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Sustainable Technology and Integrating Artificial Intelligence (AI)

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ANALYZING THE USE PICTURE DICTIONARY BASED ON DAILY LIFE CONTEXTS IN LEARNING ENGLISH VOCABULARY OF FIFTH GRADE STUDENTS AT SD NEGERI 005 PALEMBANG

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Abstrak

Vocabulary mastery is a fundamental component in English language learning, especially for elementary school students who require meaningful and engaging learning media. This study aims to analyze the use of a picture dictionary based on everyday contexts in English vocabulary learning among fifth-grade students at SD Negeri 005 Palembang. This study used a qualitative case study design. Participants consisted of 26 fifth-grade students and one English teacher. A comprehensive data collection approach was used, including classroom observations, questionnaires, interviews, and document analysis, with the aim of gaining a comprehensive understanding of the learning process. The results showed that the use of a picture dictionary had a significant impact on improving students' vocabulary learning, thereby increasing comprehension, motivation, and engagement in class. The majority of students showed positive responses and high levels of enthusiasm, as contextual images facilitated the association of new vocabulary with real-life situations. The integration of visual and contextual elements has been shown to reduce students' reliance on memorization and translation, thus making vocabulary learning more meaningful and enjoyable. The study concluded that picture dictionaries based on everyday life contexts are effective learning media to improve English vocabulary learning among elementary school students and are recommended for use in elementary school English classes.

Keywords *: Picture Dictionary; Vocabulary Learning; Daily-Life Contexts; Young Learners; Elementary School Students*

Introduction

English continues to play a central role in global communication, digital interaction, and educational development in the 21st century. In Indonesia, English is introduced from early grades to build learners' foundational language competence. Recent research highlights that vocabulary remains the key determinant of language proficiency, especially for young learners who are still developing cognitive, linguistic, and conceptual understanding (Nation, 2022). Without adequate vocabulary, students struggle to comprehend instructions, engage in communication, and process classroom materials effectively (Schmitt, 2022).

However, vocabulary learning in elementary schools often remains challenging because many teachers still rely on traditional methods such as memorization and translation, which are less engaging for children. Studies emphasize that young learners require visual, contextual, and meaningful materials that connect new words to real-life situations (Fitriani & Rahayu, 2023). One of the effective innovations for young learners

is the use of picture dictionaries, which integrate images and words to support memory, comprehension, and motivation.

Recent findings show that picture dictionaries enhance vocabulary mastery by helping students form strong visual associations, reducing cognitive load, and increasing interest during learning (Putra et al., 2023; Abdullah & Hassan, 2023). When picture dictionaries are developed based on daily-life contexts—such as home, school, or community—students are better able to connect new vocabulary with their real experiences, which strengthens understanding and long-term retention (Rahmawati & Ananda, 2024).

At SD Negeri 005 Palembang, many fifth-grade students still find difficulties in memorizing and using new English vocabulary. The use of a contextual picture dictionary is therefore expected to make learning more meaningful, enjoyable, and effective. This research aims to analyze how a picture dictionary based on daily-life contexts supports vocabulary

Development among fifth-grade students and to examine the learning process in real classroom settings.Therefore, this study aims to analyze the use of picture dictionaries based on daily life contexts in learning English vocabulary among fifth-grade students at SD Negeri 005 Palembang. The results are expected to contribute to developing more effective and enjoyable vocabulary learning strategies for young learners.

Literature Review

1. Definition of Vocabulary

Recent literature defines vocabulary as a collection of words and multiword units that learners must understand and use to communicate meaningfully. Schmitt (2022) explains that vocabulary knowledge involves more than word meaning—it includes form, pronunciation, spelling, grammar, and appropriate usage. Nation (2022) further states that vocabulary is the foundation of language competence because it supports comprehension and production across all language skills. Thus, vocabulary is a multidimensional component that enables learners to understand messages and express ideas effectively.

2. Types of Vocabulary

Vocabulary can be classified into several categories depending on the perspective:

a. Receptive and Productive Vocabulary
   - Receptive vocabulary refers to words learners understand when listening or reading.
   - Productive vocabulary refers to words learners can use in speaking or writing. (Nation, 2022)

b. Active and Passive Vocabulary
   - Active vocabulary consists of words used frequently and accurately.
   - Passive vocabulary consists of words understood but rarely produced in communication.(Fitriani & Rahayu, 2023)

c. Oral and Written Vocabulary
   - Oral vocabulary relates to words used in spoken interaction.
   - Written vocabulary is used in reading and writing tasks.(Rahmawati & Ananda, 2024)

These categories highlight the need for both recognition and production practice in vocabulary learning.

3. Function of Vocabulary

Recent studies emphasize several functions of vocabulary:

1. Supporting Comprehension, Vocabulary determines learners' ability to understand spoken and written texts (Nation, 2022).
2. Enhancing Communication, Learners with strong vocabulary express ideas more clearly and confidently (Schmitt, 2022).
3. Developing Literacy Skills, Vocabulary facilitates reading comprehension and writing fluency (Abdullah & Hassan, 2023).
4. Increasing Learning Motivation, Meaningful vocabulary activities with rich visual media improve motivation and participation (Fitriani & Rahayu, 2023).

4. Definition of Picture Dictionary

A picture dictionary is a learning resource that presents vocabulary items together with images to help learners understand word meaning easily. Recent research identifies picture dictionaries as effective tools that support visual learning, reduce cognitive effort, and make vocabulary more concrete for young learners (Putra et al., 2023). Digital versions of picture dictionaries may also include audio, animations, or interactive elements that enhance engagement and comprehension (Rahmawati & Ananda, 2024).

5. Types of Picture Dictionary

Recent sources classify picture dictionaries into:

1. Thematic Picture Dictionaries – Organizing vocabulary by themes such as food, school, and home (Putra et al., 2023).
2. Bilingual Picture Dictionaries – Presenting vocabulary in English and the learner's first language.
3. Digital Picture Dictionaries – Incorporating multimedia for interactive learning (Rahmawati & Ananda, 2024).
4. Contextual Picture Dictionaries – Presenting vocabulary based on real-life situations commonly experienced by children (Abdullah & Hassan, 2023).

6. Function of Picture Dictionary

Based on recent studies (2022–2024), picture dictionaries serve several key functions:

1. Strengthening Visual Memory, Pictures help learners create strong associations, improving long-term retention (Putra et al., 2023).
2. Improving Comprehension, Learners can understand word meanings without relying on translation (Rahmawati & Ananda, 2024).
3. Increasing Engagement, Visual materials make learning enjoyable and motivate young learners (Abdullah & Hassan, 2023).
4. Supporting Independent Learning, Students can explore and understand vocabulary autonomously by interpreting images.
5. Enhancing Contextual Understanding, When vocabulary is linked to daily-life contexts, learning becomes more meaningful and relevant (Fitriani & Rahayu, 2023).

Research Method

This study employed a qualitative research design, which is appropriate for exploring the use of a picture dictionary in improving English vocabulary among young learners. Creswell and Poth (2023) state that qualitative inquiry is appropriate when researchers seek to interpret participants' perspectives within their natural learning environment .A classroom case study design was used, following Yin's (2023) assertion that case studies are suitable for investigating complex educational phenomena where the boundaries between the phenomenon and the context are not clearly defined.The It allows the researcher to capture the students 'learning experiences, teachers' perceptions, and the effectiveness of the media in a natural classroom setting.

The study was conducted at SD Negeri 005 Palembang, specifically involving fifth- grade students as the primary participants. The selection of this school was based on its characteristics as a public elementary school where English is taught as a foreign language and students often experience difficulties in mastering vocabulary. Random sampling in which all students in the class were assigned numbers and selected randomly. Etikan (2023) highlights that **Random Sampling** in qualitative educational research can help minimize selection bias and provide a more balanced representation of participants, especially in small classroom populations. The participants included:

- Fifth-grade students (approximately 20–26 students), who served as the main subjects of observation and interviews.
- The English teacher, who provided insights into instructional practices, challenges, and perceptions of the picture dictionary.

Population

No	Class	Numbers Of Students
1	5a	28
2	5b	26
	Total	56

Source: SD Negeri 005 Palembang

Sample

No	Class	Numbers Of Students
1	5b	26
	Total	26

Source: SD Negeri 005 Palembang

To obtain comprehensive data, multiple techniques were employed: Classroom Observation – Non-participant observation was conducted to examine how the picture dictionary was implemented in vocabulary learning activities. The observations followed Merriam's (2023) guidelines, emphasizing the importance of recording classroom interactions, student engagement, and teacher strategies to capture the natural flow of learning.

Semi-structured interviews were conducted with 8–10 students and the English teacher because, as Kvale (2023) argues, this interview format provides flexibility and allows deeper probing into participants' experiences while maintaining consistency across interviews. Questioner – Supporting documents such as lesson plans, students' worksheets, and picture dictionary materials were analyzed to cross-check data from observation and interviews. Using triangulation of document analysis strengthens data in qualitative studies Bowen's (2023)

Results and Discussion

The present study was based on research conducted on 26 questionnaire respondents. The respondents expressed a high level of enthusiasm and eagerness to learn English using the picture dictionary method, which was found to facilitate the learning process.

Tabel 1

Category	Respondent	Percentage
Often	24	80%
Always	2	20%
Sometimes	0	0
Never	0	0
Total	26	100%

Source: SD Negeri 005 Palembang

As shown in the table above, 24 respondent with presentage 80% answered "often", 2 respondent with presentage 20% answered "always", and none respondent answered "sometimes" or "never". Therefore, based on this information, it can be concluded that students find it very helpful to learn vocabulary using picture dictionaries.

Based on the above description, using picture dictionaries to learn English is a very good way to get students excited and motivated to learn. Students are very happy, focused and enthusiastic about learning in class.

Conclusions

Using a picture dictionary based on everyday contexts positively impacts students' vocabulary learning. It enhances their understanding, motivation, and participation by linking new words to real-life situations. The integration of visuals makes learning more meaningful and enjoyable, while reducing dependence on memorisation and translation. Overall, this method effectively improves vocabulary mastery among fifth-grade students at SD Negeri 005 Palembang and is recommended for continued use in English language teaching for young learners.

Additionally, the findings indicate that picture dictionaries promote a more interactive classroom environment, where students feel more confident exploring new vocabulary independently. This media supports differentiated learning, allowing students with varying learning styles—especially visual learners—to benefit equally. Therefore, picture dictionaries can serve as a practical and sustainable tool for improving vocabulary instruction in primary schools.

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THE ANALYZING OF INTERACTIVE MEDIA TO ENHANCE GRAMMAR LEARNING IN FOURTH GRADE STUDENTS AT SD NEGERI 005 PALEMBANG

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Abstract

Grammar is a fundamental element in English language learning, especially for elementary school students, as it supports the formation of clear and meaningful sentences. However, grammar learning is often considered difficult due to traditional teaching methods that rely heavily on memorization and rule-based instruction. This study aims to analyze the use of interactive media in enhancing grammar learning among fourth-grade students at SD Negeri 005 Palembang. The research employed a qualitative descriptive method using a questionnaire to gather students' perceptions of learning grammar through interactive media. The participants consisted of 27 fourth-grade students selected through random sampling. The data were analyzed descriptively to identify patterns of students' engagement and learning frequency. The results showed that 60% of students reported using interactive media often, while 40% reported always using it, with no students selecting sometimes or never. These findings indicate a high level of consistency and positive acceptance of interactive media in grammar learning. In conclusion, interactive media plays a significant role in increasing students' engagement, motivation, and understanding of grammar, making it an effective tool for grammar instruction in elementary school settings.

Keywords: *Interactive media, grammar learning, fourth-grade students, English as a Foreign Language (EFL), elementary school*

Introduction

Grammar is a fundamental component of English language learning, serving as the foundation that enables learners to construct clear, meaningful, and accurate sentences. In Indonesian elementary schools, however, grammar is often perceived as a difficult subject because it is traditionally taught through rote memorization and rule-based instruction. According to Richards and Schmidt (2023), grammar instruction must be meaningful, contextualized, and integrated with interactive experiences to enhance young learners' understanding. Many fourth-grade students still struggle with basic grammar structures such as simple present tense, which often affects their ability to communicate effectively in English.

In the current educational context, especially with the implementation of the Merdeka Curriculum, teachers are encouraged to use more flexible, studenst-centered approaches that promote active engagement. Interactive media has emerged as an effective tool to support this shift. Mishra and Sharma (2022) emphasize that digital interactive media can significantly increase students' motivation, provide visual reinforcement, and simplify complex language concepts into enjoyable learning activities. For elementary students, interactive learning environments—with animations,

audio, quizzes, and touch-based navigation—make grammar more approachable and less intimidating.

Despite these potential benefits, the use of interactive media for grammar instruction in Indonesian primary schools remains limited. Many teachers still rely on textbooks and worksheets, which may not fully support students' diverse learning needs. This gap highlights the need for developing grammar-focused interactive media tailored to the cognitive level and learning style of young learners. Moreover, the urban school context of SD Negeri 005 Palembang presents an opportunity to integrate low-cost digital tools into classroom instruction, given the increasing availability of mobile devices and school technology facilities.

Therefore, the development of interactive media in this research is aimed at improving students' understanding of grammar through visually rich, user-friendly, and pedagogically structured digital content. The media is expected not only to support more effective grammar learning but also to enhance students' engagement, autonomy, and confidence in using English. This study explores how interactive media can transform grammar instruction, particularly for fourth-grade students, and examines students' perceptions through qualitative data obtained from questionnaires.

In addition, the rapid advancement of educational technology in recent years has created new opportunities for enhancing language learning through multimodal resources. Studies from 2024–2025 increasingly emphasize that interactive digital platforms can support deeper cognitive processing by combining visual, auditory, and kinesthetic elements in a single learning environment. For young learners, this multimodal exposure is crucial, as it allows them to internalize grammar patterns through repeated practice, immediate feedback, and context-driven tasks rather than passive instruction. Thus, integrating interactive media into grammar learning aligns with current educational demands and the developmental characteristics of elementary students.

Furthermore, the integration of interactive media in grammar learning supports differentiated instruction, allowing students with varying learning styles and proficiency levels to engage with the material at their own pace. Visual learners benefit from animations and illustrations, auditory learners gain support through sound and narration, while kinesthetic learners interact with touch-based activities. According to Widiastuti (2024), technology-enhanced grammar instruction enables teachers to tailor learning experiences, making it possible to address individual difficulties more effectively than traditional paper-based methods. This flexibility is particularly important for fourth-grade students who are still developing their cognitive and linguistic abilities.

Additionally, interactive media aligns with global trends in 21st-century education, where digital literacy and independent learning are essential competencies. Recent studies highlight that students exposed to technology-rich environments tend to display higher levels of engagement, curiosity, and motivation in language learning tasks (Nurhayati, 2024). When students actively participate through games, drag-and-drop tasks, or instant feedback quizzes, they develop not only grammatical competence but also digital problem-solving skills. Therefore, the development of interactive media in this study aims to foster a learning environment where grammar is not only understood intellectually but also practiced meaningfully through continuous interaction and exploration basid on the objavtim in sd negeri 010 palembang interview with inggris sech the referch will be condulted

Literature Review

1. Definition of Grammar

Grammar refers to the system of rules that governs how words are formed, arranged, and used to convey meaning in a language. According to Crystal (2023), grammar is "the structural framework that allows speakers to construct meaningful, coherent, and intelligible sentences." Grammar plays a central role in enabling learners to understand how linguistic elements interact within a sentence.

Similarly, Harmer (2022) explains that grammar is not merely a set of prescriptive rules but a meaningful system that helps learners express ideas accurately and appropriately in different contexts. Larsen-Freeman (2020) further emphasizes that grammar consists of three interconnected dimensions: form, meaning, and use, which must be understood together to achieve communicative competence.

Recent studies also highlight a more dynamic view of grammar. According to Sari and Putra (2023), grammar in modern pedagogy is seen as a flexible cognitive tool rather than a fixed structure, allowing learners to build language awareness through meaningful input, interaction, and feedback. Thus, grammar is essential not only for accuracy but also for fluency and effective language development.

2 Types of Grammar

Several types of grammar are relevant in language learning, particularly in the context of English instruction for young learners:

1. Descriptive Grammar, Descriptive grammar refers to the way language is actually used by speakers. It describes natural language patterns without judging correctness. Crystal (2023) notes that descriptive grammar helps learners understand real-life usage and variations in language.
2. Prescriptive Grammar, Prescriptive grammar focuses on the "correct" or standard forms of language. According to Richards and Schmidt (2023), prescriptive grammar provides formal rules and conventions that guide proper language use in academic and formal settings.
3. Pedagogical Grammar, Pedagogical grammar is specifically designed for teaching and learning purposes. Harmer (2022) explains that this type of grammar simplifies rules, presents examples, and uses contextualized explanations to support learners' understanding. It is especially suitable for elementary students.
4. Functional Grammar, Functional grammar, introduced in modern ELT approaches, highlights how grammar works to express meaning and achieve communicative purposes.Mustafa and Arifin (2023) state that functional grammar helps students understand not only how sentences are formed but why certain forms are used in specific contexts.
5. Generative Grammar, Although more theoretical, generative grammar (Chomskyan perspective) describes the innate rules that allow humans to create infinite sentences. Recent educational interpretations (Nurhayati, 2024) argue that exposure to rich input helps children develop intuitive grammatical competence.

3 Functions of Grammar in Language Learning

Grammar plays several important functions in the process of language acquisition, especially for young learners:

1. Structural Function, Grammar provides the basic framework that arranges words into meaningful phrases, clauses, and sentences. As Larsen-Freeman (2020) notes, grammar is essential for constructing well-formed utterances that can be clearly understood by others.
2. Communicative Function, Grammar helps learners convey ideas accurately. According to Harmer (2022), mastering grammar allows students to communicate

with precision, avoid ambiguity, and express different time frames, intentions, and relationships between ideas.

3. Cognitive Function, Grammar supports the development of higher-order thinking skills. Sari and Putra (2023) argue that understanding grammar enhances learners' ability to categorize information, recognize patterns, and apply rules logically.

4. Meaning-Making Function, Modern grammar teaching views grammar as a tool for constructing meaning. Richards and Schmidt (2023) emphasize that grammar enables learners to choose appropriate structures based on context and communicative purpose.

5. Learning-Awareness Function, Grammar provides learners with metalinguistic awareness. Recent research (Widiastuti, 2024) shows that when students learn grammar consciously through interactive media, they become more aware of language patterns, which improves accuracy and fluency over time.

Methodology

This research employed a qualitative descriptive method with a questionnaire-based approach. The purpose was to obtain in-depth information about students' and teachers' perceptions of using interactive media in grammar learning. The participants were 55 of fard greadl elementry school SD Negeri 005 Palembang 2025/2026 academic year. The participants were selected using Random sampling,

Population

No	Class	Numbers Of Students
1	IVa	28
2	IVb	27
Total		55

Source: SD Negeri 005 Palembang

Sample

No	Class	Numbers Of Students
1	IVa	28
Total		28

Source: SD Negeri 005 Palembang

The data collection technique was a questionnaire consisting of open-ended and closed-ended questions. The questionnaire explored students' experiences, motivation, and challenges in learning grammar through interactive media. Responses from the questionnaire were categorized and interpreted thematically to identify patterns related to the effectiveness, usability, and engagement aspects of the developed interactive media

Result and Discussion

The present study was based on research conducted on 27 questionnaire respondents. The respondents expressed a high level of enthusiasm and eagerness to learn English using the picture dictionary method, which was found to facilitate the learning process.

Tabel 1

Category	**Respondent**	**Percentage**
Often	23	60%

Always	4	40%
Sometimes	0	0
Never	0	0
Total	**27**	**100%**

Source: SD Negeri 005 Palembang

Based on the data above, out of a total of 27 respondents, the majority reported **often**, with 23 respondents or **60%**. Meanwhile, 4 respondents or **40%** reported **always**. There were no respondents who selected **sometimes** or **never**, each accounting for **0%**. This indicates that all respondents fall into high-frequency categories, namely often and always, with no respondents reporting low frequency.

The data indicate a very strong tendency toward frequent and consistent behavior among respondents, as 100% of them fall into the categories of *often* and *always*. This suggests that the activity being measured is well established and regularly practiced by all respondents.

Conclusion

The findings from the table demonstrate that students show a very high level of consistency in engaging with the activity being measured. All 27 respondents fall into the categories of *often* (60%) and *always* (40%), with no responses in the *sometimes* or *never* categories. This indicates that the use of interactive media in grammar learning is not occasional but regularly experienced by the students, reflecting strong acceptance and frequent implementation in the learning process.

Furthermore, the absence of low-frequency responses suggests that interactive media has become an integral part of grammar instruction for the respondents. This consistent exposure likely contributes positively to students' motivation, engagement, and understanding of grammar concepts. Overall, the data support the conclusion that interactive media is effectively integrated into grammar learning and plays a significant role in enhancing students' learning experiences.

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EXPLORING CAKE APP FOR LISTENING SKILLS: A CASE STUDY IN THE ELEMENTARY LEVEL OF ENGLISH COURSE

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Abstract

The use of technology as a learning tool is essential in the digital age. Incorporating the Cake mobile application as an innovative learning medium can enhance students' listening abilities in elementary-level English courses. Listening is one of the fundamental skills required for learning English, as it supports the development of other language skills. This study aimed to investigate students' perceptions and experiences of using the Cake application as a supporting tool for listening learning. A descriptive quantitative approach was employed, with data collected through a closed-ended questionnaire using a Likert scale. The research design involved a survey of 16 students enrolled in an elementary-level English course. The findings reveal that students hold positive perceptions of the Cake application as a tool for supporting listening learning. The participants reported increased motivation to practice listening and recognized that regular use of the application consistently improves their listening skills. Moreover, all students agreed that the application is user-friendly and practical, indicating that its simplicity and accessibility are well-suited to elementary-level learners.

