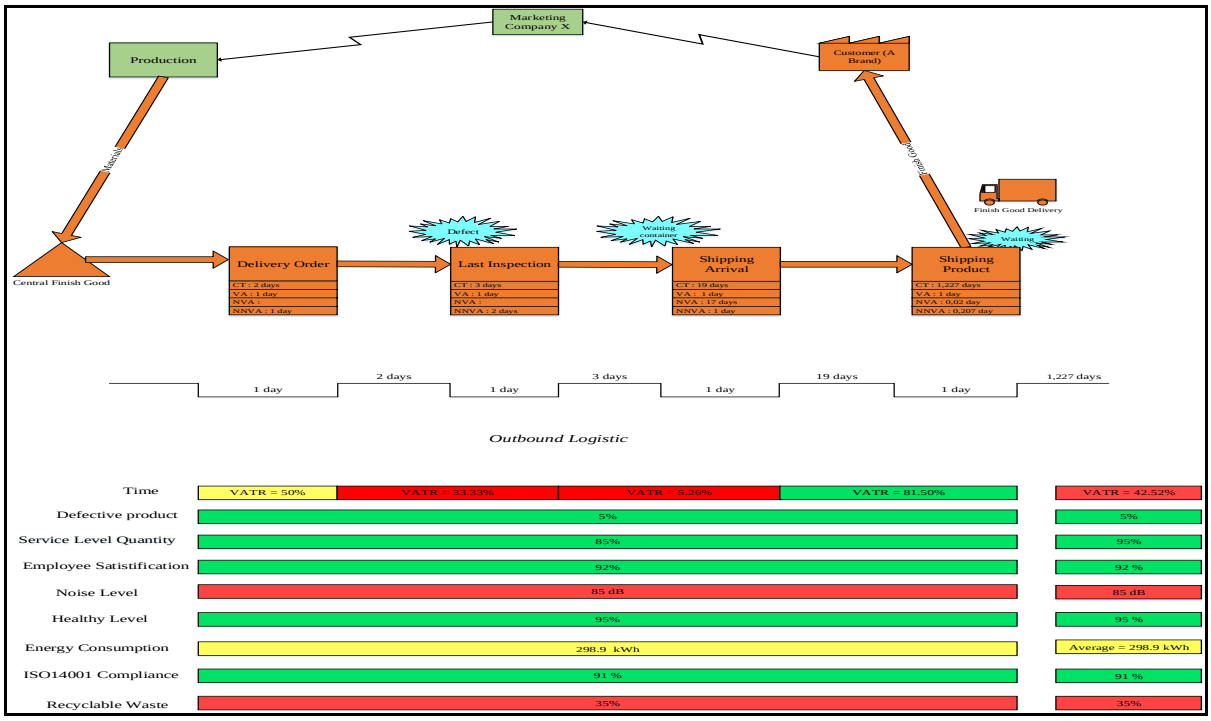

Figure 3. Current SVSM of X football shoes operation

Furthermore, calculating the total SI value for each activity is carried out by determining the weight of each pillar through a pairwise comparison matrix. The SI values indicate the level of sustainability performance, with the minor improvement effort identified in the operational process at 129.45%, followed by the inbound process at 143.32%, and the outbound process requiring the most significant improvement effort at 288.50%. The results suggest that the outbound process necessitates significant effort for improvement, as the deviation from the required percentage value is substantial. Notably, the outbound process must improve time management and minimal recycling practices. These findings provide valuable insights into the current state of the supply chain processes and highlight areas that require attention and improvement to enhance sustainability performance.

3.2. Future Condition Mapping and SI

Based on the proposed improvements on each pillar, the condition after improvement is predicted using future SVSM and SI prediction calculations. Proposed improvements in economic aspects such as 5S implementation and intensive operator training and better material handling. In social aspects make improvements to working conditions related to health and safety, work environment, and ergonomic workstation. In terms of environmental aspects, namely the 6R Strategy that implement circular economy method. This strategy has goals to decrease waste and increase recyclable waste that can be used for the production process. Another suggestion for improving the environmental aspect is energy saving, which proposes using LED, which is more efficient with estimated energy savings of 20–40%.

Future SVSM results for the operation process result in VAT of 389556.80 seconds with a decrease in MLT to 570736.29 seconds, and PCE increased by 68.26%. In the sustainability of the production process, there are improvements such as more efficient use of energy and improved working conditions, such as reducing noise levels and training to improve operator skills, reducing the occurrence of waste defects. In SVSM future outbound distribution, lead time will change to 16.503 days with a VAT of 4 days Compared to current conditions, there is

a change in the number of activities, a decrease in the amount of waste, and an increase in the percentage of value-added time. The percentage of value added (VA) in the process for inbound suppliers increased by 4.22% to 66.09%. The increase in distribution efficiency based on the value-added value increased to 24.24%.