Keywords*: Cake Application, Listening skills, Elementary-level*

1. INTRODUCTION

English is an essential skill for both academic and professional advancement. Ilyosovna (2020) states that English is one of the most widely used languages in the world. Similarly, Clement and Murugavel (2018) emphasize that English proficiency has become increasingly necessary in both native and non-native English-speaking countries. A global survey on workplace language proficiency reveals that more than 95% of employers in many non-English-speaking countries highly value English language skills. Therefore, strong English proficiency should be a top priority for students, as it contributes significantly to academic success, personal development, and competitiveness in the global workforce. Thus, mastery of English is no longer optional but a fundamental requirement in today's globalized academic and professional environments.

In Indonesia, English is a priority language within the education system. Putri and Siregar (2024) note that English is an essential subject in the national curriculum. English language instruction is provided across educational levels, from elementary school to

university. Previous studies indicate that English learning is regarded as a crucial aspect of students' skill development and has been implemented consistently at elementary, junior high, and senior high school levels (Salim & Hanif, 2021; Aditama et al., 2022; Muslim et al., 2020). This widespread implementation reflects the growing recognition of English as a vital competency for academic achievement and global communication. Therefore, the Indonesian education system places English learning as a strategic foundation for students' future success.

Listening is a fundamental skill in language education, playing a crucial role in second language acquisition. According to Rost (2024), listening involves a complex cognitive process encompassing the perception, processing, and interpretation of spoken language. In the context of second language learning, listening comprehension provides essential input that supports the development of other language skills, including speaking, reading, and writing. Moreover, listening accounts for approximately 40–50% of daily communication, making it a core skill that must be developed to effectively acquire information in a new language (Sartika, 2017). Therefore, listening serves as a foundational component of overall language proficiency and warrants focused attention in language instruction.

Despite the importance of listening in language learning, many students continue to struggle with developing listening comprehension skills. Sartika (2017) identifies several common problems, including rapid speech delivery, limited opportunities for repetition, insufficient vocabulary, difficulty interpreting speakers' pronunciation and speech patterns, challenges in understanding the overall content, and the tendency to focus on understanding every individual word. These difficulties are further compounded by learners' limited attention spans and low motivation. Similarly, previous studies report that listening development is hindered by factors such as speech rate, restricted vocabulary knowledge, and cultural differences, particularly among EFL learners (Chen, 2019; Jiang & Dewaele, 2019). Additionally, Yip and Fisher (2022) note that sustained listening demands can cause listener fatigue, which negatively impacts comprehension. Collectively, these challenges underscore the need for effective instructional strategies and technological support to address learners' diverse listening needs and enhance their listening proficiency.

Technology plays a crucial role in enhancing human capabilities by developing and applying tools and processes. In education, technology contributes to improved learning outcomes, the development of essential skills, and preparation for participation in a digital society (Kalyani, 2024). Mobile applications have gained popularity due to their accessibility and interactive features. Ratheeswari (2018) explains that integrating technology into classroom instruction supports the development of 21st-century skills. Therefore, the integration of educational technology is a promising solution for enhancing students' learning experiences and skill development.

One technological tool that has gained attention in English language learning is the Cake application. According to Yanthi (2020), Cake is a popular Android-based mobile application developed in South Korea. Unlike many language-learning applications, Cake enables users to practice English using authentic content, rather than relying solely on translations into their native language (Nushi & Eqbali, 2017). Fitri et al. (2021) state that Cake is a free application released by Cake Corp in 2018, offering practice in listening, speaking, and vocabulary through real-life conversational materials. These features make learning more practical and engaging for students (Kristanti et al., 2024). Hence, the Cake

application provides an innovative and accessible platform for improving English listening skills.

Several studies have examined the use of the Cake application in English learning contexts (Putri et al., 2023; Sugandi & Syafiq, 2023; Octavianita et al., 2022). Research findings indicate that the Cake application effectively improves students' English listening skills, particularly among secondary school students in Indonesia (Putri & Siregar, 2024; Juliana, 2024). Furthermore, Hardiyanti (2023) suggests that the Cake app is a practical and highly recommended learning tool for enhancing listening comprehension. Overall, previous research has demonstrated that the Cake application has a positive impact on students' listening abilities and encourages independent English learning. Therefore, this study aims to explore students' perceptions and experiences in using the Cake application as a listening learning support tool.

2. METHOD

This study employed a descriptive quantitative research approach. Data were collected using a questionnaire adapted from Putri and Siregar (2024). The questionnaire employed a Likert scale comprising several statements related to students' motivation, enjoyment, and learning experiences with the Cake application for listening practice. The response options ranged from "strongly agree" to "disagree," enabling the researcher to identify students' levels of agreement with each statement. All responses were systematically organized and analyzed to obtain an overall picture of students' perceptions of the Cake application in supporting listening learning. The samples were asked to complete the questionnaire after using the Cake application, ensuring that their responses reflected their actual learning experiences.

The sample of this study consisted of 16 students enrolled in an elementary-level English course at an institution designed to develop learners' basic English language skills. All participants had used the Cake application as part of their English learning activities before completing the questionnaire. Moreover, the students had attended the course for a sufficient period, allowing them to provide meaningful and reflective responses regarding their experiences with the Cake application. Consequently, the selected sample was deemed suitable for examining students' perceptions of using the Cake application in listening learning.

3. RESULTS AND DISCUSSION

This section presents and discusses the study's findings, based on the data collected from the questionnaire. The analysis focuses on students' perceptions and experiences regarding the use of the CAKE application as a supporting tool for learning English listening skills. The results are presented descriptively to illustrate how students respond to the use of the application in their learning process.

The findings indicate that the CAKE application is one of the online learning applications accessed via smartphones that students consider very useful for supporting and enhancing their English listening skills (Table 1). Specifically, the results show that students perceive the CAKE application as an effective and practical learning tool that assists them in improving their listening comprehension.

Table 1. Result of the Questionnaires

No	Statements	SA	A	N	SD	D

1.	After using the CAKE app, I feel more confident in understanding spoken English.	9 (56%)	6 (38%)	1 (6%)	0 (0%)	0 (0%)
2.	The CAKE application helps me to focus and improve my listening skills.	8 (50%)	7 (44%)	1 (6%)	0 (0%)	0 (0%)
3.	I feel more motivated to learn English listening after using the CAKE application.	8 (50%)	7 (44%)	1 (6%)	0 (0%)	0 (0%)
4.	The CAKE app has a variety of materials that help improve my listening skills.	9 (56%)	7 (44%)	0 (0%)	0 (0%)	0 (0%)
5.	I felt a significant improvement in my listening ability after using the CAKE app.	9 (56%)	5 (31%)	1 (6%)	0 (0%)	1 (7%)
6.	The CAKE application is an English learning application that is easy to use and effective for me to improve my English skills, especially listening skills.	10 (62%)	6 (38%)	0 (0%)	0 (0%)	0 (0%)
7.	Regular use of the CAKE app helps me to develop my listening skills consistently.	7 (44%)	7 (44%)	2 (12%)	0 (0%)	0 (0%)
8.	I found using the CAKE app effective in helping me understand accents and variations in the English language.	8 (50%)	7 (44%)	1 (6%)	0 (0%)	0 (0%)
9.	I would recommend the CAKE app to my friends as an aid in improving English listening skills.	7 (44%)	7 (44%)	2 (12%)	0 (0%)	0 (0%)

The results of the questionnaire showed that most students had a positive view of the Cake application's ability to improve their listening skills. "After using the Cake application, I feel more confident in understanding spoken English" was the first statement that 94% of students agreed with, with 56% strongly agreeing and 38% agreeing. This showed that the Cake app's audio-visual exposure to native speakers helps students learn pronunciation, intonation, and speaking speed more organically. This outcome, supported by Rost (2024), suggests that repeated exposure to relevant, real-world input facilitates the optimal development of listening skills. Additionally, students are more engaged in learning spoken English using the Cake app (Syafi'i, 2024).

"The Cake application helps me to focus and improve my listening skills" was the second assertion. Based on the questionnaire results, 94% of students agreed with this statement, with 50% strongly agreeing and 44% agreeing. The short video format and interactive listening activities in the cake application feature likely help students stay focused while practicing listening. This aligns with Juliana (2024), who states that most students perceive Cake to be a tool that supports concentration and the development of listening skills. Moreover, this is still related to the statement, "I felt a significant improvement in my listening ability after using the Cake app." The fifth statement showed

that 56% of students strongly agree and 31% agree, indicating that 87% of students feel a significant improvement in their listening skills, while 7% feel less agreeable. This suggests that most students agreed that using the Cake application could improve their English listening skills (Putri & Siregar, 2024).

In response to the third statement, "I feel more motivated to learn English listening after using the Cake application," 50% strongly agreed, and 44% agreed, resulting in 94% of students feeling more inspired to learn English listening. The questionnaire findings suggest a very positive outcome. This aligns with Losi (2022), who states that the Cake app boosts the motivation, interest, vocabulary, and listening skills of EFL students. Furthermore, the Cake application successfully boosts students' motivation to learn English and enhances the overall language learning experience in the classroom (Kristanti et al., 2024).

Regarding the fourth statement, "the Cake app has a variety of materials that help improve my listening skills", 56% of students strongly agreed, and 44% agreed that the materials provided by the Cake app helped improve their listening abilities. Additionally, the sixth statement, "The Cake application is an English learning application that is easy to use and effective for me to improve my English skills, especially listening skills," received a response from 62% of students who strongly agreed, and 38% who agreed, indicating that 100% of students responded positively. This aligns with the view of Chotimah and Pratiwi (2022), who note that the Cake app is a free application with a simple interface that allows students to learn anytime, anywhere, and offers various features, making it ideal for beginner-level learners. Moreover, the Cake app has various interesting features that allow learners to experience different listening contexts (Juliana, 2024).

The consistency in the development of listening skills is also apparent in the seventh statement, "Regular use of the Cake app helps me to develop my listening skills consistently". A total of 44% of students strongly agreed, and 44% agreed, indicating that 88% of students recognize that using the Cake app regularly helps them continuously improve their listening skills. Regular exposure to spoken English strengthens students' understanding of vocabulary and sentence structure. Putri and Siregar (2024) reported that regular use of the Cake app can improve students' overall understanding of English, including their listening skills.

"I found using the Cake app effective in helping me understand accents and variations in the English language". The eighth statement showed that approximately 94% of students feel a positive impact from using the Cake application. Features such as subtitles, audio repetition, and short videos enable students to understand the material in a step-by-step manner. The features of the Cake app are invaluable for language learners, offering exposure to diverse linguistic nuances that enrich their language acquisition experience (Juliana, 2024). Furthermore, the Cake app offers students numerous opportunities for use, is ad-free, features a diverse range of options, and includes a variety of videos (Kristanti et al., 2024).

Furthermore, the last statement, "I would recommend the Cake app to my friends," received 88% approval (44% strongly agreed and 44% agreed). This demonstrates that the Cake app not only improves listening abilities but also provides an enjoyable and compelling learning experience. To support this, Juliana (2024) states that the Cake app improves listening skills while providing a user-friendly and interactive experience. Thus, the Cake app's interactive elements and possibilities for app collaboration inspire students

to explore the content more deeply, making learning more enjoyable (Tawali & Kamarudin, 2022).

Furthermore, this study demonstrates that participants perceive the Cake app as a valuable tool for developing listening skills. The high level of agreement in the questionnaire results shows that students experienced increased confidence, motivation, and consistency in listening practice. This means the Cake app effectively supports listening learning by providing easily accessible and engaging listening input. In terms of learning impact, the Cake app can serve as an effective supplementary tool in listening learning. Ease of use and engaging content support self-directed learning, encouraging students to practice listening more consistently, especially at the elementary level of English courses.

4. CONCLUSION

This study concludes that elementary-level English course students positively perceive the Cake application as an effective supporting tool for learning listening skills. The findings indicate that most students experienced increased confidence in understanding spoken English after using the application, as reflected in their agreement that Cake helps them maintain focus, recognize various English accents, and develop listening comprehension through repeated exposure to authentic audio-visual materials. Additionally, the results show that the application enhances students' learning motivation and sustained engagement, encouraging regular listening practice and supporting consistent skill development. All participants also perceived the Cake application as easy to use and accessible, suggesting that its user-friendly design is appropriate for elementary-level learners. However, this study is limited by its small sample size and reliance on self-reported questionnaire data, which may not fully capture actual improvements in listening performance. Therefore, future research is recommended to involve larger and more diverse samples, incorporate experimental or mixed-method designs, and include objective measures such as listening tests or classroom observations to provide a more comprehensive evaluation of the effectiveness of the Cake application in improving students' listening skills.

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THE EFFECTIVENESS OF TOTAL PHYSICAL RESPONSE (TPR) TO IMPROVE VOCABULARY MASTERY: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

This article aims to conduct a systematic review of using Total Phsyical Response (TPR) to improve vocabulary mastery. The search strategy is based on the following keywords: "Total Phsyical Response (TPR)"," vocabulary mastery " from Google Scholar. Based on the results of this article, only 5 articles analysis became. One of strategy to improve vocabulary is Total Phsyical Response (TPR) because this strategy can make the students improve their vocabulary mastery. Vocabulary is a fundamental component of language proficiency, yet many learners experience difficulties due to limited exposure and monotonous teaching strategies. Total Phsyical Response (TPR) has a positive impact on learners' vocabulary mastery, retention, motivation, and classroom engagement. Moreover, Total Phsyical Response (TPR) helps reduce learners' anxiety and encourages active participation through kinesthetic learning. In line with Noviandari & Rustipa, (2023) said that The Total physical response method helps foster a calm learning atmosphere where students can enjoy learning and advance their foreign language communication skills.

Keywords : *Total Phsyical Response (TPR) and Vocabulary Mastery*

INTRODUCTION

Vocabulary is the basic level in learning a foreign language . Vocabulary is one of the most essential elements in learning a foreign or second language. Without sufficient vocabulary knowledge, learners may face difficulties in understanding texts, expressing ideas, and participating in communicative activities. Learning vocabulary is more important than grammar in leaning a foreign language, it related with Wilkins (1972, p. 111) said that "While without grammar little can be conveyed, without vocabulary nothing can be conveyed". Vocabulary is the first thing of learning a foreign language because students need to know the meaning, when and how the vocabulary is used in utterances.

Wardani (2015) said that vocabulary is an important aspect in language because it appears in every skill including language skills namely listening, speaking, reading, and writing. In line with Musdalifah (2021) Vocabulary is essential to language learning and teaching because it allows us to effectively and efficiently express our thoughts, feelings, and desires. In addition Graves (2018) identified four elements of an effective vocabulary program namely:

1. Consistently read widely or in-depth on your own to increase your vocabulary.

2. Teaching certain terms to improve understanding of writings that use phrases.
3. Providing teaching in independent word-learning techniques.
4. Word awareness and word-play activities to encourage and increase learning.

English teachers must identify appropriate teaching strategies to make young students enjoy fantasy, and the best approach for learning mobility and creativity is movement (Deni & Fahriany, 2020; Orosz, 2017). The TPR method (total physical response) was designed as a language learning strategy based on the coordination of orders, speech, and action; it aims to teach language through physical activity (motor) (Hanim et al., 2013; Sofialina & Hanifah, 2020).

TPR is a method that incorporates movement and gestures into the learning process (Rusiana & Nuraeningsih, 2016). A physical activity involving movement can boost students' desire for learning while enhancing their memory (Mohammadian et al., 2016). Furthermore, help the students learn vocabulary more quickly and easily (Sariyati, 2013).

THE CONCEPT OF TOTAL PHYSICAL RESPONSE (TPR)

TPR involves having students listen to a command in a foreign language and immediately responding with the appropriate physical action (Asher, 1964). TPR is one of the English teaching approaches and methods developed by Dr. James J Asher. It has been applied for almost thirty years. This method attempts to center attention to encouraging learners to listen and respond to the spoken target language commands of their teachers. In other words, TPR is a language teaching approach that emphasizes the integration of spoken language with physical movement, aiming to facilitate learning through motor activities. Asher's Total Physical Response is a "natural method" since Asher views first and second language learning as parallel processes. He argues that second language teaching and learning should reflect the naturalistic processes of first language learning.

(Rokhayani, 2017) state that the advantages of using Total Physical Response in English teaching and learning activities:
(1) is fun, so many children enjoy participating this type of teaching and learning process,
(2) can help the students remember English words and expressions,
(3) can be applied in large and small class,
(4) is not only appropriate for young learners but also adult learners,
(5) is suitable for active students in class

THE CONCEPT OF VOCABULARY MASTERY

Vocabulary has long been a core element of the English as a foreign language curriculum and plays a crucial role in all four language skills. Given its importance, vocabulary should be taught as effectively as possible in teaching English. In line with Richards and Reynanda (2020:255) argue that vocabulary is a core part of language, which provides the basic concepts to know how students can speak, write, listen, and read . in addition Suwandi (1990): "Vocabulary is the mastery of words or the richness of words."

Brown (2020:40) explains several simple communicative ways to teach vocabulary. First, teachers should choose the right time so the learning situation is comfortable. Second, teachers should use a monolingual dictionary, which means using only English. Third, teachers play an essential role in guiding and assisting learners in developing strategies for guessing word meanings. Finally, vocabulary learning can happen naturally without careful planning.

METHOD

Description of the sample

This study adopts a literature review methodology to investigate the effectiveness of Total Phsyical Response (TPR) to improve vocabulary mastery. (Pandey, 2024) state that a literature review is a systematic process that identifies, summarizes, and synthesizes existing knowledge relevant to a specific researh question, serving as a foundational element in the research process. In the search strategy, this article used a set of keywords selected by the authors according to the title theme of the systematic literature. The keywords searched include**:** Total Phsyical Response (TPR) and Vocabulary Mastery.The search was conducted in several journal databases from Google. There are some criteria to be part of this article.

Procedure

The researcher list of keywords to conduct a preliminary search.

Article selection criteria

This article examines recent research according to the following inclusion criteria:

a) Articles focus on Total Phsyical Response (TPR) and Vocabulary Mastery.
b) Articles published from Google Scholar,
c) Last 5 years, i.e. articles published from 2020 to 2024,
d) Articles provide clear explanation of strategies, method and discussion used by teachers.

While for exclusion criteria are :

a) Articles not focused on Total Phsyical Response (TPR) and Vocabulary Mastery
b) Lack of empirical or theoretical basis
c) Articles published before 2020
d) Articles in non English languages.

FINDINGS AND DISCUSSION

The purpose of this article is to summarize previous study on using Total Phsyical Response (TPR) and Vocabulary Mastery. This Article uses 5 studies on using Total Phsyical Response (TPR) to improve Vocabulary Mastery published from 2020 to 2024 over the past 5 years. I

nformation on article characteristics, research design, and related key findings are presented in Table 1. Summary and Characteristics of the Selected Final Article. In 5 studies reviewed, all studies found that using Total Phsyical Response (TPR) has proven to be able to improve Vocabulary Mastery. In addition The Total Phsyical Response (TPR) is strategy that can be used easily by the teacher in teaching and learning process. It is a simple strategy that can adapt or be adapted in many different functions and activities.

Table 1 : Summary and Characteristics of the Selected Final Article

No	Authors	Sample	Research Design	Finding
1.	(Afrianti, Rustipa, 2023)	Fourth Grade at SDN 03 Karangayu, Semarang	Qualitative Researrch	Total Physical Response (TPR) can encourage and increase students' motivation to learn,

				as shown by the activeness of students when participating in class and maintaining easy students, as well as adding to students' vocabulary every day.
2.	(Salma, Wafa, 2024)	Seventh grade of MBS PP. Daruth Thalibin	Classroom action research (CAR)	TPR approach may help increase their vocabulary.
3.	(Nabila, 2022)	Fifth grade students of State Elementary School at Mendalanwangi 03	Pre-experimental quantitative research methods	TPR learning method is effective in students' vocabulary mastery. Students will be active and interested in improving vocabulary memorization, not only perform physical movements but also pronounce vocabulary.
4	(Febian, 2023)	Fifth grade of MI Muhammadiyah Larangan, Purbalingga	a quasi-experimental design and quantitative approach	Total Physical Responses Method can increase students' English vocabulary and also make students enthusiastic and interested in learning
5.	(Rahmatullah, Kone, Syarifuddin, 2023)	Tenth grade of SMA Negeri 12 Sinjai	Qualitative method	TPR helps students increase vocabulary and pronounce fluently.

Vocabulary is a fundamental component that students must acquire in order to develop proficiency in this language skill. Ur (1996) argues that vocabulary plays a vital role in language learning, alongside grammar and pronunciation. In line with Aris Yunisah (2007), who stated that vocabulary mastery is a measure of understanding of English vocabulary and students' fluency in exploring vocabulary both orally and in writing. Add by Richards and Reynanda (2020) argue that vocabulary is a core part of

language, which provides the basic concepts to know how students can speak, write, listen, and read.

There are five articles from Table 1 which explain the sample, research design, findings and strategy used by teachers to improve vocabulary mastery. The researchers propose the use of the Total Physical Responses supported by evidence from prior related research from (Afrianti, Rustipa, 2023), (Salma, Wafa, 2024), (Nabila, 2022), (Febian, 2023) and (Rahmatullah, Kone, Syarifuddin, 2023) demonstrated that Total Physical Response is effective in improving students' vocabulary mastery also make students enthusiastic and interested in learning.

Therefore, it can be concluded that over the past five years, similar strategies have continued to be used in the teaching and learning process. The evaluation results indicate that teachers apply various methods, strategies, and instructional programs to enhance students' vocabulary mastery.

The TPR believes it is crucial for students to enjoy their experience when learning to communicate in a foreign language (Gusmuliana, 2018; Hidayah, 2017). There are further benefits of the TPR method (Richards & Rodgers, 1986): 1) Students can participate actively in teaching-learning by performing the teacher's instruction through their actions. 2) Students are able to comprehend the material without difficulty because they practicel directly through action. 3) Students can develop their speaking abilities since doing the teacher's instructions frequently makes the words easier to understand.

Furthermore, Total Physical Responses can enhance students' vocabulary mastery and also pronounciation fluently.

CONCLUSION

Based on the research overview of employing Total Physical Responses several important things can be concluded: Total Physical Responses is effective ways in students' vocabulary mastery, Total Physical Response facilitates vocabulary development by actively involving learners both physically and emotionally, lowering anxiety levels, and enhancing motivation. The results indicate that teachers are advised to integrate TPR into vocabulary teaching, particularly at the early stages of language learning. Future studies may examine the combination of TPR with digital media or its use in teaching abstract vocabulary and more advanced learners. Through such investigations, a more comprehensive understanding of TPR's potential in English language teaching can be obtained.

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TRADITIONAL AND MODERN TEACHING METHOD FOR COLLEGE STUDENTS: CHALLENGES AND BENEFITS

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Abstract

The purpose of the study to compare traditional and teaching methods for college students. This study used descriptive qualitative method. With the population were the students of fifth semester majoring English Education Study Program and 20 students selected as sample. The sample was selected through purposive sampling. In collecting the data, the study used questionnaire. There were 2 questionnaires given to the students. Questionnaire for Traditional Teaching method with 50 questions and modern teaching method with 50 questions. In analysing the data, descriptive analysis was used. The results showed that the students prefer to choose modern teaching method than traditional teaching method

Keywords: Traditional teaching method, modern teaching method, challenges, benefits

1. INTRODUCTION

In this Digital Transformation Era, the use of English will be important. It makes people need to learn and practice more, so that they can communicate and expand their networking. The use of English will be challenging for college students especially majoring English. The need of English makes students must find out the strategy to learn and improve their quality. Therefore, understanding and mastering English is not merely an additional skill but an essential requirement for students to compete in the job market and actively participate in the global community (Putri, 2021)

In Order to develop students skill, the lecturers will have important role. The method and strategy in teaching will be the main thing. Teacher identity is not a stable essence but a dynamic, developing composite of beliefs, experiences, values, and professional aspirations conditioned by social, institutional, and ideological contingencies(Wong & Liu, 2024). The lecturers must find out kinds of method which are appropriate to the students' need.

In this case, the lecturers usually use traditional and modern method for college students. Traditional methods of teaching depend on the deductive methods of teaching, in which the teacher is the centre of the classroom (Mehta, 2019). The use of traditional method will help the teaching and learning process, but it depends how the condition of the school it is. Hadi & Izzah (2018) found that the English language skills of students significantly improved when the method was implemented, thereby enhancing the overall learning process

Traditional method usually provides students in learning through lecturer's explanation. The students listen and get explanation about the lesson. In this case, the lectures will be more active than the students. So, the condition will influence whether this method appropriate to the classroom or no. Rather than facilitating knowledge distribution, the teacher focuses on repetition and memorization (Dimitrios et al., 2013)

On the other hand, the use of Modern teaching method is appropriate to classroom where students will be more active than the lecturers. According to Erni (2012), Student-Centred Method (SCM) is a teaching technique that shifts the focus of activity from teachers to student. In terms of challenges and benefits, some experts argue about the use of traditional and modern teaching methods. According to Fullan & Seam (2019) Direct

Teacher-Student Interaction: Personal level guidance can help with picky student problems. Classroom Discipline: Promotes focus and an atmosphere of respect in learning situations. But traditional teaching methods, even while beneficial, may lack flexibility at times, further meet the diverse needs of learning, and fight to keep up with the rapidly changing knowledge. Talking about the challenge, it is very important to overcome the challenge and create the solution to come out from the problem.

The challenging of Traditional teaching method is the way teachers transfer the knowledge and make the students enthusiastic to learn. Because in traditional teaching method, teacher will be the centred in giving and providing the lesson. and for the modern teaching method the challenging is how the students can be cooperative and creative in terms learning activity, because in this study, the students will be centre.

In terms of benefits, the traditional teaching method makes the teachers can control students activity. On the other hands, in modern teaching method, students feel free to learn from many sources and be independent in learning. Based on the description about, the problem has been formulated, to compare the use of traditional teaching method and modern teaching method for college students. Based on the description above, the study about traditional and modern teaching method for college students has been conducted.

2. METHOD

In this study, descriptive qualitative method has been used. There are several different methods for conducting qualitative research; however (Leedy & Ormrod, 2001) recommend the following five: Case studies, grounded theory, ethnography, content analysis, and phenomenological. The population of the study were students of English Education Study Program in Universitas Palembang and the sample were 20 students. In selecting the sample, purposive sampling has been used. The use of purposive sampling because the study must be conducted to the students who know and understand about the difference of traditional and modern teaching method. So, in this case students of the fifth semester majoring English Education Study Program have been taken as sample with 20 students. The details of the sample is described in this table

Table 1
Sample

No	Class/year level	Number of Students
1	5th semester class B	20
Total		20

Source: English Education Study Program, Palembang University

In collecting the data, the questionnaire was used. Questionnaires are one of the most common tools used to collect data in both qualitative and quantitative research (Taherdoost, 2022). The questionnaire consists of 50 questions for traditional teaching method and 50 questions for modern teaching methods. The students just answer yes or no based on the questions on questionnaire. In analysing the data, the descriptive method was used. So, the description was used to explain results after the questionnaire given to the students and the results must be explained.

3. RESULTS AND DISCUSSION

The results of the study has been analysed through descriptive analysis. The results of the students' respond have been analysed through likert type scale in terms of categories very good, good , average, poor and very poor. The results are
described in this table.

Table 2
Score Distribution of Questionnaire for Traditional Teaching Method

Category	Respondent	Percentage
Very Good	8	40%
Good	8	40%
Average	4	20%
Poor	0	0
Very Poor	0	0
Total	20	100%

Based on the table above, there are 8 students answer very good with percentage 40%, 8 students answer good with percentage 40% and 4 students answer average with percentage 20 % and no students answer poor and very poor.

Table 3
Score Distribution of Questionnaire for Modern Teaching Method

Category	Respondent	Percentage
Very Good	16	80%
Good	4	20%
Average	0	0%
Poor	0	0
Very Poor	0	0
Total	20	100%

Based on the table above, there are 16 students answer very good with percentage 80% and 4 students answer good with percentage 20% and no students answer average , poor, and very poor.

In this study, the questionnaire has been given to the students. With 50 questions for traditional teaching method and 50 questions for Modern teaching method. Students answer the questionnaire with the likert type scale in term of categories very good, good, average, poor, and very poor. After the questionnaire was given the results can be described. Based on the score distribution for traditional teaching method, the result showed that 8 students answer very good , 8 students answer good and 4 students answer average. And for the score distribution of questionnaire for Modern teaching method, 16 students answer very good and 4 students answer good. Based on the result of those two questionnaires, it can be concluded that the students choose modern teaching method as method which is effective in teaching and learning process.

4. CONCLUSION

In this digital era, the method for teaching will be important. It makes teaching and learning process will be more interesting. In this study, dividing the method into two, Traditional and Modern teaching methods. Traditional teaching method will teacher centre where the teacher explains and gives explanation to the students. So, in this method, teacher will be more active and the students will wait the teachers' instruction. On the other hand, Modern teaching method, students will be more active, they are independent to find out the explanation and explore their critical thinking. In this method, lecturers and teachers only guide, supervise and control students' activity. So, it makes students get chance to develop their self-confident and brave.

Although the result show that modern teaching method is more interesting based on the questionnaire, but teachers also have authority to choose what kinds of method will be used to make students understand easily. If it is possible the modern teaching method can be applied because this method makes the student independent and develop their critical thinking and self confidence.

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INTEGRATING SUSTAINABLE TECHNOLOGY AND ARTIFICIAL INTELLIGENCE IN PANCASILA EDUCATION: STRENGTHENING ETHICAL, HUMANISTIC, AND SOCIAL JUSTICE VALUES IN THE DIGITAL ERA

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Abstract

The rapid development of artificial intelligence (AI) and sustainable technology has profoundly transformed educational systems worldwide. However, the integration of AI in education often prioritizes efficiency and innovation while neglecting ethical, humanistic, and social dimensions. This article examines the integration of AI-based sustainable technology in Pancasila Education as a normative and ethical framework to guide digital transformation in Indonesia. Using a qualitative literature review method, this study analyzes contemporary scholarship on AI in education, sustainable technology, and Pancasila values. The findings indicate that AI integration grounded in Pancasila can enhance educational quality while safeguarding human dignity, social justice, and national identity. This study argues that Pancasila Education plays a critical role in ensuring that AI-driven educational innovation remains ethically responsible, socially inclusive, and aligned with sustainable development goals.

Keywords: Artificial Intelligence, Sustainable Technology, Pancasila Education, Ethics, Social Justice

1. INTRODUCTION

The digital revolution marked by artificial intelligence (AI), big data, and automation has reshaped educational practices across the globe (Luckin et al., 2016). AI-based educational technologies offer adaptive learning systems, intelligent tutoring, and data-driven assessment models that promise efficiency and personalization (Holmes et al., 2019). Despite these advantages, scholars have raised concerns regarding ethical risks, data privacy, algorithmic bias, and the dehumanization of education (Floridi et al., 2018). In Indonesia, education is not merely a technical process but a moral and ideological endeavor rooted in Pancasila, the state philosophy that emphasizes humanity, social

justice, democracy, and unity (Kaelan, 2019). The challenge lies in integrating advanced technologies without eroding foundational ethical and cultural values. Pancasila Education therefore plays a strategic role in mediating technological advancement and moral responsibility.

Recent studies highlight the need for value-based frameworks to guide AI implementation in education (UNESCO, 2021). However, limited research has explored how national ideologies such as Pancasila can function as ethical anchors for AI-based sustainable education systems. This article addresses this gap by examining the integration of sustainable technology and AI within Pancasila Education.

2. METHODOLOGY

Research Design

This study employed a qualitative literature review methodology to critically examine the integration of artificial intelligence (AI)-based sustainable technology in Pancasila Education as a normative and ethical framework guiding digital transformation in Indonesia. A qualitative approach was selected to enable conceptual, interpretive, and normative analysis, which is essential for exploring ethical values, philosophical principles, and socio-cultural dimensions embedded in educational transformation.

Rather than measuring causal relationships, this study aimed to synthesize theoretical insights, identify ethical implications, and construct a value-oriented analytical framework grounded in Pancasila. This approach is particularly appropriate for research addressing ethics, ideology, civic education, and public values in the context of emerging technologies.

Data Sources and Literature Selection

The data consisted of secondary sources obtained from reputable academic and institutional publications. The literature was drawn from:

1. Peer-reviewed international journals on AI in education, educational technology, and digital ethics
2. Scholarly works on sustainable technology and sustainable development in education
3. Foundational and contemporary literature on Pancasila, civic education, and Indonesian political philosophy
4. Policy documents and reports related to AI governance, education digitalization, and sustainable development

Databases used for literature retrieval included Scopus, Web of Science, Google Scholar, and ERIC, ensuring academic credibility and international relevance.

3. CONCLUSION

This study concludes that the integration of sustainable technology and artificial intelligence (AI) in Pancasila Education is a crucial strategy for strengthening ethical, humanistic, and social justice values in the digital era. When designed and implemented in alignment with Pancasila principles, technology and AI function not merely as innovative learning tools but also as instruments for character formation, fostering critical thinking, civic responsibility, and moral awareness among learners. The central proposition of this research demonstrates that the effectiveness of digital transformation in Pancasila Education depends on the harmonization of technological advancement with human dignity, public morality, and collective well-being.

The practical implications of these findings highlight the essential roles of educators, educational institutions, and policymakers in developing curricula, pedagogical models, and AI-based educational systems that are ethical, inclusive, and sustainable. The

application of AI in Pancasila Education must be accompanied by critical digital literacy, ethical governance of technology, and regulatory frameworks that ensure fairness, inclusivity, and the protection of human values. Through this approach, Pancasila Education remains relevant and transformative, serving as a normative foundation that guides the responsible use of technology and artificial intelligence toward the development of Indonesian citizens who embody ethical integrity, social justice, and Pancasila-based character in the digital age.

4. RESULTS AND DISCUSSION

Results

The qualitative analysis of the selected literature reveals four major interrelated themes concerning the integration of artificial intelligence (AI) and sustainable technology in Pancasila Education.

1. Ethical Risks and Value Gaps in AI-Driven Education

The literature consistently indicates that AI integration in education has largely been driven by goals of efficiency, personalization, and scalability. While these technological advancements enhance learning outcomes and administrative effectiveness, many studies highlight significant ethical risks, including data privacy violations, algorithmic bias, surveillance practices, and the commodification of learners. These findings suggest a growing value gap between technological innovation and ethical responsibility in educational contexts.

In the Indonesian context, the absence of a strong ethical framework risks reducing education to a technocratic process that overlooks moral development and civic responsibility. The reviewed studies emphasize that without normative guidance, AI-driven education may undermine human dignity and exacerbate social inequalities.

2. Pancasila as a Normative Framework for Ethical AI Integration

The analysis demonstrates that Pancasila provides a comprehensive ethical and philosophical foundation capable of guiding responsible AI integration in education. Each of the five principles of Pancasila offers normative direction: belief in God emphasizes moral accountability; just and civilized humanity affirms human dignity; national unity safeguards cultural identity; democracy promotes participatory decision-making; and social justice ensures equity and inclusion.

The literature supports the argument that embedding these principles within Pancasila Education enables educators to critically assess AI technologies not only in terms of functionality but also in relation to ethical implications and societal impact. This positions Pancasila as a contextualized ethical compass for digital transformation in Indonesian education.

3. Humanistic and Social Justice Dimensions of Sustainable Educational Technology

Findings indicate that sustainable technology in education extends beyond environmental concerns to encompass social sustainability, inclusivity, and intergenerational responsibility. Studies reviewed suggest that AI applications aligned with humanistic values can foster empathy, collaboration, and reflective thinking when designed and implemented ethically.

Conversely, when sustainability is framed narrowly as technological efficiency, AI risks reinforcing existing power asymmetries and digital divides. The literature emphasizes that Pancasila's commitment to social justice offers a critical lens for evaluating whether AI-supported educational practices genuinely promote equitable access and fair learning opportunities.

4. The Strategic Role of Pancasila Education in the Digital Era

The analysis reveals that Pancasila Education plays a strategic role in mediating the relationship between technological innovation and moral development. Rather than functioning as a supplementary subject, Pancasila Education emerges as a central platform for cultivating ethical digital citizenship, critical awareness of AI, and value-based reasoning.

Several studies argue that integrating AI literacy into Pancasila Education encourages learners to engage with technology reflexively, recognizing both its potential benefits and ethical challenges. This approach strengthens national identity while preparing students to participate responsibly in a global digital society.

Discussion

The findings of this study reinforce the argument that technological innovation in education must be accompanied by robust ethical and normative frameworks. The dominance of efficiency-oriented narratives in AI-driven education reflects a broader global trend that prioritizes instrumental rationality over moral considerations. This study extends existing scholarship by demonstrating that Pancasila offers a distinctive, culturally grounded ethical framework capable of addressing these challenges.

By positioning Pancasila Education as a normative guide, this research contributes to the discourse on ethical AI governance in education, particularly within non-Western contexts. Unlike universalist ethical models that may overlook local values, Pancasila integrates moral, social, and national dimensions in a holistic manner. This supports calls in the literature for pluralistic and context-sensitive approaches to AI ethics.

Furthermore, the emphasis on social justice and human dignity aligns Pancasila-based AI integration with the Sustainable Development Goals (SDGs), especially those related to quality education, reduced inequalities, and sustainable institutions. The findings suggest that Pancasila Education can function as a bridge between global sustainability agendas and local ethical traditions.

This study also highlights the need for policy alignment between educational digitalization strategies and ethical frameworks. Without such alignment, AI adoption risks reinforcing exclusion and dehumanization. Embedding Pancasila values within curriculum design, teacher training, and AI governance mechanisms offers a pathway toward ethically responsible and socially inclusive educational innovation.

5. CONCLUSION

This study concludes that the integration of sustainable technology and artificial intelligence (AI) in Pancasila Education is a crucial strategy for strengthening ethical, humanistic, and social justice values in the digital era. When designed and implemented in alignment with Pancasila principles, technology and AI function not merely as innovative learning tools but also as instruments for character formation, fostering critical thinking, civic responsibility, and moral awareness among learners. The central proposition of this research demonstrates that the effectiveness of digital transformation in Pancasila Education depends on the harmonization of technological advancement with human dignity, public morality, and collective well-being.

The practical implications of these findings highlight the essential roles of educators, educational institutions, and policymakers in developing curricula, pedagogical models, and AI-based educational systems that are ethical, inclusive, and sustainable. The application of AI in Pancasila Education must be accompanied by critical digital literacy, ethical governance of technology, and regulatory frameworks that ensure fairness, inclusivity, and the protection of human values. Through this approach,

Pancasila Education remains relevant and transformative, serving as a normative foundation that guides the responsible use of technology and artificial intelligence toward the development of Indonesian citizens who embody ethical integrity, social justice, and Pancasila-based character in the digital age.

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TECHNOLOGY MEETS EDUCATION: EXPLORING COLLEGE STUDENTS' INSIGHTS ON USING GINGER WRITER TO BOOST WRITING SKILL

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Abstract
This study aimed to explore college students' perceptions of using Ginger Writer to enhance their English as a Foreign Language (EFL) writing skills. Employing a descriptive quantitative methodology, data were collected through a closed-ended questionnaire using a Likert scale. The participants were 19 students from the English Language Education Study Program at the Islamic University of Ogan Komering Ilir, Kayuagung, consisting of five male and fourteen female students who had prior experience using Ginger Writer. The questionnaire comprised 20 items addressing the use of Ginger Writer, its strengths in subject–verb agreement and sentence structure, and its perceived weaknesses. Data were analyzed using descriptive statistical techniques. The findings revealed that most students held positive perceptions of Ginger Writer, particularly regarding its ability to improve grammatical accuracy, sentence structure, writing quality, confidence, and efficiency in detecting errors. Students strongly agreed that the tool was effective in identifying subject–verb agreement errors and enhancing sentence clarity and coherence. However, some limitations were reported, including restricted features in the free version and the relatively high cost of the premium version. Overall, Ginger Writer is perceived as an effective and supportive tool for enhancing EFL students' writing skills when used as a complementary aid alongside teacher guidance. The study suggests that AI-based writing tools can foster learner confidence and autonomy if pedagogically integrated, and it recommends future research employing qualitative approaches and longitudinal designs to examine long-term impacts on writing development.
Keywords: English writing skills, Ginger Writer, artificial intelligence, EFL learners, writing support tools

1.INTRODUCTION

Writing is a crucial skill in learning English, yet it remains one of the most challenging areas for many students, particularly in the English as a Foreign Language (EFL) context. Writing requires continuous cognitive processes, such as planning, decision-making, evaluation, and revision, which demand high levels of mental flexibility and self-regulation (Novitaningrum, 2023). Despite its importance, many EFL learners struggle to balance linguistic accuracy with idea development, often resulting in anxiety, hesitation, and low confidence in expressing ideas in written form (Dwimaulani et al., 2024).

Structural differences between students' first language and English further contribute to difficulties in organizing ideas, using appropriate vocabulary, and applying correct writing mechanics (Sartika & Nery, 2018). Therefore, mastering writing in EFL settings requires not only linguistic competence but also emotional resilience and cognitive adaptability.

Among Indonesian EFL students, particularly those at the early stages of university study, writing is frequently perceived as the most demanding language skill. While many students can express ideas orally, they often struggle to organize and articulate those ideas coherently in written texts. These challenges arise from both linguistic limitations and psychological barriers, including fear of making errors and low self-efficacy (Hadiani, 2024). Consequently, effective writing instruction should address not only grammatical accuracy but also students' confidence, self-expression, and reflective awareness. From a qualitative literacy perspective, affective and metacognitive development are essential indicators of writing growth, as they support learners' ability to engage meaningfully with the writing process (Sartika & Rachmanita, 2017). In this sense, writing pedagogy must adopt a holistic approach that integrates linguistic, affective, and reflective dimensions of learning.

From a sociocultural perspective, writing is understood as a socially mediated practice rather than an isolated activity. Learners construct meaning through interactions with peers, teachers, and technological tools that extend their learning agency (Supiatman et al., 2024). When integrated meaningfully, technology functions as a mediating artifact that supports the exploration of ideas, iterative revision, and reflective learning. Digital scaffolds, such as visual and interactive feedback tools, have been shown to enhance writing content, organization, and mechanics while encouraging learner autonomy and active engagement in text production (Sartika et al., 2024). Thus, sociocultural and technological mediation provide a supportive environment that fosters both collaboration and independent learning in writing.