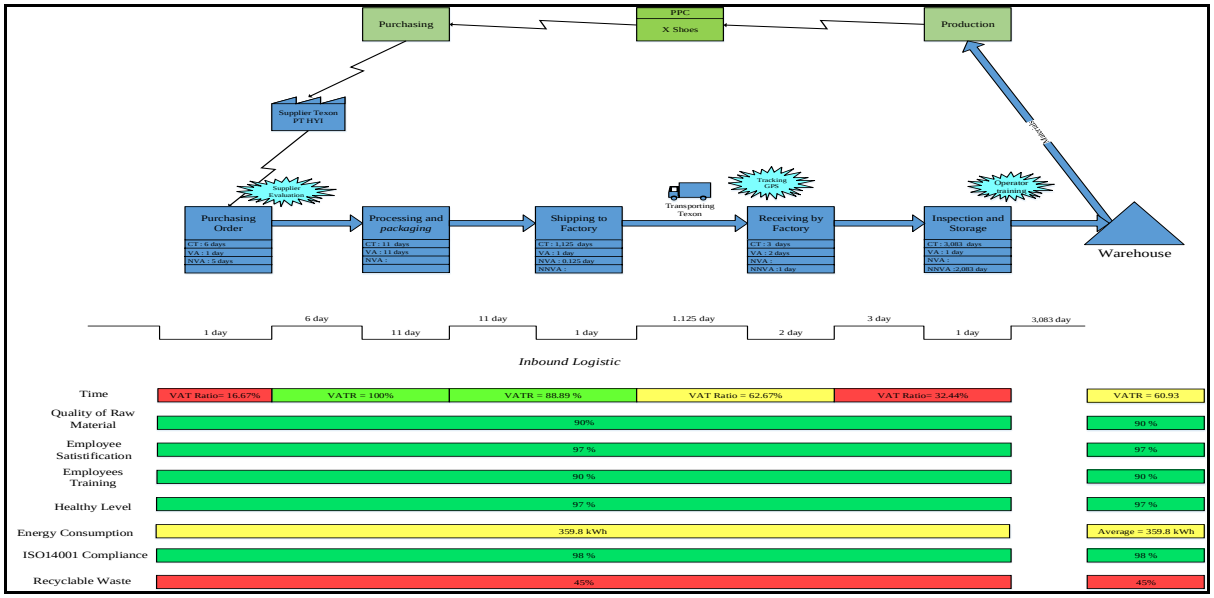

Figure 4. Future SVSM of X Football Shoes Inbound Supplier

Figure 4 is the Future-SVSM for the Inbound process. The recyclable waste indicator is still red because it is below the target but shows improvement from the previous 35% to 45% of recycled and processed waste for production support materials. In SVSM, the operation process consists of cutting, sewing, and assembly processes (Figure 5), showing increased process efficiency and improvements in several indicators. The outbound process (Figure 6) shows improvements in the sustainability pillar dashboard on defect reduction and energy use efficiency.