The integration of automated writing evaluation (AWE) tools such as Ginger Writer has been widely recognized for its capacity to enhance students' writing quality, engagement, and self-regulated learning. Previous studies indicate that AI-powered writing assistants provide timely and individualized feedback that supports improvements in grammar, coherence, and overall writing performance, particularly for second-language learners (Nazari et al., 2021; Fleckenstein et al., 2023). When implemented appropriately, AWE tools encourage deeper involvement in the writing process by promoting revision and reflection, which ultimately leads to improved writing quality (Alharbi, 2023). Students also tend to demonstrate higher motivation and engagement when they perceive such tools as beneficial, fostering a sense of ownership and responsibility for their writing development (Chan & Hu, 2023; Wischgoll, 2017). In summary, previous studies show that AWE tools such as Ginger Writer are effective in supporting students' writing development. By providing immediate and personalized feedback, these tools help improve writing accuracy, increase student engagement, and encourage independent learning. When used appropriately, Ginger Writer can support students in revising their work and developing better writing skills, especially in EFL contexts.

Beyond writing quality, Ginger Writer contributes to the development of self-regulated learning by enabling learners to independently monitor, evaluate, and revise their writing. Structured and continuous feedback supports self-efficacy and strategic revision practices that are essential for sustained writing improvement (Zimmerman &

Kitsantas, 2002; Kellogg, 2008). From an instructional perspective, the automation of initial feedback allows teachers to focus on higher-level pedagogical support and individualized guidance, increasing instructional efficiency, particularly in large classroom contexts (Alharbi, 2023). These findings collectively suggest that Ginger Writer serves not only as a learning aid for students but also as a scalable instructional support tool for educators.

Recent advancements in artificial intelligence (AI) and AWE systems have further transformed writing pedagogy by enabling immediate and adaptive feedback on grammar, structure, and language use (Cao et al., 2025). However, scholars emphasize that such tools must be pedagogically guided to avoid overreliance and diminished critical reflection (Maharani, 2022). When positioned as collaborative mediators rather than replacements for instruction, AI-assisted tools can enhance learners' linguistic awareness while preserving the teacher's essential role in fostering critical thinking. Within a process-based writing framework that views writing as a recursive cycle of planning, drafting, revising, and reflecting (Rahman et al., 2024), AI tools function most effectively as scaffolds that support, rather than replace, the writing process. In other words, the effectiveness of AI-assisted writing tools depends on their thoughtful integration as supportive scaffolds that complement the writing process and instructional guidance, rather than functioning as standalone solutions.

Ginger Writer exemplifies such an AI-assisted tool, utilizing natural language processing to provide real-time feedback on grammar, spelling, sentence structure, and language clarity (Ginger Software Ltd., 2023). By offering contextual explanations and alternative sentence constructions, Ginger Writer enables learners to understand and learn from their errors instead of merely correcting them. Its features—such as subject–verb agreement detection, sentence rephrasing, and clarity enhancement—are particularly beneficial for EFL learners who often struggle with accuracy and coherence. As an AWE tool, Ginger Writer provides formative feedback during the revision stage, promoting self-editing, iterative improvement, and learner autonomy (Ranalli et al., 2017). Previous research suggests that such immediate and personalized feedback can reduce writing anxiety, increase confidence, and support independent learning (Bitchener & Ferris, 2012). In conclusion, Ginger Writer serves as a supportive digital scaffold that facilitates accurate, reflective, and autonomous writing practices, particularly for EFL learners during the revision process.

To address challenges in EFL writing, recent advancements in artificial intelligence (AI) have introduced automated writing evaluation (AWE) tools that function as digital scaffolds in the writing process. Among these tools, Ginger Writer has gained increasing attention for its capacity to provide real-time, individualized feedback on grammar, sentence structure, and language clarity, particularly in EFL contexts. Despite growing quantitative evidence supporting the effectiveness of Ginger Writer in improving linguistic accuracy, limited research has explored students' subjective experiences with this tool during the writing process. Qualitative inquiry is therefore necessary to understand how learners perceive, interpret, and respond to AI-assisted feedback (Creswell & Poth, 2018). Grounded in an interpretive paradigm, this study aims to explore college students' perceptions of using Ginger Writer to support their English writing development by examining how technology-mediated feedback influences motivation, confidence, and learner autonomy, thereby offering pedagogical insights into the effective integration of AI tools as supportive partners in developing reflective and autonomous EFL writers in the digital era.

2.METHODOLOGY

This study employed a descriptive quantitative approach using a closed-ended questionnaire with a Likert scale to capture students' perceptions of Ginger Writer. According to Sugiyono (2019), descriptive quantitative research is conducted to describe phenomena or characteristics of a population using numerical data without testing hypotheses or manipulating variables. This approach was selected because it allows for the systematic measurement of learners' attitudes and experiences using numerical data, enabling the identification of general trends without manipulating variables. By employing descriptive statistics, the study aims to provide an objective overview of how students perceive the role of Ginger Writer in supporting their EFL writing process.

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The samples of this study consisted of 19 college students from the Islamic University of Ogan Komering Ilir Kayugung. The sample consisted of 5 male students and 14 female students**.** The participants were selected using purposive sampling, which means that only students who had experience using Ginger Writer as part of their writing activities were included. Etikan (2019) explains that purposive sampling is appropriate when participants are chosen based on specific characteristics relevant to the research objective. This sampling method was used to ensure that the participants could provide relevant and meaningful responses based on their experience with the application.

The data were collected using a closed-ended questionnaire designed to gather detailed and descriptive responses from participants. The questionnaire consisted of 20 items and had four indicators such as the use of Ginger Writer (1-5), the strengths of Ginger Writer in terms of subject-verb agreement (6-10), the strengths of Ginger Writer in terms of sentence structure (12-17), and the weaknesses of Ginger Writer (18-20), which were adapted from Kholishatuzzahra (2025). A closed-ended question is a question that restricts respondents' answers to a set of predetermined options, such as yes/no choices or rating scales, rather than allowing free-form responses (Creswell, 2014). The data collection process was executed online via Google Forms. Questionnaires were distributed to students who participated in classes using the Ginger Writer. Within the questionnaire, respondents were presented with five response options: Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), and Strongly Agree (5).3.

3. RESULTS AND DISCUSSION

The results section presents descriptive statistical findings derived from students' questionnaire responses, while the discussion section interprets these findings in relation to relevant theories and previous studies. The results indicate that students generally perceived Ginger Writer as a useful tool for supporting their writing activities, particularly in improving grammatical accuracy, sentence structure, and confidence. These findings are discussed in relation to prior research on automated writing evaluation tools, which highlights the role of immediate and individualized feedback in enhancing writing performance and learner engagement.

The results show the percentage of students' perceptions of the effectiveness of Ginger Writer in boosting their writing skills, as indicated in a questionnaire. The Scales used for this research question are Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), and Strongly Agree (SA), divided into four sections. The results for the first section asked about the use of Grammarly, which a percentage of students use in developing their writing skills with the Ginger Writer. The results of the first section on the use of Ginger Writer are shown in Table 1.

Table 1. Percentage of the Use of Ginger Writer

No.		Statement	SD	D	N	A	SA
1.	1.	I use Ginger Writer in writing	0	0	15.8 (3)	68.4 (13)	15.8 (3)
	2.	Ginger Writer helps me in writing	0	0	10.5 (2)	10.5 (2)	79.0 (15)
	3.	Ginger Writer helps me improve the quality of my writing	0	0	10.5 (2)	5.2 (1)	84.1 (16)
	4.	I feel more confident with my writing when using Ginger Writer	0	0	10.5 (2)	26.3 (5)	63.1 (12)
	5.	Ginger Writer is saving my time in detecting writing errors	0	0	10.5 (2)	10.5 (2)	79.0 (15)

In the aspect of using Ginger Writer, 19 students were given five statements to answer based on their experience with Ginger Writer. The first statement was *"I use Ginger Writer in writing".* It shows that 13 students (68.4%) agree, while three students (15.8%) are neutral and three students (15.8%) strongly agree that the students use Ginger Writer in their writing. Meanwhile, no one (0%) stated 'disagree' or 'strongly disagree'. It can be concluded that students agree and mostly use Ginger Writer in their writing.

The second statement was *"Ginger Writer helps me in writing".* There were 15 students (79.0%) who strongly agree, two students (10.5%) who agree, and two students (10.5%) who were neutral. However, no one (0%) stated 'disagree' or 'strongly disagree'. According to the percentage results, in the second statement, most students felt that Ginger Writer helped them with their writing.

The third statement was, *"Ginger Writer helps me improve the quality of my writing*." The results showed that 16 students (84.1%) strongly agreed, two students (10.5%) were neutral, and one student (5.2%) agreed. Meanwhile, no one (0%) chose to disagree and chose strongly disagree. According to some of the percentage results, most students reported that Ginger Writer helped them improve their writing.

The fourth statement was, *"I feel more confident with my writing when using Ginger Writer*." The results showed that 12 students (63.1%) chose "strongly agree," 2 students (10.5%) chose "neutral," and five students (26.3%) stated that when using Ginger Writer, they felt more confident with their writing. On the other hand, no one (0%) stated 'disagree' or 'strongly disagree'. The highest percentage of students who chose to agree indicates that most students felt more confident in exploring ideas in their writing because of Ginger Writer.

The fifth statement was, *"Ginger Writer is saving my time in detecting writing errors."* It received a positive response from 15 students (79.0%), who stated they strongly agreed, two students (10.5%) answered neutral, and two students (10.5%) said they agreed with the statement. On the other hand, no one (0%) chose "disagree" or "strongly disagree."

The students agreed that Ginger Writer can save time in detecting errors and mistakes in writing.

The second section focuses on Ginger Writer's strengths related to subject–verb agreement, and the corresponding percentage results are shown in Table 2.

Table 2. The Strengths of Ginger Writer in Terms of Subject-Verb Agreement

No.		Statement	SD	D	N	A	SA
2.	6.	Ginger Writer helps me to understand the connection between subjects and verbs in complex sentences	0	0	36.8 (7)	47.3 (9)	15.8 (3)
	7.	Ginger Writer helps me to identify mistakes in subject-verb agreement that I am not aware of	0	0	10.5 (2)	15.8 (3)	73.6 (14)
	8.	Ginger Writer provides clear explanations regarding subject-verb agreement errors	1 (5.2)	0	26.3 (5)	52.6 (10)	15.8 (3)
	9.	Ginger Writer is effective in detecting and correcting my writing errors in the subject-verb agreement	0	0	10.5 (2)	21.0 (4)	68.4 (13)
	10.	I rarely make grammar mistakes, especially subject-verb agreement, after using Ginger Writer.	0	0	10.5 (2)	0	89.4 (17)
	11.	Ginger Writer helps me to know when to use the singular or plural forms in verbs	0	0	10.5 (2)	26.3 (5)	63.1 (12)

In terms of the strength of Ginger Writer in subject-verb agreement, the researcher provided six statements that required answers based on students' experiences with Ginger Writer. The sixth statement was "*Ginger Writer helps me to "nderstand the connection between subjects and verbs in complex sentences"*. The result showed that 9"students (47.3%) stated agree, seven students (36.8%) neutral, and three students (15.8%) chose strongly agree that Ginger Writer helps them to know and understand the connection between subject and verb agreement in complex sentences. On the other hand, no one (0%) chose to disagree and chose strongly disagree. Based on the most significant percentage, most students agreed that Ginger Writer helped them feel more familiar with the connection between subjects and verbs in complex sentences.

The seventh statement was "*Ginger Writer helps me to 'identify mistakes in subject-verb agreement that I am not aware of"*. It can be described that"a small number of students (15.8%) 3 students said they agree that they felt helped by Ginger Writer to identify mistakes in subject-verb agreement that they were not aware of. Almost all students, 14 students (73.6%), strongly agree with this statement. On the other hand, two students (10.5%) expressed neutrality, and no one (0%) chose 'disagree' or 'strongly disagree'. It can be concluded that the student agreed and felt helped by Ginger Writer in identifying mistakes in subject-verb agreement that they were not aware of.

The eighth statement was "*Ginger Writer provides clear explanations regarding subject-verb agreement errors*". The result showed that a"small number of the students (3 students) said strongly agree (15.8%), and 10 students (52.6%) chose to agree with the statement given. Meanwhile, five students (26.3%) stated 'neutral', no one stated 'disagree', and only one student (5.2%) stated 'strongly disagree'. To sum up, the students agreed that Ginger Writer provides a clear explanation regarding subject-verb agreement errors.

The ninth statement was *"Ginger Writer is effective" in detecting and correcting my writing errors in the subject-verb agreement.* There were four students (2".0%) who stated agree, and more than half of the students (68.4%) stated strongly agree that Ginger Writer is effective in detecting and correcting their writing errors in subject-verb agreement. While two students (10.5%) chose to answer 'neutral', no one (0%) chose 'disagree', and no one (0%) chose 'strongly disagree' with the statement. In short, the students agreed on the effectiveness of Ginger Writer in detecting and correcting their writing errors related to subject-verb agreement.

The tenth statement was, "*I rarely make grammar mistakes, especially subject-verb agreement, after using Ginger Writer."* There were 17 students (9.4%) who strongly agreed that they rarely make grammar mistakes, especially in subject-verb agreement, after using Ginger Writer. Additionally, two students (10.5%) chose neutral, while none (0%) chose agree, disagree, or strongly disagree. To sum up, the results indicated that students rarely made grammatical mistakes, especially in subject-verb agreement, after using Ginger Writer.

The eleventh statement was "*Ginger Writer helps me to 'know when to use singular or plural forms in verbs'".* The results showed that "2 students (63.1%) strongly agreed, and five students (26.3%) agreed that Ginger Writer can help them know when to use the singular or plural form of verbs. While only two students (10.5%) chose neutral, and no one (0%) chose to answer 'disagree' or 'strongly disagree' with the statement. To conclude, most students strongly agreed that Ginger Writer helped them recognize when to use singular or plural forms in verbs.

The results for the third section, which examines the strengths of Ginger Writer in terms of sentence structure, are presented in Table 3.

Table 3. The Strengths of Grammarly in Terms of Sentence Structure

No.	Statement	SD	D	N	A	SA
3.	12. Ginger Writer is effective in assisting me in correcting the sentence structure in my writing.	0	0	10.5 (2)	15.8 (3)	73.6 (14)
	13. Ginger Writer provides relevant suggestions to improve my sentence structure.	0	0	10.5 (2)	21.0 (4)	68.4 (13)
	14. Ginger Writer helps me to identify sentences that are not parallel or illogical.	0	0	10.5 (2)	74.6 (14)	15.8 (3)
	15. Ginger Writer helps me provide suggestions to add certain elements to make my sentences clearer.	0	0	10.5 (2)	5.2 (1)	84.1 (16)
	16. Ginger Writer helps me to understand how to make sentences more coherent and structured.	1 (5.2)	0	10.5 (2)	5.2 (1)	79.0 (15)
	17. Ginger Writer provides frequent suggestions to correct sentences that are too long or ambiguous in my writing.	2 (10.5)	1 (5.2)	10.5 (2)	0	73.6 (14)

In this part, the students were given six statements or points to answer related to the strengths of Ginger Writer in terms of sentence structure. The twelfth statement was *"Ginger Writer is effective in assisting me to correct the sentence structure in my writing"".* The results showed that three students (15.8%) chose to answer "agree", and more than half of the students (73.6%) chose to answer "strongly agree" that using Ginger Writer made them feel effective in correcting sentence structure in their writing.

Additionally, two students (15%) expressed neutrality, no one (0%) disagreed, and no one (0%) strongly disagreed with the statement. Ginger Writer is effective in helping students correct sentence structure in their writing.

The thirteenth statement was *"Ginger Writer provides relevant suggestions to improve my sentence structure""*. The results showed that 13 students (68.4%) strongly agreed with the statement, and four students (21.0%) agreed. In comparison, two students (10.5%) said 'neutral', no one (0%) said 'disagree', and no one strongly disagreed with the statement given. It can be inferred that they agree that Ginger Writer provides relevant suggestions to improve their sentence structure.

The fourteenth statement was *"Ginger Writer helps me to identify sentences that are not parallel or illogical""*. It was described that 14 students (73.6%) stated they agreed, three students (15.8%) stated they strongly agreed, and two students (10.5%) stated they were neutral about the effectiveness of Ginger Writer in helping them correct sentence structure in their writing. In comparison, no one (0%) disagreed, and no one (0%) strongly disagreed with the statement. Based on the data obtained, it was known that the students agreed with the assistance of Ginger Writer that they can identify sentences that were not parallel or illogical.

The fifteenth statement was *"Ginger Writer helps me in providing suggestions to add certain elements to make my sentences clearer""*. There were a small number of students (10.5%) who chose to answer neutral, 16 students (84.1%) chose to answer strongly agree, and one student (5.2%) chose to answer agree that by using Ginger Writer, it could provide suggestions to add certain elements to make their sentences more straightforward. While no one (0%) chose to answer 'disagree' or 'strongly disagree' with the statement. The students agree that they felt helped by Ginger Writer in providing suggestions to add certain elements that make their sentences clearer.

The sixteenth statement was *"Ginger Writer helps me to understand how to make sentences more coherent and structured""*. There were 15 students (79.0%) who strongly agreed, and only one student (5.2%) agreed that using Ginger Writer can help them understand how to make sentences more coherent and structured. Meanwhile, a small number of students (10.5%) stated that they were neutral, no one (0%) stated that they disagreed, and one student (5.2%) stated that they strongly disagreed with this statement. The result showed that the students agreed that Ginger Writer helped them to understand how to make sentences more coherent and structured.

The seventeenth statement was *"Ginger Writer provides frequent suggestions to correct sentences that are too long or ambiguous in my writing""*. It showed that 14 students (73.6%) strongly agreed, and two students (10.5%) said they were neutral, that Ginger Writer provides frequent suggestions to correct sentences that are too long or ambiguous in their writing. Then, no one (0%) stated that they were neutral, only one (5.2%) disagreed, and two students (10.5%) strongly disagreed with this statement. It can be concluded that the students agreed that Ginger Writer could provide frequent suggestions to correct sentences that are too long or ambiguous in their writing.

The result of the percentage for the fourth section, which asks about the weakness of Ginger Writer. The results are shown in Table 4.

Table 4. The Weakness of Ginger Writer

No.		Statement	SD	D	N	A	SA
4.	18.	I have to double-check when using Ginger Writer to get an optimal result in writing	12 (63.1)	4 (21.0)	15.8 (3)	0	0
	19.	The premium version of Ginger Writer is	1	0	31.6	42.1	21.0

expensive for me as a student at university	(5.2)		(6)	(8)	(4)
20. I have limitations in checking word errors when using the free version of Ginger Writer	0	1 (5.2)	10.5 (2)	15.8 (3)	68.4 (13)

Three statements were given to the students regarding the weaknesses of Ginger Writer. The eighteenth statement was, *"I have to double-check when using Ginger Writer to get an optimal result in writing."* It was indicated that 12 students (63.1%) chose to answer 'strongly disagree', four students (21.0%) chose to answer 'disagree', and three students (15.8%) chose to answer 'neutral'. When using Ginger Writer, they had to double-check to get an optimal result in writing. No one (0%) chose to answer 'strongly agree' with this statement. Referring to the data, it can be concluded that the students strongly disagree about whether they had to double-check when using Ginger Writer to get optimal results in writing.

The second statement was *"The premium version of Ginger Writer is expensive for me as a student at university".* There were four students (21.0%) who chose 'strongly agree', eight students (42.1%) answered 'agree', and six students (31.6%) stated 'neutral' with the statement. In comparison, no one (0%) stated 'disagree', and one student (5.2%) stated 'strongly disagree' if the premium version of Ginger Writer is expensive. It can be concluded that the students agreed that the premium version of Ginger Writer is too expensive for them as university students.

The third statement was, "*I have limitations in checking word errors when using the free version of Ginger Writer."* It showed that 13 students (68.4%) strongly agreed, and three students (15.8%) agreed that the free version of Ginger Writer has limitations in checking word errors. On the other hand, only two students (10.5%) chose neutral, no one (0%) chose to disagree strongly, and one student (5.2%) chose to disagree with the statement. When using the free version of Ginger Writer, there were limitations in checking word errors.

The findings of this study reveal that Ginger Writer is positively perceived by students as an effective AI-assisted writing tool, particularly in supporting writing practice, grammatical accuracy, and sentence-level development. Across the four indicators examined, the results suggest that Ginger Writer functions not only as a technical aid but also as a pedagogical scaffold that supports learners' confidence, autonomy, and engagement in the writing process.

Regarding the **use of Ginger Writer (statements 1–5)**, the high level of student acceptance indicates that the tool is widely embraced as part of students' writing practices. The absence of disagreement across all usage-related statements reflects a strong perceived usefulness and ease of integration into academic writing tasks. Students reported that Ginger Writer helps them write more efficiently, improves writing quality, increases confidence, and saves time in detecting errors. These findings align with previous studies suggesting that AI-based writing tools can create a more engaging and supportive learning environment by reducing anxiety and cognitive overload during writing (Li et al., 2015; Widiawati et al., 2023). The increase in confidence reported by students further suggests that immediate and non-judgmental feedback plays a crucial role in fostering positive writing experiences, particularly for EFL learners who often fear making grammatical mistakes. Thus, Ginger Writer appears to function as a formative learning tool that encourages frequent writing and sustained engagement.

In terms of the **strengths of Ginger Writer related to subject–verb agreement (statements 6–10)**, the findings demonstrate that the tool is particularly effective in

detecting and correcting errors. Most students strongly agreed that Ginger Writer helped them identify subject–verb agreement errors that they had previously overlooked and reduced the frequency of such errors over time. This supports existing research emphasizing the role of automated feedback in enhancing grammatical accuracy by making learners more aware of recurring mistakes (Alharthi, 2021; Fitrawati & Safitri, 2021). However, the relatively high percentage of neutral responses regarding conceptual understanding of subject–verb relationships and clarity of explanations suggests that while Ginger Writer is effective diagnostically, it may not fully support deep grammatical understanding for all learners. This finding underscores the importance of pedagogical mediation, as grammar tools are most effective when used in conjunction with explicit instruction and reflection (Ciesielkiewicz, 2015). Nevertheless, Ginger Writer's ability to support singular–plural verb distinctions indicates its value as a practical scaffold for common ESL grammatical challenges.

Regarding the **strengths of Ginger Writer in sentence structure development (statements 12–17)**, the data reveal overwhelmingly positive perceptions. Students reported that Ginger Writer effectively assists in correcting sentence structure, providing relevant suggestions, improving clarity, enhancing coherence, and addressing issues related to sentence length and ambiguity. These results suggest that Ginger Writer supports higher-level writing concerns beyond surface grammar, aligning with process-based writing theories that emphasize revision and refinement (Flower & Hayes, 1980; Kellogg, 2008). By highlighting illogical or non-parallel constructions and offering suggestions for clearer expression, the tool appears to reduce cognitive load, allowing students to focus more on meaning-making. This supports the notion that AI-assisted feedback can serve as a cognitive aid, helping learners internalize structural patterns through repeated exposure and revision (Graham et al., 2015). Consequently, Ginger Writer contributes to the development of coherence and readability, which are critical components of effective academic writing.

Despite its strengths, the findings also reveal **weaknesses of Ginger Writer (statements 18–20)** that warrant consideration. Students' strong disagreement with the need to double-check Ginger Writer's suggestions indicates a high level of trust in the tool's accuracy. While this reflects confidence, it also raises pedagogical concerns about potential overreliance and reduced critical engagement. This finding echoes Maharani's (2022) caution that unguided use of AI tools may limit learners' reflective thinking. Additionally, students perceived the premium version as expensive and acknowledged limitations in the free version, particularly in error-checking capabilities. These financial and functional constraints may restrict equitable access and sustained use, especially for students with limited resources. As previous studies suggest, affordability and access significantly influence students' adoption of educational technologies (Bolton et al., 2003; Baicker et al., 2013). Therefore, while Ginger Writer is effective, its optimal use depends on institutional support and pedagogical guidance.

Overall, the discussion indicates that Ginger Writer serves as a valuable AI-assisted writing tool that enhances writing accuracy, sentence quality, and learner confidence in EFL contexts. Its strengths lie in providing immediate feedback, supporting revision, and promoting learner autonomy. However, its limitations highlight the importance of guided implementation, critical reflection, and consideration of accessibility issues. When integrated thoughtfully into writing instruction, Ginger Writer can function as a complementary tool that supports, rather than replaces, meaningful writing pedagogy.

4. CONCLUSION

This study examined college students' perceptions of using Ginger Writer as an AI-assisted writing tool in the EFL context and found that the tool was positively received as a supportive aid throughout the writing process. The findings indicate that Ginger Writer contributes to improved grammatical accuracy, sentence structure, writing confidence, and efficiency, functioning as a formative digital scaffold that promotes learner autonomy. The primary contribution of this study lies in its focus on students' perceptions of Ginger Writer, offering empirical insight into how AI-assisted feedback is experienced by EFL learners in higher education. Despite its strengths, the study also highlights limitations related to potential overreliance on automated feedback and issues of accessibility due to cost and feature restrictions. Therefore, Ginger Writer should be integrated into writing instruction with clear pedagogical guidance to encourage critical reflection and balanced technology use. Future research is recommended to employ mixed-method or longitudinal designs to further investigate the sustained impact of AI-assisted writing tools on learners' writing proficiency and self-regulated learning skills.

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THE IMPACT OF DIGITAL TRANSFORMATION ON THE TRANSPARENCY AND ACCURACY OF FINANCIAL INFORMATION

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Abstract

Objectives; This study aims to critically analyze the impact of the adoption of disruptive technologies—including Big Data Analytics, Blockchain (Distributed Ledger Technology), and Artificial Intelligence (AI)—on the transparency and accuracy of information in financial sector financial reporting, by placing the CIA Trias framework (Confidentiality, Integrity, and Availability) as the foundation for accounting data analysis.

Methodology; This study uses a descriptive qualitative approach based on literature studies through a systematic synthesis of relevant academic findings and industry practices. The analysis focused on how digital transformation affects the quality of financial information, especially in terms of data integrity, reliability of reporting processes, and information disclosure for stakeholders.

Results: The results of the study show that digital transformation significantly increases the potential for financial information accuracy through three main mechanisms, namely: (1) Robotic Process Automation (RPA)-based accounting process automation that suppresses errors due to human error and strengthens data integrity; (2) the application of Blockchain that inherently improves the integrity and reliability of data through the immutable nature and triple-entry accounting mechanism; and (3) the use of Big Data Analytics which enables real-time risk analysis and asset valuation with a higher level of predictive accuracy. However, the increase in accuracy is accompanied by serious challenges to transparency, especially related to the "black box" problem of AI algorithms that make it difficult to verify assumptions and assessment objectivity, as well as the complexity of massive data management that hinders source tracking and data cleansing methodologies.

Conclusion: This study concludes that digital transformation has the potential to strengthen the quality of financial reporting, especially in terms of information accuracy, but simultaneously poses a risk of decreased transparency if not managed adequately. Therefore, the realization of the benefits of digital technology requires the support of adaptive regulation and governance.

Contributions: This research contributes theoretically by expanding the digital accounting discourse through the integration of the CIA's Triassic framework in the analysis of financial reporting transparency and accuracy. Practically, this study recommends the application of the Explainable AI (XAI) standard which is mandatory in financial reporting as well as the development of a digital audit framework that focuses on validating the integrity of input data and algorithm transparency, in order to ensure the quality and credibility of information for the capital market.

Keywords: Digital Transformation, Financial Transparency, Information Accuracy, Big Data, Blockchain, Digital Audit, Explainable AI.

Introduction

1.1. Background and Radical Transformation of the Financial Sector

The global financial sector is in the midst of an inevitable phase of radical transformation, driven by the massive acceleration of technological innovation. In the last decade, business processes that were traditionally manual, periodic, and based on physical documents, have now shifted to automated, *real-time*, and digital data-driven processes. This digital transformation, defined as the integration of technology into all aspects of a company's operations, has fundamentally changed the way financial data is generated, processed, verified, and communicated to stakeholders (Bhimani & Willcocks, 2014).

This change is not just an increase in efficiency, but a structural shift supported by three main technological pillars: (1) The availability of Big Data (*Big Data*) and its analytical capabilities (*Analytics*); (2) Artificial *Intelligence* (AI) and *Machine Learning* (ML) for automation and predictive decision-making; and (3) Distributed Ledger *Technology* (DLT), especially *Blockchain*, which promises to improve data integrity. The integration of this technology has revolutionized accounting, financial reporting, and auditing functions, promising unprecedented speed in the reporting cycle.

1.2. Information Quality Pillar: Transparency and Accuracy

In the capital market ecosystem, the quality of financial information is the foundation of trust and efficiency of capital allocation. This quality is measured based on two main interrelated pillars, as set out in the accounting conceptual framework: Transparency and Accuracy of Financial Information.

Financial Information Accuracy refers to the reliability of information, which means that the information must be a *faithful representation* of the entity's economic condition, free from material errors, and bias. Digitalization, through automation (RPA) and massive data verification, is intuitively supposed to improve accuracy by reducing the potential for *human error*.

Financial Information Transparency refers to openness, clarity, and ease of access to information for all stakeholders (Healy & Palepu, 2001). This ensures that the information presented is comprehensive enough to allow users, such as investors and regulators, to understand the condition and performance of the entity in the absence of significant *information asymmetry*. Transparency is very important because it strengthens public trust in financial statements.

Traditional financial reporting works on the assumption that accuracy can be verified through clear audit pathways and documented reporting measures, thus guaranteeing process transparency. However, in the digital era, this synergistic relationship between Accuracy and Transparency is beginning to be questioned.

1.3. Urgency of the Problem: Digitalization Conflict

Although ICT offers solutions to old problems, its adoption creates a new dilemma that is urgent to analyze: Is digital transformation, which increases Accuracy, simultaneously eroding Transparency?

1.3.1. Accuracy vs. Automation

On the one hand, technologies like *Blockchain* promise absolute accuracy due to their *immutable* nature and the audit trail inherent in every transaction (Yermack, 2017). *Big Data* analysis allows for *fraud detection* and estimation of asset values that are much

more predictively accurate than previous discretionary accounting models (Cao et al., 2020). Process accuracy is improved because *human intervention* is minimized.

1.3.2. Transparency vs. Algorithm Complexity

On the other hand, this increase in accuracy is achieved through the use of highly complex computational models, especially AI and ML. When an asset's value or risk allocation is determined by *machine learning* algorithms, the decision-making process is often incomprehensible or reexplained by humans. This phenomenon is known as the algorithm's "Black Box" problem.

The challenge of transparency arises when auditors or investors are required to verify the objectivity and assumptions behind AI-generated numbers. If this verification process fails due to the confidentiality or complexity of the algorithm, then trust in numbers—even if technically accurate—will collapse, creating a new, more severe information asymmetry.

In addition, the volume of *Big Data Inputs* used to train and run AI creates new transparency challenges regarding raw data sources, their validity, and data *cleansing methodologies*. The confidentiality of this data, which is often considered a competitive advantage, can hinder the openness required by capital markets.

1.4. Research Objectives and Contributions

By weighing this fundamental dilemma, this study aims to provide a critical and structured analysis of the dualistic impact of digital transformation on financial reporting. The specific objectives of this study are:

1. Analyzing Accuracy Improvement Mechanisms: Identify and dissect specifically how technologies (AI/RPA, *Blockchain*, and *Big Data*) mechanically improve the accuracy, data integrity, and predictive validity of financial information.
2. Identifying Transparency Failure Points: Analyzes how the complexity and nature of new technologies (especially *Black Box* AI issues and input data volumes) pose serious challenges to the principles of reporting transparency.
3. Formulating Regulatory and Audit Needs: Developing practical recommendations for regulators (such as OJK, IFRS, FASB) and the audit profession to bridge the gap between digital accuracy and transparency, particularly through the demands of XAI (*Explainable AI).*

2. Literature Review

This literature review provides a theoretical framework for analyzing the impact of digital transformation on the quality of financial information. The main focus is placed on the conceptual definition of Transparency and Accuracy, as well as an in-depth understanding of the mechanisms of disruptive technologies (AI, *Big Data*, and *Blockchain*) that are shaping the future of accounting and reporting.

2.1. Theoretical Foundations of Financial Information Quality

The quality of financial information is the foundation for the efficient functioning of the capital market. A conceptual framework of accounting (such as that established by the FASB or IFRS) identifies the fundamental and enhancing-qualitative characteristics of information.

2.1.1. Accuracy (Honest Representation)

Financial Information Accuracy is theoretically positioned under the fundamental characteristic of Honest Representation (*F aithful Representation*). Honest representation requires that information must be complete, neutral, and free from material errors (IFRS, 2018). In the digital context, accuracy not only means the correct number, but also includes:

1. Data Integrity: Data must not be altered after it has been recorded and must be consistent from source to final report.
2. Predictive Validity: The ability of reports, especially estimates and *valuations*, to accurately reflect future economic risks and values.

Digital transformation promises increased accuracy through the elimination of human error (neutrality) and an increase in the volume of verified data (completeness).

2.1.2. Transparency (Comparability and Comprehension)

Transparency is an improving characteristic, very closely related to Understandability and Comparability. Transparency ensures that information is presented clearly, concisely, and in enough detail so that users can understand the economic substance behind the reported numbers (Healy & Palepu, 2001). The *corporate disclosure* literature consistently shows that transparency is key to reducing *information asymmetry* between management and investors, ultimately lowering the company's capital costs (Bhimani & Willcocks, 2014).

In the digital context, transparency is challenged when the processes that generate numbers (e.g., the logic of AI algorithms) become complex or inaccessible to auditors and external users.

2.2. The Role of Disruptive Technologies in Accounting

Three key technologies are responsible for the radical transformation in the accounting and reporting cycle:

2.2.1. Big Data Analytics and Artificial Intelligence (AI)

Big Data Analytics allows companies to process data that has a very high volume, speed, and variety (*3 Vs*). The use of *Big Data* in accounting includes market sentiment analysis, *real-time* fraud *and anomaly* detection, and more accurate credit risk analysis (Cao et al., 2020).

AI and *Machine Learning* (ML) leverage *Big Data* to automate routine accounting tasks (*Robotic Process Automation* (RPA) and generate highly complex estimates (e.g., *Fair Value Accounting*). RPA directly improves operational accuracy by eliminating manual entry errors. However, the use of ML in assessment triggers interpretation and verification issues. Cao et al. (2020) highlight that AI, while improving predictive accuracy, can undermine transparency due to the *black box* mechanisms inherent in *deep learning models*.

2.2.2. Blockchain and Distributed Ledger Technology (DLT)

Blockchain is a distributed and encrypted ledger technology that has two fundamental properties: Immutability and Decentralization. Each recorded transaction is validated by the network and added to the chain with a timestamp, so theoretically, data integrity is guaranteed.

Yermack (2017) argues that *Blockchain* has the potential to replace traditional *double-entry* accounting systems with Triple-Entry Bookkeeping (Ijiri, 1989). In a *triple-entry* system, every transaction is verified and recorded by a third entity (*Blockchain* network), not just by the sender and receiver. This intrinsically guarantees the accuracy and integrity of the data at the *input* level, significantly reducing the need for external verification (*ex-post*) by auditors.

2.3. Literature on the Dilemma of Transparency vs. Accuracy

The latest academic literature focuses on the dilemma created by AI. There is a consensus that AI/RPA improves operational accuracy through automation. However, the biggest concerns center on transparency:

- Black Box issues: Studies such as Marr (2021) and Cao et al. (2020) show that the most accurate ML models (e.g., *Neural Networks*) are often also the most *unexplainable*. Auditors and regulators need a deep understanding of the variables and weights of the algorithms used to generate value estimates. If management can't explain why the algorithm produces certain numbers, reporting transparency is threatened, even if those numbers are proven to be predictively accurate.
- Input Data Transparency: Another challenge arises from the volume and variation of *Big Data* itself. Companies are often reluctant to disclose the source of the raw data used to train AI, as doing so can reveal a competitive advantage. The lack of transparency in input *data* (*garbage in, gospel out*) creates a risk that bias in raw data will be reinforced, ultimately leading to systemic bias and dishonest accuracy.
- DLT Regulation and Audit: Yermack (2017) highlights that while *Blockchain* promises integrity, its decentralized nature poses regulatory and jurisdictional transparency challenges. The accounting profession does not yet have clear standards regarding the recognition, measurement, and presentation of assets recorded in DLT in traditional financial statements (IFRS/GAAP). The lack of a regulatory framework creates uncertainty and inconsistencies, which undermine transparency.

3. Method

This study aims to analyze the dualistic impact of digital transformation on two pillars of financial information quality: Transparency and Accuracy. Because this issue is conceptual, multidisciplinary (involving accounting, information technology, and regulation), and based on the rapid evolution of industrial practices, this study adopts a structured qualitative methodology.

3.1. Types of Research and Methodological Justification

This research is classified as a *Qualitative Descriptive Literature Study*, by implementing the *Systematic Literature Review* procedure. This approach was chosen based on several key justifications:

1. Complex Conceptual Synthesis: Digital transformation in accounting is a new phenomenon that does not yet have a single, well-established theoretical framework. The *systematic review* method allows researchers to holistically collect, evaluate, and synthesize various conceptual models (e.g., the *Ijiri Triple-Entry* framework, *the Black Box* AI model, and the IFRS Information Quality standard) to build a comprehensive analytical framework.
2. Evidence-Based Validity: Compared to traditional literature reviews, *systematic reviews* use strict and transparent protocols in source selection, minimize selection bias, and ensure that the conclusions drawn are supported by credible academic evidence and industry practice (Tranfield et al., 2003).
3. Analysis of Dualistic Dilemmas: This study specifically analyzed the impact *of the double-edged sword*—increased accuracy versus decreased transparency. Descriptive qualitative methodologies are particularly appropriate for dissecting conflicting arguments and identifying technological mechanisms that support one pillar while challenging the other.

3.2. Data Sources and Data Collection Procedures

The data used in this study is secondary. To ensure reliability, only credible academic publications and authoritative documents are used as primary data sources.

3.2.1. Key Data Sources

The main data sources are divided into three categories, with an emphasis on relevance and credibility:

1. Reputable Scientific Journals: Articles from highly-indexed journals that focus on Accounting, Auditing, Management Information Systems (SIM), and FinTech (e.g., *Journal of Accounting Research*, *The Accounting Review*, *MIS Quarterly, and* Blockchain/AI-related *journals).*
2. Authority and Standards Reports: Official documents issued by global regulators and standard-setting bodies, such as IFRS (International Financial Reporting Standards), FASB (Financial Accounting Standards Board), AICPA (American Institute of CPAs), and reports from institutions such as the OECD or WEF that discuss the impact of AI and DLT on governance.
3. Theoretical Reference Book: A fundamental work that defines the core concepts of accounting (*Faithful Representation*) and disruptive technologies (*Triple-Entry Bookkeeping*, *Big Data theory*).

3.2.2. Search Procedure and Selection Criteria (Search Protocol)

Search procedures are conducted systematically in major electronic academic databases (ScienceDirect, Scopus, Google Scholar, and JSTOR) with a time span focused on the last five to eight years (2018–2025), to reflect the rapid development of AI and DLT.

Phase I: Keyword Determination and Database

The search was conducted using a combination of structured Boolean keywords that associate technology with accounting concepts:

- Set A (Technology): ("Artificial Intelligence" OR "AI" OR "Machine Learning" OR "ML" OR "Blockchain" OR "DLT" OR "Big Data")
- Set B (Information Quality Concept): ("Transparency" OR "Transparency" OR "Accuracy" OR "Accuracy" OR "Faithful Representation" OR "Black Box")
- Set C (Context): ("Financial Reporting" OR "Financial Reporting" OR "Accounting" OR "Accounting" OR "Audit")

The logical search combination used is: (Set A AND Set B AND Set C).

Phase II: Inclusion and Exclusion Criteria (Screening)

To maintain the focus and validity of the research, strict criteria are applied to the documents found:

Criteria	Inclusions (Accepted)	Exclusion (Denied)
Time Range	Publication in the last 8 years (2018–2025) to focus on the latest disruptive technologies.	Publication before 2018 (except for fundamental theoretical works such as Ijiri or Healy & Palepu).
Topic Relevance	Focus on the impact of ICT on accuracy, transparency, auditing, or *governance* in the context of financial (company) reporting.	Focus on ICT in the non-financial, e-commerce, or *personal finance fields* without the context of corporate reporting.
Methodology	Empirical, theoretical, or robust literature review from *peer-reviewed*	Opinion articles, news, blogs, or *working papers* that have not been finalized and validated.

Criteria	Inclusions (Accepted)	Exclusion (Denied)
	journals or official institutional reports.	

Each document that passes the *title* and *abstract screening* is then read in *full-text* to ensure compliance with the criteria.

3.3. Data Analysis Techniques

The data that was successfully extracted from the selected literature was analyzed using Thematic *Content Analysis*. The purpose of the analysis is to map the mechanism of technology into its impact (positive/negative) on Accuracy and Transparency.

3.3.1. Open Coding

The initial step involves *labeling (codes*) each identified technological mechanism. Examples *of codes*: *improving integrity through Blockchain immutability*, *risk of Big Data input data bias*, *difficulty in AI black box verification*, *RPA automation reducing human error*.

3.3.2. Developing Thematic Categories

Codes are grouped into higher categories and synthesized based on two pillars of information quality:

1. Theme 1: Accuracy Improvement Mechanisms: Covers all the technological mechanisms that improve Honest Representation and Data Integrity (e.g., *Triple-Entry Blockchain*, RPA Automation, AI Predictive Accuracy).
2. Theme 2: Transparency Challenges: Covers all the technological mechanisms that undermine Comprehension and Comparability (e.g., *Black Box Problem*, Data Input Complexity, DLT Regulation Issues).

3.3.3. Synthesis and Strategy Formulation

The final stage is to relate the two themes to formulate a dualistic dilemma. Evidence that supports increased accuracy is opposed to evidence that challenges transparency. This synthesis is then used to formulate logical and well-reasoned recommendations, especially regarding the need for XAI (*Explainable AI) standards* and the transformation of audit methodologies, which is the ultimate goal of this study. This process guarantees that the research conclusions are not only descriptive, but also normative and applicative.

4. Results and Discussion

This section presents key findings from the systematic review, which is grouped under two major themes—Improving Accuracy and Transparency Challenges—while also discussing the implications of this dualistic dilemma for the future of financial reporting.

4.1. Findings: Mechanisms for Improving Information Accuracy

Analysis of the literature confirms that digital technologies strongly contribute to the increased potential of financial information accuracy, particularly in terms of data integrity and predictive validity. This mechanism can be categorized into three main pillars:

4.1.1. Automation and Reduction of Operational Errors

The use of Robotic Process Automation (RPA) and artificial intelligence at the operational level drastically reduces the potential for *human error* which is the main source of inaccuracies (Bhimani & Willcocks, 2014). RPA automates data entry, reconciliation, and processing of recurring transactions with a consistency rate of nearly 100%. These findings support the characteristic *of Faithful Representation* which

requires information to be free from material errors. With reduced manual intervention, the integrity of operational data is improved, allowing accounting information to approach neutrality.