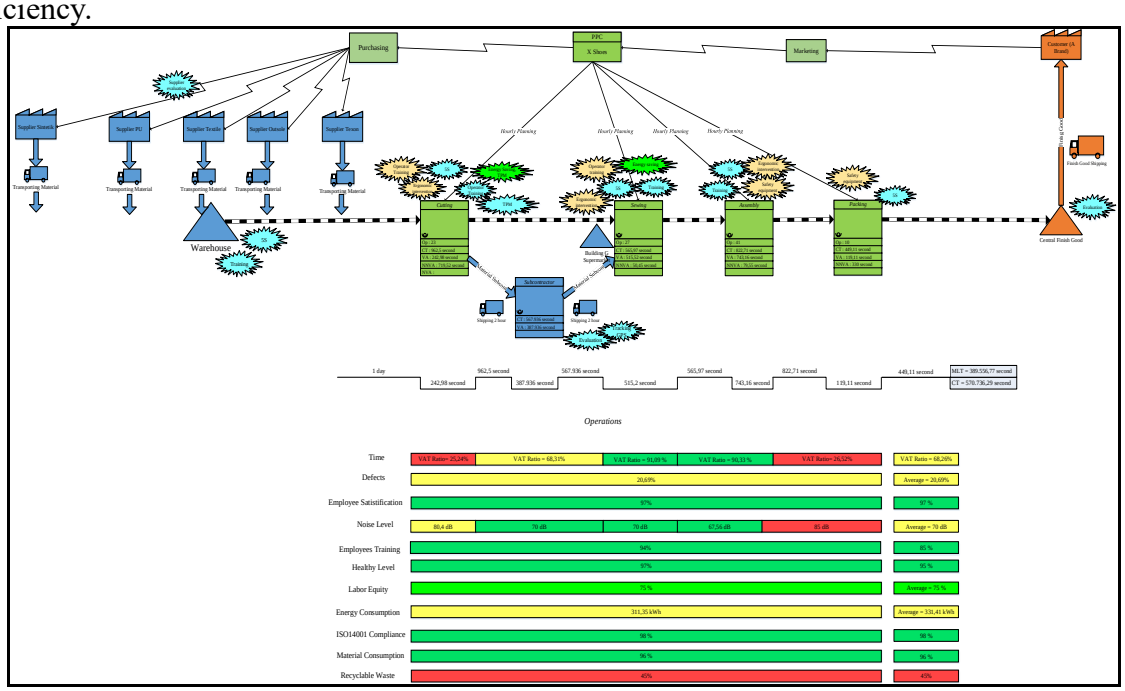

Figure 5. Future SVSM of X football shoes process operation

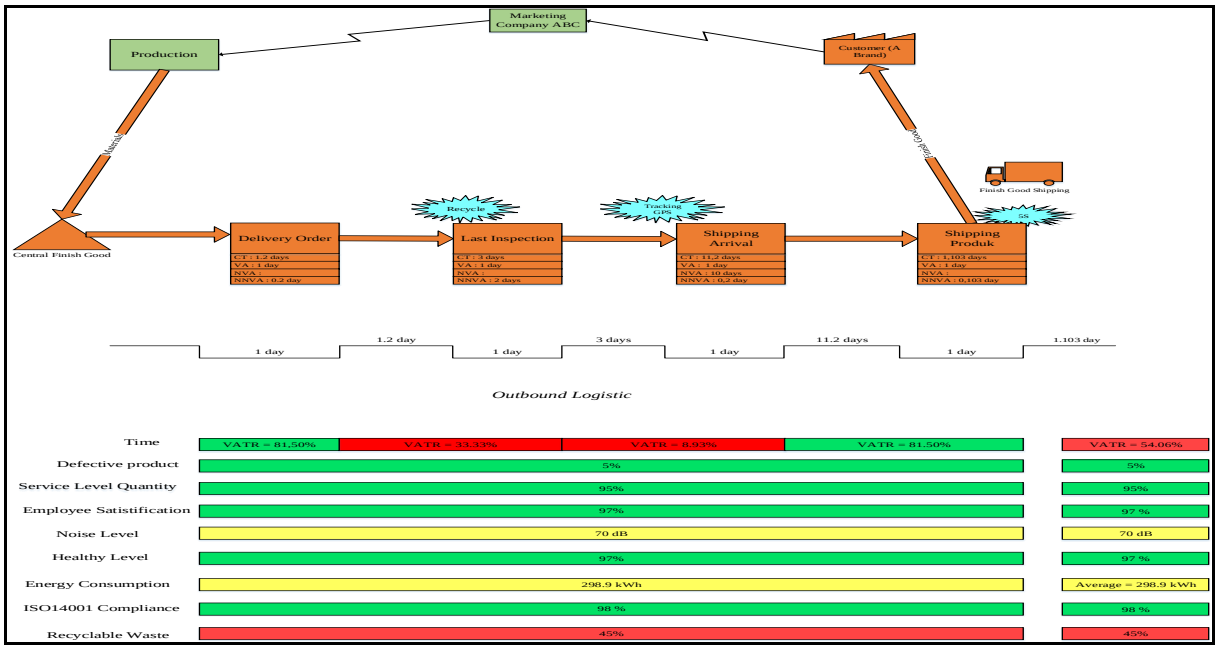

Figure 6. Future SVSM of X football shoes outbound distribution

The proposed improvements encompass various dimensions of sustainability, aiming to enhance the supply chain's economic, social, and environmental aspects. In the economic domain, implementing lean systems is suggested to eliminate NVA activities and reduce defects. Furthermore, the social dimension is targeted for improvement by making worker conditions more convenient. In the environmental sphere, proposed solutions include energy savings and using recycled materials for production. These initiatives aim to reduce environmental impact and promote sustainable resource utilization within the supply chain.

Table 3 compares the SI of inbound, operational, and outbound activities, demonstrating the potential for SI reduction through improvements. This comparison underscores the capacity for enhancements to improve sustainability conditions in the supply chain.

Table 3. Comparison of current and future SI

Aspects	SI Outbound		Difference	SI Operation		Difference	SI Inbound		Difference
	Before	After		Before	After		Before	After	
Economy	85.99%	66.69%	19.30%	31.56%	30.87%	0.69%	212.97%	129.75%	83.22%
Environment	37.96%	26.40%	11.56%	53.12%	35.71%	17.41%	62.43%	38.18%	24.25%
Social	19.37%	17.93%	1.44%	44.78%	19.43%	25.34%	13.16%	16.39%	3.23%
Total	143.32%	111.02%	32.30%	129.45%	86.01%	43.44%	288.56%	184.33%	104.23%

4. CONCLUSION

The estimated improvement in the supply chain process for operational activities is evidenced by the increase in PCE to 68.26% and the reduction in MLT to 570736.29 seconds, compared to the pre-improvement PCE of 62.34% and MLT of 624,874.01 seconds. This improvement is attributed to eliminating NVA and implementing proposals to enhance productivity. Before improvement, SI values indicate that the SI for inbound activities was 143.2%, the SI for the operational process was 129.45%, and the SI for outbound activities was 288.56%. After the implementation of improvements, the SI values for the inbound process decreased to 11.02%,

while the operational process exhibited an increase to 86.01%, and the outbound activities decreased to 184.33%. This reduction in SI values reflects the anticipated outcomes of the applied improvements, indicating the interventions' potential impact on the supply chain's sustainability performance. These findings provide valuable insights into the effectiveness of the proposed improvements in enhancing the sustainability performance of the shoe production supply chain at Company X.

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