4.1.2. Data Integrity Through *Blockchain* and *Triple-Entry*

Blockchain technology offers a qualitative leap in Data Integrity. Its *immutable* and decentralized nature guarantees that once a transaction is logged and validated by the network, it cannot be manipulated by a single entity. The literature corroborates Yermack's (2017) view that *Blockchain* enables the practice of Triple-Entry Bookkeeping (Ijiri, 1989), where data is verified by a neutral third party (network), rather than just recorded by the sender and receiver. This mechanism intrinsically embeds the audit *trail* into the data itself, fundamentally improving data accuracy at the *input level* and reducing the risk of *internal fraud*.

4.1.3. Predictive Accuracy with *Big Data* and AI

AI and *Big Data Analytics* improve predictive accuracy in reporting. In contrast to traditional accounting models that rely on historical data and samples, AI is capable of analyzing *Big Data* volumes (internal and external, such as social media sentiment or supply chain data) in *real-time* (Cao et al., 2020). This capability allows for a more careful and *forward-looking* estimation of credit risk, the fair value of complex assets, and reserve needs, making financial statements more relevant and accurate in reflecting the risk and future economic value of the entity.

4.2. Findings: Challenges of Transparency in the Digital Age

Although accuracy is improved, the literature analysis identifies serious challenges that directly threaten the transparency of financial information, especially related to Understandability and *Comparability*.

4.2.1. AI *algorithm* "black box" dilemma

The biggest transparency challenge is the "Black Box" phenomenon inherent in sophisticated *Machine Learning* models (Marr, 2021). In the case of determining accounting estimates (e.g., *impairment test* or *Fair Value Accounting*) performed by *Deep Learning* models, the internal logic, variable weights, and assumptions that produce the final numbers are often not humanly explainable or verified.

This problem poses significant consequences:

- Incomplete Audits: Auditors, as independent guarantors of transparency, cannot provide a convincing opinion if they do not understand why the algorithm generates these figures. The audit process risks only verifying *the output* without validating the *input process* and its logic.
- New Information Asymmetry: Investors, who rely on transparency for decision-making, cannot compare the estimated quality of two companies if the two companies use different AI models with undisclosed logic. This undermines the

4.2.2. Complexity of Input Data and Competitive Confidentiality

The massive *volume of Big Data* creates transparency challenges at *the input* level. The accuracy of AI estimation is highly dependent on the quality of the raw data. However, companies tend to keep the external data sources, *data cleansing* methodologies and features used by AI models confidential, citing competitive secrecy. This lack of disclosure creates a risk that the biases present in the raw data (*garbage in*) will be passed on and reinforced by the algorithm, meaning the resulting accuracy may be technically statistically correct but not dishonest substantially. Auditors and regulators need transparency on *inputs* to verify neutrality.

4.2.3. DLT Regulation and Compliance Issues

Although *Blockchain* guarantees data integrity, its decentralized and often *permissionless nature* raises regulatory transparency issues. Accounting practices do not yet have a standard of how assets and liabilities recorded in DLT should be recognized, measured, and presented in IFRS/GAAP financial statements (Yermack, 2017). The lack of a clear regulatory framework creates uncertainty, inconsistencies in reporting between companies, and difficulties for regulators in tracking compliance, all of which undermine Transparency.

4.3. Discussion: Bridging the Dualistic Dilemma

The impact of digital transformation on financial reporting can be summed up as a dualistic dilemma: technology provides the best tools to achieve Accuracy (through better data integrity and prediction), but complexity and lack of adaptive regulation threaten Transparency.

Bridging this dilemma requires shifting the focus from just the output to the process and validity of the algorithm. The solution does not lie in limiting innovation, but in developing an *Algorithmic Governance* framework.

Therefore, the accounting profession must adopt technology-centric principles:

1. XAI (Explainable AI) standardization: Regulators should require companies to provide adequate documentation of AI processes, including model assumptions, bias testing, and disclosure of weights of key variables that affect material estimates. This is the only way to address *the black box* problem and restore transparency.
2. Transformation of Audit to Continuous Auditing: The audit methodology should shift from *ex-post* sample testing to Continuous Audit which involves real-time *testing of input data* and validation of algorithmic code. Future auditors must be experts in *Data Science* to guarantee that digital accuracy is underpinned by process transparency.

With this adaptation, digital transformation can serve as a catalyst for more accurate *and* more transparent accounting.

5. Conclusion

5.1. Summary of Critical Findings and Reaffirmation of Research Objectives

This research aims to critically analyze the dualistic impact of digital transformation, driven by *Big Data*, AI, and *Blockchain*, on the two pillars of financial information quality: Transparency and Accuracy. Through a systematic review of the academic literature and industry practice, the fundamental conclusion drawn is that digital transformation is a double-edged sword that simultaneously drives accuracy while posing a serious risk to transparency.

Improved Accuracy: The findings confirm that digitalization fundamentally increases the potential for accuracy through three main mechanisms: (1) Automation of accounting processes with RPA and AI, which minimizes *human error* and ensures consistency (Bhimani & Willcocks, 2014); (2) Absolute Improvement of Data Integrity through the *immutable* and decentralized nature of Blockchain, which supports *the Triple-Entry Bookkeeping* model (Yermack, 2017); and (3) Improved Predictive Accuracy in asset valuation and risk management thanks to the ability *of Big Data Analytics* and *Machine Learning to process* real-time volumes of data that is impossible for human analysts to reach (Cao et al., 2020).

Transparency Challenges: While accuracy is improving, the biggest challenge lies in the Process Transparency that generates these numbers. The main challenge identified is the "*Black Box*" problem of AI algorithms, where the complexity of *deep learning models*

prevents auditors, regulators, and investors from understanding or verifying the logic and assumptions underlying critical financial estimates (Marr, 2021). In addition, the Massive Complexity of Input Data and the company's unwillingness to disclose raw data cleansing methodologies and external data sources (citing competitive secrecy) create new information asymmetry, undermining Comprehensibility and Comparability.
This dilemma demands adaptation. If digital accuracy is not supported by adequate transparency, market confidence will be threatened, and the numbers produced—even if technically correct—will be considered unfaithful *representation* because the external verification process fails.

5.2. Policy and Practical Implications

The findings of this study yield urgent implications for global regulators and professional practices.

5.2.1. Policy and Regulation Implications

Regulators such as IFRS, FASB, and OJK must take a proactive role in establishing an adaptive *Algorithmic Governance* framework. Crucial policy implications include:

1. Mandatory XAI (*Explainable AI)* Standard: There is a need to develop and establish reporting standards that require entities to disclose comprehensive, auditable documentation of AI algorithms used in material assessments and estimates. This documentation should include model assumptions, weights of variables used, bias testing, and *error-handling* mechanisms. XAI demands are the only way to solve the *black box* problem and restore process transparency.
2. DLT/Blockchain Accounting Framework: Accounting standards should be updated to provide clear and consistent guidelines regarding the recognition, measurement, and presentation of assets and liabilities recorded through *Distributed Ledger Technology*. Regulations should address jurisdictional issues and compliance identification needs in a decentralized environment to ensure Comparability.
3. Monitoring the Quality of Input Data: Regulators need to establish stricter disclosure requirements regarding the source and methodology of *Big Data* cleansing used to train AI models. The goal is to mitigate the risk *of data bias* that can lead to systemically dishonest accurac.

5.2.2. Practical Implications for the Audit Profession

The audit profession (internal and external auditors) must undergo a fundamental transformation to be relevant in the digital age. Practical implications include:

1. Transition to *Continuous Auditing*: Audit methodologies should shift from *ex-post* sample-based testing to *continuous auditing* models that involve *real-time* data monitoring and automation testing. This makes use of the accuracy offered by the technology itself.
2. Improved Data Science *Competency*: Future auditors must complement traditional accounting skills with *Data Science competencies*, including an understanding of programming languages, advanced statistics, and algorithmic code auditing . This capability is critical to being able to validate the internal logic of *the black box* model and test the integrity of *Big Data inputs*.
3. AI Audit Tool Development: Audit firms need to invest in the development of their own AI and ML tools to validate *client outputs and processes, creating* an AI vs. AI audit environment *that can compete with the complexity of audited technologies.*

5.3. Research Limitations and Further Research Suggestions

This study provides a conceptual synthesis and a strong strategic framework but has methodological limitations because it is a descriptive qualitative literature study. The study relies on available publications and theoretical views, rather than primary empirical data (e.g., audit test results of actual AI models in companies).

Further Research Suggestions: Future research is strongly recommended to conduct empirical validation to measure hypothesized impacts:

1. Experimental Studies on XAI: Conducting an experimental study in which investors are presented with AI-generated financial statements of different XAI levels, to measure the impact of XAI on their perceptions of Transparency, Trust, and investment decisions.
2. Algorithm Audit Empirical Research: Conduct extensive case studies or surveys with large audit firms (*Big Four*) to document and evaluate the methodologies and practical challenges they face in auditing *code* and *Big Data* inputs from ML models used by clients.
3. Cost vs. Benefits of DLT Modeling: Perform quantitative modeling to compare the cost of *implementing Blockchain* for *Triple-Entry Bookkeeping* with the benefits gained from reduced audit costs and increased stock prices (due to higher transparency).

By focusing on the empirical validation of new regulatory and audit frameworks, future research can ensure that digital transformation in the financial sector actually supports a more stable, accurate, and transparent capital market.

5. Conclusion (1000 Word Development)

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DIGITAL TRANSFORMATION AS A DRIVER OF BUSINESS GROWTH: OPPORTUNITIES AND RISKS FOR GROWING COMPANIES

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Abstract

Objective: This study aims to analyze how digital transformation plays a role as a driver of business growth in emerging companies, as well as identify challenges and risks that arise during the process of implementing digital technology (Matt, Hess, & Benlian, 2015; Vial, 2019).

Methodology: This study uses a qualitative approach through a systematic literature review that summarizes research related to digitalization, technological innovation, and organizational readiness to face the dynamics of the Industry 4.0 era. The analysis was carried out based on academic sources that discuss the integration of technologies such as Artificial Intelligence, Internet of Things, and big data as part of the company's digital strategy (Schwab, 2016).

Results: The results of the study show that digital transformation is able to strengthen productivity, expand market coverage, and increase the competitive strength of developing companies through the creation of new value and process efficiency (Brynjolfsson & McAfee, 2014). However, the findings also reveal the existence of major obstacles, including high investment needs, reliance on digital infrastructure readiness, and increasing cybersecurity risks (Susanti et al., 2023). In addition, the success of implementation is greatly influenced by the readiness of human resources in adopting a digital work culture (Westerman, Bonnet, & McAfee, 2014).

Conclusion: Digital transformation can serve as a strategic foundation for emerging companies to improve performance and competitiveness. However, the digitalization process requires an adaptive strategy that takes into account internal capabilities, technological readiness, and organizational culture changes.

Contributions: This research makes a theoretical contribution by offering a comprehensive understanding of the driving factors, challenges, and impacts of digital transformation on emerging companies. In addition, the results of this study can be a practical reference for business people in designing digital strategies that are sustainable and responsive to technological changes.

Keywords: Digital transformation; Industry 4.0; The company is growing; Business growth; Digital risks; Competitive advantage; Information technolog

Introduction

The development of digital technology in the last two decades has created significant structural changes in almost all industrial sectors in the world (Schwab, 2016). This transformation shifts traditional business patterns towards an ecosystem that is increasingly integrated with data, automation, and artificial intelligence, so companies are required to adapt their operational processes in a more innovative way (Vial, 2019). The Industrial Revolution 4.0, which is the fourth phase of global industrial development, has given rise to various cutting-edge technologies such as Artificial Intelligence, Internet

of Things, Cloud Computing, and big data analytics that directly affect the organization's growth strategy (Lasi et al., 2014). In this context, digital transformation is not just the introduction of new technologies, but is a fundamental change in the way organizations create value and conduct their business activities (Westerman, Bonnet, & McAfee, 2014).

Emerging companies, which are in the transition phase from small businesses to more established organizations, are the group that needs the most adaptation to these digital developments (Nambisan et al., 2017). This is due to the increasingly fierce market competition, especially with the presence of technology-based companies that are able to move faster and flexibly in responding to customer needs (Brynjolfsson & McAfee, 2014). Awareness of the urgency of digital transformation is increasing along with evidence that organizations that effectively execute digital strategies tend to have higher growth than companies that are slow to adapt (Kane et al., 2015). These changes not only have an impact on technological aspects, but also on organizational structures, work culture, and increasingly data-driven decision-making patterns (Hess et al., 2016).

On the other hand, digital transformation also opens up great opportunities for emerging companies to expand markets and improve operational efficiency (Verhoef et al., 2021). By utilizing digital technology, companies can reduce production costs, improve service quality, and accelerate the product innovation process (Bharadwaj et al., 2013). The use of real-time data allows companies to better understand customer behavior so that marketing strategies can be adjusted more accurately (Chen, Chiang, & Storey, 2012). In addition, digital platforms such as e-commerce, social media, and digital payment systems provide new growth opportunities for emerging companies, especially in expanding global markets without large geographical barriers (Liu & Kumar, 2021).

However, the digital transformation process does not always run smoothly and presents challenges that need to be seriously considered (Susanti et al., 2023). One of the main obstacles is the high cost of implementing the technology which is often a burden for emerging companies that have limited capital (Matt, Hess, & Benlian, 2015). In addition, reliance on digital infrastructure, such as a stable internet network and a robust data security system, is a crucial factor in determining the success of digital transformation (Omar, Leach, & March, 2020). Developing companies also face an increasing risk of cyberattacks along with the increasing intensity of digital technology use, so that information security protection is a necessity that cannot be ignored (Susanti et al., 2023).

The human resource aspect is also an important challenge in the digital transformation process because the success of this change is highly dependent on the ability of employees to adopt new technologies (Kane et al., 2015). Many developing companies are still experiencing a digital competency gap, where employee capabilities are not in line with the ever-evolving technology needs (Hess et al., 2016). Lack of training and lack of technology-based work culture are obstacles that can hinder the effectiveness of digital transformation in the long term (Vial, 2019). In addition, resistance to change often arises because employees feel unprepared for new work systems that demand speed, automation, and more data-intensive utilization (Nambisan et al., 2017).

Digital transformation also brings strategic implications related to business risks, such as uncertainty over investment returns, potential system implementation failures, and highly dynamic changes in customer preferences (Verhoef et al., 2021). Developing companies must be able to balance opportunities and risks by formulating a digital

strategy that is systematic, measurable, and in accordance with the capacity of the organization (Bharadwaj et al., 2013). Companies that are able to manage digital risk well tend to have greater business resilience in the face of rapid market changes (Liu & Kumar, 2021). Therefore, the digital transformation process requires careful planning and strong managerial support in order to have a positive impact on the company's long-term growth (Matt, Hess, & Benlian, 2015).

Within this framework, research on digital transformation as a driver of business growth is becoming increasingly relevant to understand, especially for emerging companies that are in the expansion phase (Schwab, 2016). Analysis of the opportunities and risks arising from this digitalization process is important to help organizations formulate more adaptive and innovative strategies in running their business operations (Vial, 2019). This article seeks to examine how digital transformation can serve as a key driver of business growth while identifying the risks that companies need to pay attention to in their implementation process (Bharadwaj et al., 2013). By understanding these two aspects, it is hoped that companies can create a more comprehensive and sustainable digital strategy in the face of modern economic challenges (Verhoef et al., 2021).

Research Methodology

This research uses a descriptive qualitative approach to understand how digital transformation plays a role as a driver of business growth and the risks faced by companies to develop during its implementation process (Creswell, 2014). This approach was chosen because it allows researchers to explore the phenomenon in depth through the interpretation of the literature, empirical findings, and previous research results related to digitalization in an organizational context (Merriam & Tisdell, 2015). Through qualitative analysis, this study seeks to provide a comprehensive picture of the opportunities and challenges of digitalization without being tied to rigid numerical variables (Patton, 2015).

This research method adopts literature study techniques as the main source of data collection. The literature analyzed includes reputable international journals, research reports, academic books, as well as scientific publications that discuss digital transformation, business growth, and technological risks (Snyder, 2019). The use of literature studies was chosen because it provides a strong theoretical basis and allows researchers to compare various research results relevant to the digitalization phenomenon in emerging companies (Xiao & Watson, 2019). In addition, this method is effectively used to identify current research patterns, gaps, and trends that can enrich data analysis (Webster & Watson, 2002).

The literature selection process is carried out through several stages to ensure the quality and relevance of the data. The first stage is to search literature using keywords such as *digital transformation*, *business growth*, *SMEs*, *digital risks*, and *Industry 4.0* in databases such as Google Scholar, ScienceDirect, and JSTOR (Snyder, 2019). After that, screening is carried out by year of publication, with priority on sources between 2010–2024 to ensure that the data used reflects the latest developments in the field of digital transformation (Xiao & Watson, 2019). The literature is then systematically analyzed to ensure its fit for the research focus.

The data analysis technique uses the thematic analysis method, which is the process of identifying, grouping, and interpreting the main themes that emerge from the collected literature (Braun & Clarke, 2006). This approach makes it easier for researchers to organize information into several categories, such as digital transformation opportunities, factors driving business growth, implementation challenges, and strategic risks that arise

for emerging companies (Clarke & Braun, 2014). Thematic analysis was chosen because it is flexible and able to describe complex phenomena in the context of organizations that are being digitally transformed.

In order to produce an objective analysis, this study applies the source triangulation technique, which is comparing findings from various publications to ensure the consistency of information and reduce the subjectivity of interpretation (Flick, 2018). This step is done by matching research results from various authors, organizations, and theoretical perspectives so that the conclusions obtained have a higher level of credibility (Patton, 2015). In addition to triangulation, an evaluation of the quality of the literature was also carried out using criteria such as relevance, validity of research methods, and contribution to the development of science (Merriam & Tisdell, 2015).

The scope of this research is limited to growing *firms*, which are organizations that are in the expansion phase and have high digital adaptation needs (Nambisan et al., 2017). The focus of the research includes the analysis of digital transformation opportunities in strengthening business growth and the evaluation of risks that arise in the implementation process. This study did not collect field data, so the findings produced are a synthesis of existing academic literature (Snyder, 2019). Nonetheless, this approach still provides an in-depth understanding of the patterns and strategic implications of digital transformation for emerging companies.

With this methodology, the research is expected to provide theoretical and practical insights into how emerging companies can effectively leverage digital transformation as well as what strategies need to be considered to minimize the risks of its implementation. This literature-based approach also provides a solid foundation for future research that can use empirical methods to expand the understanding of the phenomenon of digitalization in the context of business growth (Braun & Clarke, 2006).

3. Discussion: Digital Transformation in MSMEs: Structural, Operational, and Long-Term Impacts

Digital transformation (TD) has become the center of attention in discussions about the development of MSMEs in Indonesia. This major change not only touches the way MSMEs manage their business, but also affects people's consumption patterns, marketing strategies, and competition dynamics between business actors. In an era that is fully automated, MSMEs are required to be more adaptive so as not to be left behind in the competition. A McKinsey report (2021) shows that the digitalization of MSMEs has the potential to significantly increase economic contributions, especially through increased productivity and market expansion. This means that digital transformation is no longer an optional option, but rather a fundamental necessity in the modern business ecosystem.

3.1. Paradigm Change of MSMEs from Manual System to Digital Operation

Digital transformation has changed the way MSMEs conduct business activities from traditional processes that rely on intuition to systems based on data and technology. This shift not only touches on operational aspects, but also reshapes the mindset of business owners in looking at efficiency, service quality, and growth opportunities. In the era before digitalization developed, most MSMEs operated their businesses with manual work patterns: recording using notebooks, stock counting with estimates, promotions based on social relations, and highly subjective decision-making. This condition makes MSMEs tend to be stagnant, difficult to develop, and vulnerable to operational errors (Tambunan, 2020).

Major changes are starting to occur as digital technologies become more accessible. The presence of cheap smartphones, free financial applications, marketplaces, and social platforms paves the way for MSMEs to change the way they work. Digitalization is not just about using applications, but updating the business structure to be more systematic, scalable, and responsive to market changes. According to Westerman, Bonnet, and McAfee (2014), digital transformation is a change that leads to deep integration between business processes and technology, where organizations no longer use technology as a supporting tool, but as the main foundation of operational strategy.

Before digitalization, MSMEs relied heavily on experience and habits in determining business steps. For example, business owners often decide on production volumes based only on previous sales estimates without data trend analysis. This has caused many MSMEs to experience inventory problems, both in the form of overstock that burdens capital, and lack of stock that makes customers disappointed. Similar problems also occur in financial management. Many MSMEs do not have a neat record, so they cannot accurately measure profits or determine the right pricing strategy. This situation is in line with the Bappenas report (2023) which shows that more than half of Indonesian MSMEs do not have an adequate financial recording system.

Digitalization overcomes most of these obstacles. With digital cashier applications such as Moka, KasirPintar, or Olsera, MSMEs can record transactions automatically, calculate daily profits, manage stock, and analyze which products sell best. This system makes decision-making data-driven, no longer assumptions. For example, food MSMEs can know the highest sales hours and the most frequently purchased menus, so they can adjust production patterns and promotion strategies.

In addition, digitalization is changing the way MSMEs access the market. In the era before digital technology developed, MSMEs only reached consumers around their area. Promotions are carried out by distributing pamphlets, putting up banners, or relying on recommendations from customers. However, after entering the digital era, MSMEs can reach a much wider range of consumers through platforms such as Instagram, TikTok, WhatsApp Business, and marketplaces such as Shopee and Tokopedia. Schwab (2016) explained that the ability to expand market reach quickly is one of the main characteristics of the Industrial Revolution 4.0 era, where physical boundaries are increasingly irrelevant.

Digitalization also has an impact on the professionalism of MSMEs. The existence of features such as ratings, customer reviews, digital catalogs, and non-cash payment methods makes small businesses look more reliable and modern. Digital payments such as QRIS, for example, provide ease of transactions while increasing automatic financial records. This change reflects the concept of operational excellence discussed by Porter (2008), where efficiency and service quality are the pillars of competitiveness.

Not only that, digital transformation is changing the communication pattern between MSMEs and customers. In the past, communication was passive and limited, but now MSMEs can build two-way relationships through chat, comments, DMs, and interactive content features. This option provides an opportunity for MSMEs to understand customer needs more deeply, increase responsiveness, and build a loyal community around their brand. This flow is in line with the findings of McKinsey & Company (2021) which emphasizes that digital interactions play a big role in shaping customer experiences and strengthening brand engagement.

Paradigm shifts are also seen in the way MSMEs view innovation. MSMEs that were previously reluctant to try new things are now encouraged to innovate because digital competition is getting tighter. Business owners are required to understand content trends, study customer behavior on social media, and adopt new technologies to maintain relevance in the market. For example, fashion MSMEs now take advantage of live streaming features to increase interaction and accelerate sales conversions.

Overall, digital transformation is not only changing the operational methods of MSMEs, but also reshaping the mindset of business owners. Those who were previously comfortable with traditional methods are finally realizing that digitalization offers much greater opportunities in terms of efficiency, productivity, and growth. As Westerman et al. (2014) explain, organizations that successfully carry out digital transformation are those that are able to change internal cultures to be more adaptive, data-driven, and innovation-oriented.

Thus, the paradigm shift from manual systems to digital operations is not just a technical phenomenon, but an overarching transformation that connects technological aspects, business strategies, and mindsets. MSMEs that are able to adapt to these changes have the potential to become more competitive and have a greater opportunity to develop in the midst of global competition.

3.2 Business Model Change and Value Innovation through Digital Transformation

Digital transformation is not only changing the way companies operate internal processes, but also fundamentally reshaping **business models** . This shift is happening because digital technology is enabling organizations to create, deliver, and capture value in ways that were previously impossible. As stated by Amit and Zott (2021), the modern digital business model is built on three main pillars—novelty, lock-in, and complementarities—that allow companies to create differentiations that are difficult to replicate. In other words, digitalization does not stop at the use of technological devices, but transforms into a value transformation strategy that has an impact on revenue structures, cost systems, and relationships with consumers.

In the context of MSMEs and developing companies, business model transformation often appears in the form of **digital storefronts**, marketplace integrations, and application-based services. Companies that used to rely on a face-to-face transaction approach are now shifting to a hybrid model that combines online and offline sales. According to Teece (2018), digital business model adaptation is a form of dynamic capabilities that allow companies to respond to market changes more quickly. In practice, this provides an opportunity for small companies to compete with large players through the use of more efficient and scalable digital distribution channels.

One real example is *Kopi Kenangan* MSMEs, which initially only relied on physical outlets, but grew rapidly after integrating ordering applications and data-based customer management systems. By utilizing consumer purchasing patterns, companies are able to design new menus, personalize promotions, and predict demand spikes based on store locations. The impact of this change in business model not only increases revenue, but also creates significant operational efficiencies. Similar findings were revealed by Verhoef et al. (2021), who stated that companies that switch to digital business models experience an increase in customer loyalty on average because consumers feel they are getting a faster, relevant, and more accessible experience.

In medium-sized growing companies, business model changes are usually more complex, especially when companies start using **digital platforms** as a core element of the business. Companies in the logistics sector, for example, are developing IoT-based

tracking services that allow customers to monitor the position of goods in real time. Models like this create new value because process transparency and certainty of delivery time increase customer confidence. This view is in line with Nambisan et al. (2019), who emphasized that digital platforms are able to generate value innovation through connectivity mechanisms and ecosystem orchestration.

In addition to product and service innovation, digital transformation also encourages changes in **subscription**, **membership**, or **freemium-based business models**, which were previously more dominant in large technology companies. Today, this system is being implemented by small companies—for example, local online education services that offer free content as an "entry point," then provide premium classes as the main source of revenue. Strategies like this have been proven to increase customer engagement because they provide an opportunity to try out services before making a purchase. According to Gassmann et al. (2020), the freemium model allows companies to maximize the scale of the platform, where the value of the business increases as users increase.

Changes in business models also often affect the cost structure. Digitalization can reduce operational costs through automation, but it also creates new cost needs such as cloud services, cybersecurity systems, or software licensing. However, research by Bharadwaj et al. (2022) shows that despite considerable upfront costs, the adoption of digital business models in the long term has been shown to increase profit margins as companies can reduce inefficiencies and improve service personalization.

In the context of value innovation, digitalization also encourages the emergence of **a data-driven value creation** approach. Companies not only sell products or services, but also additional value such as personalized recommendations, automated after-sales service, or analytics dashboards for customers. For example, a fashion MSME can use sales data to recommend outfits based on previous purchase styles. This creates added value that increases consumer convenience and strengthens the company's competitive position. As stated by Osterwalder and Pigneur (2010), the right value innovation will strengthen the *value proposition* so that companies have a strong reason for consumers to continue to choose their products.

The transformation of business models also opens up opportunities for emerging companies to enter new markets with relatively little risk. By leveraging digital platforms and marketing automation, companies can expand their geographic reach without having to open physical branches. This can be seen in various local MSMEs that have started exporting products through global marketplaces. This cross-regional expansion capacity is supported by the ease of digital logistics, creating a faster growth pattern than traditional business models. This view is reinforced by Yoo et al. (2017), who explain that digitalization removes geographical boundaries and allows companies to create global markets instantly.

Thus, changing business models through digital transformation is not only about technology modernization, but also the process of re-engineering the company's core strategy. Companies that successfully innovate value through digitalization tend to have stronger competitiveness, more efficient cost structures, and greater opportunities for market expansion. However, this success still depends on the company's ability to strategize in line with customer needs, internal capacity, and the dynamics of the ever-evolving digital ecosystem.

3.3 Comparative Analysis of MSME Performance Before and After Digital Transformation

Digital transformation is not only present as a symbol of modernization, but also brings real changes to the way MSMEs operate, interact with customers, and manage internal resources. To provide a more comprehensive picture of the impact, this section presents a comparison between the conditions of MSMEs before and after the implementation of digitalization. This analysis serves to show the most significant patterns of change, as well as illustrate how digital tools create added value through efficiency, increased revenue, and expanded market access (Rahayu & Day, 2015; OECD, 2021).
The following table illustrates fundamental changes in various aspects of MSME operations and businesses that have implemented digitalization.

Table 1. Comparison of MSME Conditions Before and After Digital Transformation

Aspects	Before Digital Transformation	After Digital Transformation
Marketing	Relying on conventional marketing (brochures, posters, word of mouth). Limited market reach.	Utilizing social media, marketplaces, and digital advertising with a wider and segmented target audience.
Sales	Sales are only done offline. It depends on the number of customers who come in person.	Sales are carried out in a hybrid manner (offline-online). Transactions are increasing through e-commerce and online checkout features.
Operational	Manual logging, error-prone, slow when recap data.	POS systems, digital accounting, and automated stock management improve accuracy and efficiency.
Customer Relations	There is no structured customer data. Limited communication.	Customer databases are available. Retargeting, personalized promotion, and responsive service through chatbots/DMs.
Cost Efficiency	Promotion and operational costs are higher. Planning is not optimal.	Promotional costs are cheaper but have a wide reach. More efficient operations through automation.
Business Decisions	Relying on the owner's intuition, minimal data.	Use analytics, performance dashboards, and real-time reports for decision-making.
Market Access	It only reaches local areas.	Able to reach national and even international markets through digital platforms.
Competitiveness	Losing competition with bigger brands that are more modern.	Competitiveness increases due to better customer experience and faster processes.

The table shows that digital transformation has a significant impact on almost all aspects of the MSME business. In terms of marketing, digitalization allows MSMEs to expand their communication reach through social media and e-commerce platforms. The ability

to target consumers more precisely makes promotional strategies more effective and cost-effective (Rahman & Wijaya, 2020).

In the operational aspect, the use of digital recording systems, automated inventory management, and financial applications has been proven to reduce the rate of administrative errors. According to Putri and Santoso (2022), MSMEs that use POS applications have experienced an increase in operational efficiency of up to 30% because the stock recap and monitoring process can be carried out in real-time.

The biggest change is seen in decision-making. Before digitalization, many MSMEs relied on the owner's intuition, so strategic decisions were not always data-driven. After adopting simple analytics—such as Instagram insights, marketplace dashboards, or digital sales reports—MSME actors can understand demand patterns, customer behavior, and the best time to promote. This improves decision accuracy and minimizes business risk.

In addition, expanding market access is one of the most prominent benefits. MSMEs that initially only reached consumers around physical locations are now able to penetrate regional and national markets. Some have even penetrated foreign markets through digital export platforms such as Tokopedia Export Hub or the GoBiz International program. This condition confirms that technology is able to remove geographical barriers that previously limited business growth opportunities.

From the overall analysis, it can be seen that digital transformation has significantly increased the competitiveness of MSMEs. Both in terms of efficiency, increased revenue, and the ability to understand customer needs, digitalization is a key factor that determines business sustainability in today's digital economy era.

3.4 Digital Transformation to Operational Efficiency and Strengthening Cost Structure

Digital transformation has a major impact on the way companies, especially MSMEs, manage their daily operational processes. In the modern business era, operational efficiency and adaptive cost structure are two important factors that determine a business's ability to survive and grow. Digitalization allows companies to automate, speed up work processes, reduce human error, and build a more compact cost structure than traditional operating models (Bouwman et al., 2019; Deloitte, 2022).

Before digitalization was widely introduced, most MSMEs carried out operational processes manually. Transaction recording, stock management, financial statement calculation, and customer service processes are carried out without digital tools. This condition causes many businesses to experience inefficiencies, such as longer processing times, high reliance on labor, and high potential for document errors and data loss. According to a Deloitte study (2022), MSMEs that have not adopted digital tools spend 40–60% longer preparing monthly reports than similar companies that have used automated systems.

Digitalization brings real changes through the use of software and platforms such as Point of Sales (POS), digital bookkeeping applications, automated inventory management systems, and customer relationship management (CRM). The use of POS, for example, provides the benefits of automatic sales recording, real-time stock monitoring, and inter-branch integration so that business owners can see sales performance at any time without having to be present at the location. Research by Putra and Wicaksono (2021) shows that the use of POS can increase recording accuracy by up to 95% and reduce stock loss (shrinkage) by 18%.

Digital transformation also has an impact on the operational cost aspect. With automation, companies can reduce the need for manpower for administrative work and focus resources on more strategic activities such as marketing, product innovation, or service quality improvement. In addition, the use of cloud technology makes the cost of data storage cheaper and more secure than physical storage, which often requires additional costs for maintenance and security. This is in line with the findings of Bouwman et al. (2019) that digitalization shifts the cost structure from high fixed costs to more flexible cost models, such as subscription-based services.

Operational efficiency also supports the company's ability to deal with fluctuations in market demand. With real-time data, companies can adjust production quantities, manage inventory more precisely, and avoid unnecessary stock buildups. Food and beverage MSMEs, for example, can use sales forecasting applications to predict demand on certain weekends or seasons. This strategy helps them reduce food waste while maintaining the quality of service to customers. A study by Johansen and Müller (2020) shows that companies that utilize predictive analytics are able to increase production efficiency by up to 25%.

In addition, a lighter cost structure makes MSMEs better prepared to face economic uncertainty. When external pressures occur, such as an increase in the price of raw materials or a decrease in people's purchasing power, the use of digital systems helps companies maintain efficiency so that they do not immediately experience an increase in operational costs. This is especially important for MSMEs that have relatively small profit margins and are vulnerable to cost changes.

Not only stopping there, digitalization also plays a role in improving the consistency of service quality. Automated systems, such as chatbots or quick response services through applications, allow MSMEs to provide a more stable customer experience without the need to add many service staff. Thus, digitalization not only reduces costs but also improves the quality of a company's interaction with customers (Marques & Ferreira, 2020).

From the overall analysis, it can be concluded that digital transformation makes a great contribution to strengthening the operational efficiency of MSMEs. The implementation of digital systems allows for cost savings, improved data accuracy, and faster and more responsive work processes. With a more flexible cost structure and increasingly adaptive operational capabilities, growing companies have a greater opportunity to optimize resources and maintain competitiveness in an increasingly competitive business landscape.

Examples of Real Cases in Improving MSME Operational Efficiency

One concrete example that illustrates the impact of digital transformation on operational efficiency is the culinary MSME *"Roti Bakar Arjuna"* in Bandung. Before digitization, all operational processes were carried out manually—starting from recording orders, raw material stocks, to daily financial statements. As a result, owners often face classic MSME problems such as stock differences, long queues because orders are recorded manually, and daily reports that are only completed late at night. In addition to wasting a lot of time, this manual process makes business decisions less accurate because they are not supported by real-time data.

In 2021, the venture began adopting a simple POS system that integrates with cashier applications, inventory, and automated daily reports. After three months of use, owners report that queues during peak hours are reduced by almost 30% because the order entry

process is much faster. Additionally, the inventory app helps owners avoid running out of raw materials suddenly, as the system provides notifications when stocks start to run low. The accuracy of sales recording is significantly improved so that daily profits can be clearly monitored without the need for repeated checks.

Another example can be seen in the local fashion MSME *"KainNusa"* which sells products through small stores in Yogyakarta. Prior to digital transformation, stock recording was often out of sync between offline and online sales, leading to double-selling on some products. In addition, monthly financial statements take up to a few days to prepare. After switching to using a digital bookkeeping system and integrating marketplaces with inventory software, these MSMEs managed to reduce stock recording errors by almost 90%. The process of compiling monthly reports that previously took days can now be completed automatically in minutes, as sales data is connected directly to the bookkeeping system.

In terms of cost, the two MSMEs have received significant benefits. *Roti Bakar Arjuna* has succeeded in reducing the need for additional labor at the cashier department because the POS system simplifies the sales flow. Meanwhile, *KainNusa* can shift manual recording costs to digital marketing investments that are proven to increase exposure and sales. These two cases show how digital transformation not only impacts the speed of work, but also creates a more efficient and flexible cost structure.

In general, these cases confirm that digitalization has a real impact on MSMEs in Indonesia. Operational processes become more accurate, efficient, and targeted, while cost structures become lighter due to the automation of various manual activities. Thus, the application of digital technology is not only theoretical, but also provides practical benefits that can be directly felt by business actors.

Case Example 3: MSMEs Laundry Service "Clean+ Laundry Service", Surabaya

MSMEs for services such as laundry also show a big impact of digital transformation on work efficiency. Before digitization, *Clean+ Laundry Service* managed the entire process manually, from order recording, estimated completion time, to calculating the weight of customer clothes. This manual system makes several problems arise, such as:

Inaccuracy of the estimated retrieval time.

Customers' clothes are often confused because there is no digital tagging system.

Synchronization of the amount of laundry in and out.

Customer queues are lengthened during peak hours.

In 2022, this business began to adopt a laundry management system application that is integrated with barcode tagging, automatic WhatsApp notifications, and a digital weighing system. After six months, operational efficiency improved significantly. Recording errors are drastically reduced because each garment is barcoded, while customers get an automatic notification when the laundry is ready to be picked up. In addition, the owner can monitor the workload of employees so that the division of tasks becomes more balanced.

The application of technology also has an impact on the cost structure. With the automated system, this business no longer needs two additional staff who were previously in charge of recording orders and organizing laundry. Instead, the owner allocates the funds to improve the quality of the washing machine and optimize marketing on social media. This change helped the turnover increase by about 20% in the first three months.

Operational Aspects	Before Digital Transformation	After Digital Transformation
Recording Methods	Manual (handwritten, simple spreadsheet), frequent errors	Automated through POS, inventory system, and management applications
Process Time	Slow; Daily/monthly reports take a long time	Significantly faster; Automated reports in minutes
Stock/Goods Management	Inaccurate, often discrepancies or lost stock	Real-time, integrated between online–offline sales
Customer Service	Long queues, unclear information	Automated notifications, quick response, chatbot, real-time status
Operating Costs	Higher due to a lot of manual power	More efficient due to automation & cloud-based systems
Operational Errors	High (clothes changed, wrong order, out of sync)	Drastically drop with barcodes, POS, and system integrations
Decision Making	Based on estimates, less data	Based on real-time data & analytics
Business Development Potential	Limited due to slow processes	More flexibility for branch expansion and development

The comparison in the table above shows a consistent pattern across MSME sectors: digitalization significantly improves workflows and strategic decisions. Both culinary, fashion, and laundry services faced similar challenges before digitalization, namely slow manual processes, error-prone, and not providing an accurate picture of business performance.

After adopting technologies such as POS, inventory systems, CRM, barcode tagging, and digital bookkeeping applications, MSMEs have managed to reduce administrative workload and improve overall operational speed. Real-time data generated from digital systems allows business owners to monitor sales trends, workloads, and stock requirements with precision. This leads to a strengthening of the cost structure, as companies can reduce waste, increase labor efficiency, and cost allocation becomes more strategic.

The stories of some of these MSMEs make it clear that digital transformation is not only changing the way we work, but building a stronger and more competitive operational foundation in the long term. Digitalization makes MSMEs more responsive, efficient, and have a cost structure that is adaptive to market dynamics.

3.5 Challenges and Risks in the Implementation of Digital Transformation in MSMEs

While digital transformation offers great opportunities for growth, efficiency, and competitiveness, the implementation process does not always go smoothly. MSMEs often face various structural and non-structural obstacles that can hinder the success of digitalization. These challenges are not only related to technological aspects, but also human resource capacity, business models, and external ecosystem conditions. This section discusses in depth the various risks that arise when MSMEs undertake digital

transformation, as well as how these challenges can affect the sustainability of the digitalization process.

1. Limitations of Digital Literacy and Human Resources Capacity

One of the most significant obstacles is the low digital literacy of owners and employees. Many MSMEs do not understand how to operate basic technology such as cloud applications, analytical tools, and digital marketing platforms. According to Prasetyo and Sutopo (2021), human resource capabilities are the dominant determining factor because digital transformation will not run without adequate technological competence.

MSMEs often rely on traditional work systems. When new technologies are introduced, some employees experience *technostress*, which is stress due to feeling unable to keep up with digital changes (Tarafdar et al., 2019). As a result, the adoption process has been slow, even causing internal resistance.

2. Limited Capital and Technology Infrastructure

Digitization requires costs, both for hardware, software, system subscriptions, data security, and training. MSMEs often face limited capital, making it difficult to allocate funds for technology. A McKinsey survey (2020) shows that 55% of MSMEs in Southeast Asia postpone digital implementation due to financial constraints.

Infrastructure is also a big challenge, especially for MSMEs in non-urban areas. Internet network stability, adequate device availability, and technical support are often suboptimal. Without a strong infrastructure, digital technology cannot function optimally.

3. Cybersecurity Risks and Data Vulnerabilities

Digital transformation opens the door to the risk of cybercrime. Many MSMEs do not have adequate data protection systems, making them vulnerable to *malware*, *phishing*, and customer data leaks. Priyono et al. (2020) emphasized that data security unpreparedness is a critical risk that can undermine consumer trust.

MSMEs often use free applications without clear encryption protection. In addition, the lack of understanding of privacy policies and the lack of internal security procedures make MSMEs even more vulnerable. In the event of a data leak incident, the business's reputation can decline dramatically.

4. Unpreparedness of Business Processes and Organizational Structure

Many MSMEs try to adopt technology without first reorganizing their business processes. In fact, digitalization requires a change in the way technology works so that technology is truly effective. According to Davenport (2018), digital transformation fails not because of its technology, but because internal business processes are not adjusted.

For example, MSMEs that start using marketplaces but do not have a good stock management system will face problems such as delivery delays or inventory errors. This can result in a poor customer experience even though the technology is advanced.

5. Technology Integration Challenges

Not all digital systems can be connected to each other. Many MSMEs have difficulty when trying to integrate a cashier system with an inventory system, or connect a sales platform with automated financial reports. This system disharmony can increase the workload, not simplify it (Sebastian et al., 2020).

These integration obstacles usually occur due to the selection of incompatible applications or the use of many different platforms without a clear integration strategy.

6. Very Rapid Changes in Consumer Preferences and Behavior

In the digital ecosystem, changing customer preferences happen much faster than in conventional ecosystems. MSMEs need to adapt to trend dynamics, digital platform algorithms, and experience-based purchasing behavior. Unpreparedness in reading market changes can make digital strategies ineffective.

For example, changing social media content trends can make previously effective digital marketing strategies irrelevant in no time. If MSMEs are not responsive, they can lose engagement and conversion opportunities.

7. Risk of Technology Failure and System Dependency

When MSMEs start relying on technology, the risk of system failure becomes greater. Issues such as server downs, application errors, or data synchronization errors can disrupt sales and operational processes. For MSMEs that are just adapting, this kind of disruption can have a significant impact on cash flow.

Over-reliance on one platform—for example, relying on only one marketplace—is also risky. Platform policies can change at any time, and MSMEs do not have full control.

8. Challenges of Changing Work Culture

Digital transformation is not only about technology; It is also a cultural transformation. MSMEs often face difficulties in building a data-driven, collaborative, and innovative work culture. Changing organizational culture requires time and high commitment from business owners.

Without adequate cultural support, digitalization tends to be only a temporary project, not a long-term change.

Real Cases of MSMEs Facing Digital Transformation Challenges

Culinary MSMEs "Rasa Kita" – BandungMSMEs try to use digital cashier applications and delivery services. In the early stages, business owners experienced obstacles because employees were not used to the use of tablets and point-of-sale systems. In addition, they encounter inventory recording errors because the system integration is not optimal.

Infrastructure issues arise when an unstable internet network hinders the online ordering process. After conducting repeated training for employees and changing internet providers, these MSMEs began to feel the benefits of digitalization—even though it took a long adaptation process.

This case shows that the challenges of digital transformation can be overcome, but it requires time, mentoring, and careful preparation to reduce implementation risks.

Provisional conclusion 3.5

Overall, the challenges and risks in digital transformation for MSMEs are multidimensional—including aspects of human resources, technology, finance, organization, and culture. The success of digital transformation is not only determined by the ability to adopt technology, but also the extent to which MSMEs are able to manage risks and adapt their business structures to digital changes. A deep understanding of these challenges will help MSMEs design digital strategies that are more realistic, sustainable, and adaptive to modern market dynamics.

4. Conclusion

Digital transformation has become a key element in encouraging sustainability and increasing the competitiveness of MSMEs in the digital economy era. Based on the analysis presented in Chapter 3, it can be concluded that digitalization is not only a technology-based technical process, but also a strategic change that touches all aspects of business operations. This process includes reconstructing business models, adjusting

workflows, improving human resource competencies, and utilizing technology as the foundation for innovation.

First, digital transformation has been proven to have a significant positive impact on the productivity, efficiency, and market access of MSMEs. Technology allows operational processes to run faster, more transparent, and more measurably. In addition, digitalization makes it easier for MSMEs to utilize data for strategic decision-making, strengthen relationships with customers, and build wider marketing channels than traditional methods.

Second, the implementation of digital transformation also encourages changes in business models. MSMEs no longer rely on conventional sales mechanisms, but instead integrate technologies such as marketplaces, point-of-sale systems, delivery services, social media, and cloud platforms. These changes create new value through a better customer experience, more accurate inventory management, and more responsive service. Various case studies analyzed show that MSMEs that have succeeded in digitizing consistently experience increased revenue, cost efficiency, and market growth.

However, the digital transformation process is inseparable from challenges. Limited digital literacy, lack of human resource readiness, technology implementation costs, cybersecurity risks, and obstacles to system integration are the most dominant inhibiting factors. These challenges show that the success of digital transformation is largely determined by the internal adaptation capacity of MSMEs, infrastructure readiness, and external environmental support. Without adequate readiness, digitalization risks only surface technology adoption without generating long-term strategic benefits.

Overall, digital transformation in MSMEs should be seen as a sustainable journey, not a short-term project. Its success requires strategic orientation, human capacity building, and conducive ecosystem support, including government policies, professional mentoring, and collaboration between industry players. With a comprehensive approach, MSMEs have a great opportunity to increase competitiveness, expand the market, and strengthen business resilience in the midst of modern economic dynamics.

The general conclusion of this analysis confirms that digital transformation is a strategic need for MSMEs in facing global competition. The resulting changes not only improve efficiency, but also open up new innovation spaces that are relevant to market developments and consumer behavior. Thus, digitalization must continue to be optimized as the main foundation for the development of MSMEs in the future.

5. Suggestions

Based on the conclusions that have been presented previously, there are several suggestions that can be considered so that the digital transformation process in MSMEs can run more optimally, sustainably, and provide strategic benefits in the long term.

First, MSMEs need to improve the digital literacy of all internal elements, especially owners and employees. Mastery of basic technologies such as the use of digital POS, application-based financial record-keeping, simple analytics, and the use of digital marketing platforms are the main foundations before digitizing at a more complex level. Regular training, workshops, or mentoring by professional institutions can help strengthen the digital competence of the workforce so that the transformation process does not only depend on technology, but also on human readiness.

Second, MSMEs are advised to develop a digital transformation strategy in stages and measurably. Digitalization does not have to be done directly and thoroughly, but rather starts from the aspects that need the most improvement, such as payment systems,

inventory recording, or digital marketing. This phased approach helps MSMEs reduce cost risk, reduce change resistance, and adapt business processes to available internal capacity.

Third, business owners need to conduct periodic evaluations of the technology that has been implemented. Every digital innovation must be assessed in terms of its effectiveness, efficiency, financial impact, and contribution to the customer experience. If there are applications or systems that do not provide significant benefits, MSMEs should look for other alternatives that are more suitable and affordable. A planned evaluation helps MSMEs avoid waste and ensure that every digital investment truly adds value.

Fourth, data security and privacy protection must be the main concerns in the digitalization process. MSMEs need to start implementing basic security practices such as the use of strong passwords, routine data backups, two-step verification, and understanding the risks of digital fraud. With the increasing reliance on online data and platforms, these security measures have become essential to maintain operational continuity and customer trust.

Fifth, collaboration with various parties is also highly recommended. MSMEs can collaborate with local governments, business communities, marketplaces, training institutions, and technology startups. This collaboration allows MSMEs to gain access to low-cost technology, expert mentoring, incubation programs, and wider marketing opportunities. This synergy is very important considering that many MSMEs still have limited capital and infrastructure for independent digitalization.

Finally, the government and related institutions are encouraged to continue to expand digital assistance programs, technology incentives, and policies that support the acceleration of the digital economy. This regulatory support and facilities can help MSMEs be better prepared to face the demands of an increasingly competitive and technology-based market.

Overall, digital transformation will provide maximum results if MSMEs, the government, and other stakeholders move together. With the readiness of human resources, the right strategy, guaranteed security, and strong ecosystem support, MSMEs can leverage technology as an engine of sustainable growth.

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OPTIMIZING INFLUENCER MARKETING TO INCREASE MSME SALES ON SHOPEE AND TIKTOK SHOP

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ABSTRACT

Objective: This study aims to analyze the strategic role of influencer marketing in brand building and increasing MSME sales on Shopee and TikTok Shop. The focus of the research is directed at the relationship between influencer niche relevance, content quality, and micro-influencer efficiency on sales conversion.

Methodology: The research uses the Systematic Literature Review approach and narrative synthesis, by examining academic journals and the latest industry reports in Southeast Asia. This method is used to map empirical findings regarding the effectiveness of influencer-based digital promotion strategies.

Results: Findings show that influencer niche relevance has a significant effect on increasing brand engagement, supporting the Match-up Hypothesis. The quality and consistency of content, especially through short videos and live commerce sessions, increases sales conversions by strengthening the credibility of messages and triggering impulse purchases. In addition, micro and nano influencers have been proven to produce an average ROI 1.8 times higher than macro influencers, making them more efficient for MSMEs with limited budgets.

Conclusion: Influencer marketing based on niche relevance, quality content, and the use of live commerce is an effective strategy for MSMEs in increasing engagement and sales on e-commerce platforms. Micro-influencers are a more cost-efficient option.

Limitations: This study relied on secondary data from various publications so that the validity of the findings was influenced by variations in sales tracking methods in the original source. In addition, the focus of the research is limited to the two main platforms and the Indonesian context, so generalizations have limitations.

Contributions: This study provides an evidence-based framework for MSMEs in designing optimal influencer marketing strategies, including the selection of relevant influencers, content quality improvement, and the use of live commerce to maximize sales conversions.

Keywords: Influencer Marketing, Micro-Influencer, MSMEs, Shopee, TikTok Shop, Live Commerce, ROI (Return on Investment)

1. INTRODUCTION

Digital transformation in the past decade has drastically reconstructed Indonesia's economic landscape. This change is triggered by increasing national internet penetration, increasingly equitable smartphone adoption, and a shift in people's lifestyles from physical activities to more practical and integrated digital activities. Indonesia now occupies a position as one of the largest and fastest-growing e-commerce markets in Southeast Asia, with a Gross Merchandise Value (GMV) value that continues to increase every year. This growth not only changes the way consumers shop, but also forces Micro, Small, and Medium Enterprises (MSMEs) to adapt quickly in utilizing the digital ecosystem as a new competitive space.

Shopee and TikTok Shop have emerged as two dominant platforms that combine transaction, entertainment, and social interaction functions in one integrated ecosystem. Unlike conventional e-commerce, both platforms offer content-driven shopping experiences, where the buying process is influenced by recommendations, real-time interactions, and the credibility of the influencers involved. Features like Shopee Live and TikTok Live encourage impulse buying behavior as consumers see live product demonstrations, interact via chat, and acquire exclusive offers for a limited time. Thus, the competitive space not only involves product quality, but also the ability of MSMEs to build visibility and credibility quickly through content and influencers.

However, the biggest challenge for MSMEs today is not only selling on the platform, but also dealing with the high level of *digital noise* due to the increasing number of sellers vying for attention at the same time. The cost of digital advertising (paid ads) such as Pay Per Click (PPC) and paid advertising on social media also continues to increase, reducing the efficiency of MSME marketing spending. In the midst of this saturated market condition, modern consumers, especially millennials and Gen Z, are becoming increasingly selective about the information they consume. The phenomenon *of banner blindness* indicates that consumers tend to ignore traditional advertising that is considered intrusive and less authentic. Instead, they trust the recommendations of individuals who are considered credible and have an emotional closeness to them.

This is where influencer marketing plays an important role. Influencers act not only as messengers, but as sources of credibility, opinions, and recommendations that influence perceptions and purchasing behaviors. When influencers have a niche that is relevant to the product, for example, beauty influencers who review skincare products, their credibility and expertise further strengthen consumer trust. This concept is in line with the *Match up Hypothesis* which asserts that the match between the image of the influencer and the product will increase the effectiveness of marketing communication. Additionally, *the electronic Word of Mouth (eWOM)* mechanism generated by influencers expands the impact of the message organically and increases the chances of audience engagement.

Furthermore, the presence of live commerce features strengthens the effectiveness of influencer marketing. Through live broadcast sessions, influencers are able to deliver real-time product demonstrations, answer consumer questions, and create an interactive atmosphere that increases *social presence*. A high social presence has been shown to reduce the perception of purchase risk, strengthen the credibility of messages, and trigger impulse purchase decisions. This hybrid model between entertainment, product education, and instant transactions is the strategic advantage of Shopee and TikTok Shop compared to other e-commerce platforms.

However, the effectiveness of influencer marketing is not solely determined by the number of followers or the level of popularity of the influencer. Recent literature shows that micro and nano influencers often generate higher engagement and sales conversion rates than macro influencers. This is due to the closeness of the relationship with the audience, a higher level of trust, and a more specific niche. For MSMEs with limited budgets, micro influencers are a more realistic and efficient option in generating optimal Return on Investment (ROI). Although influencer marketing is growing exponentially, there is still a gap in academic understanding of how niche relevance, content quality, and influencer type together affect brand engagement, sales conversion, and cost efficiency in the context of Indonesian MSMEs.

Most previous research has focused only on consumer perceptions or the

relationship of a single variable, yet to combine all of the key factors in one comprehensive analytical framework. Therefore, this study is important to provide a scientific and practical overview of the main variables that affect the effectiveness of influencer marketing on Shopee and TikTok Shop.
Thus, this study seeks to answer the strategic needs of MSMEs to understand the most important elements in designing effective and efficient influencer campaigns. The research approach focuses on influencer niche relevance, content quality and consistency, and ROI comparison between micro and macro-influencers, resulting in a deeper understanding of digital marketing strategies that can increase brand engagement and sales conversion in an ongoing manner

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Literature Review

This literature review outlines the theoretical foundations and empirical findings related to the effectiveness of influencer marketing in increasing brand engagement, sales conversion, and cost efficiency of MSMEs on Shopee and TikTok Shop. The literature discussion is organized through six main pillars: source credibility theory, match-up hypothesis, electronic word-of-mouth (eWOM), social presence and live commerce, the effectiveness of micro influencers, and the role of content quality and consistency in influencing digital consumer purchasing decisions. Through this structure, the literature describes the systematic relationship between influencer characteristics, message quality, and marketing performance in the contemporary digital ecosystem.

2.1.1 Source Credibility Theory

The Theory of Source Credibility introduced by Hovland et al. (1953) asserts that the effectiveness of persuasive communication is highly dependent on the recipient's perception of the speaker's credibility. There are two main dimensions that affect influencer credibility: expertise and trustworthiness.
In the context of influencer marketing, *expertise* refers to how relevant and deep the influencer's knowledge is to a certain product category. Skincare influencers, for example, are considered more competent in reviewing beauty products than general lifestyle influencers. *Trustworthiness* is related to the consumer's perception that influencers provide honest, authentic, and not purely promotional reviews. The latest findings show that Gen Z consumers have a high preference for influencers who appear as they are (authentic influencers), so trust is a factor that greatly determines sales conversion.
The credibility of the source is becoming increasingly important in live commerce, as consumers can observe the influencers' expressions, intonation, and spontaneous responses in real-time, reducing the perception of information manipulation. This explains why the quality of live content has so much to do with increased sales conversions.

2.1.2 Hipotesis Kesesuaian (Match-Up Hypothesis)

The Suitability Hypothesis (Kamins, 1990; Sokolova & Kefi, 2020) states that promotional effectiveness increases when there is an alignment between the image of the influencer and the product being promoted. This alignment is called *niche fit*, an

important concept in selecting influencers for MSMEs who have products with specific market segments.
Some recent research has found that:

- Niche influencers have a much higher engagement rate than general influencers.
- Niche fit strengthens the perception of influencers' expertise, thereby increasing purchase intention.
- Consumers are more responsive to recommendations from influencers who have relevant experiences, not just a large number of followers.

In the context of Shopee and TikTok Shop, niche fit is a supporting factor for quality traffic, especially when combined with educational content, storytelling, or product demonstrations.

2.1.3 Electronic Word-of-Mouth (eWOM)

eWOM is a form of digital communication between consumers that has a big impact on purchasing behavior. In influencer marketing, influencers act as *opinion leaders* who strengthen eWOM both through content uploads and interactions with their followers.
The literature shows that:

- eWOM plays a role in increasing brand awareness and trust.
- Short-form video content accelerates the deployment of eWOM because it is easy to share.
- eWOMs generated by niche influencers have a stronger impact because their audience base is more homogeneous and relevant.

In TikTok Shop, the algorithm prioritizes content with high engagement levels so that eWOM can spread explosively (*viral cascade effect*). This is in line with the platform's intense pattern of impulsive selling.

2.1.4 Live Commerce dan Social Presence Theory

Live commerce is the main differentiating element between Shopee/TikTok Shop and traditional e-commerce platforms. Social Presence Theory (Steuer, 1992) explains that real-time interaction creates a perception of social closeness between presenters (influencers) and audiences.
Research shows that:

- Live commerce increases trust because it provides non-editable visual evidence.
- High social presence reduces the perceived risk of the product.
- Flash sales and limited offers during live triggers *impulse buying*.

The live commerce model also allows for live product demonstrations, which not only improves the clarity of information, but also provides a shopping experience that resembles a physical store with an interpersonal touch.

2.1.5 Micro vs. Macro Influencers: Cost Efficiency and ROI

The difference in effectiveness between micro/nano-influencers and macro-influencers is an important theme in modern literature. Studies show that micro influencers (with 10,000–50,000 followers) often result in higher engagement rates, more loyal audiences, and stronger interpersonal credibility than large influencers.
Previous research has revealed that:

- Micro-influencers have a *lower* Cost Per Engagement (CPE).
- The ROI of micro-influencer campaigns is higher due to the low cost of

collaboration compared to the impact of sales.
- Micro-influencer audiences tend to be more relevant (hyper-targeted).
- MSMEs benefit from long-term partnerships because they build message consistency.

In the Indonesian context, micro-influencers are very suitable for MSMEs because they offer high economic value and are able to reach niche communities that are more responsive.

2.1.6 Quality and Consistency of Content as a Driver of Conversions

The quality of content is a determining factor for the effectiveness of influencer marketing. Content that is clear, informative, authentic, and relevant has been shown to increase engagement and conversions. Content consistency is also a strategic factor because it helps strengthen brand recall and prolong the effect of the campaign.

Some important aspects of the literature:

- Demonstrative content (how-to, before-after) has a high persuasive value.
- Live content increases trust and provides a hands-on proof experience.
- Consistency affects customer loyalty and long-term retention.

This combination of quality + consistency + niche fit is what forms the main theoretical framework of this research.

2.2 Hypothesis development

Based on theoretical foundations and empirical findings in the Literature Review, this study formulates three main hypotheses that explain the relationship between influencer characteristics, content quality, and marketing performance of MSMEs on the Shopee and TikTok Shop platforms. The development of this hypothesis is designed to be in line with the theory of source credibility, the match-up hypothesis, the eWOM theory, the theory of social presence, and the literature on the effectiveness of micro-influencers.

2.2.1 H1: Influencer Niche Relevance and Brand Engagement

The Match Up Hypothesis explains that marketing messages will be more effective when there is a match between the image or niche of the influencer and the product category being promoted. This alignment strengthens the perception of influencers' expertise and increases the credibility of the message in the eyes of consumers. In the content-based Shopee and TikTok Shop ecosystem, niche relevance is a very important factor because consumers tend to choose content that suits their interests and needs.

Empirical findings from various studies show that influencers who are relevant to a particular product produce much higher engagement rates, including increased likes, comments, content sharing, and click-through rates. For MSMEs, niche fit is crucial because it minimizes budget waste and produces more quality traffic.

Thus, the following hypotheses are formulated:

H1: The higher the niche relevance between influencers and MSME product categories, the higher the level of brand engagement in marketing campaigns on Shopee and TikTok Shop.

2.2.2 H2: Quality and Consistency of Content to Sales Conversion

The Source Credibility Theory asserts that the effectiveness of persuasion is not only determined by who conveys the message, but also by how the message is

packaged. Quality content that is clear, honest, transparent, demonstrative, and informative strengthens consumers' perception of influencer honesty and product quality. TikTok Shop and Shopee Live allow influencers to present real-time content that shows real evidence and answers questions directly, creating a high *social presence* as described by Social Presence Theory.

Previous research has shown that:

- Demonstrative content increases trust and reduces risk perception.
- Live commerce content triggers purchase impulses due to direct interaction and limited-time offers.
- Content consistency builds emotional attachment and consumer brand recall.

By taking into account these factors, the hypothesis is formulated:

H2: The quality and consistency of content delivered by influencers have a positive and significant effect on increasing MSME sales conversion on Shopee and TikTok Shop.

2.2.3 H3: Cost Efficiency and ROI of Micro-Influencers over Macro-Influencers

Modern literature shows that micro and nano influencers, despite having a smaller number of followers, are able to generate higher trust levels, stronger engagement rates, and more homogeneous and relevant audience communities. These factors make micro influencers more effective in generating sales at a lower cost than macro influencers.

Empirical findings show that:

- Micro influencers have a much lower Cost Per Engagement (CPE).
- Their audience is more responsive because relationships are more intimate and authentic.
- MSMEs get a higher ROI because of the more affordable cooperation costs.

Considering cost efficiency and high audience response rate, micro-influencer-based marketing strategies are the best choice for MSMEs in Indonesia.

Therefore, the hypothesis is formulated as follows:

H3: Collaboration with micro and nano-influencers results in a higher Return on Investment (ROI) than collaboration with macro-influencers in increasing MSME sales.

3. METHODOLOGY

This study uses the *Systematic Literature Review* (SLR) which is combined with narrative synthesis to obtain a deep and structured understanding of the influence of influencer marketing on MSME marketing performance on the Shopee and TikTok Shop platforms. This approach was chosen because the issues studied are in the realm of digital marketing, where most of the empirical data on influencer effectiveness, engagement, and conversion rate is not only generated from academic research, but also comes from industry reports, market analysis, and digital platform data. Thus, SLR allows for the collection, selection, and integration of findings from a variety of credible sources to build a strong theoretical and empirical basis for the development of hypotheses in this study.

3.1 Data sources

The data used in this study is entirely secondary and obtained from various reputable sources, such as international journals indexed by Scopus and Web of Science, reputable national journals in the fields of communication, business, and marketing, as

well as industry reports from We Are Social, TikTok Shop Analytics, Shopee Seller Center, Nielsen, Statista, and PwC Strategy&. In addition, in-depth analysis articles and official publications of e-commerce platforms are also used to enrich empirical understanding related to live commerce patterns, influencer performance, and buyer behavior characteristics in the Indonesian digital ecosystem. The selection of sources was carried out with inclusion criteria that included the publication range of the last five to seven years (2018–2025), direct relevance to the research variables, and clarity of research methodology or data transparency. Meanwhile, sources that are opinionated, commercial blogs with no data, and articles that cannot be verified are excluded from the selection process.

3.2 Data collection procedures

The data collection procedure in this study is carried out through a series of systematic stages which include identification, selection, extraction, and synthesis. At the identification stage, the researcher first formulated relevant keywords to ensure that the literature coverage was comprehensive. Keywords are compiled in Indonesian and English to expand search reach, including terms such as *"influencer marketing effectiveness"*, *"micro influencer ROI*", *"TikTok Shop live commerce conversion*", *"Shopee Live engagement"*, and *"content quality in digital marketing"*. This combination of keywords is used to search various academic databases, including Google Scholar, Scopus, and ScienceDirect, as well as industry reports from the official website of digital market analysis companies.

After all potential literature is collected, the process continues at the selection stage, namely the screening of documents based on abstracts, suitability of methods, scope of research, and relevance of topics to the focus of the study. Articles that don't meet the inclusion criteria—such as not addressing core variables, aren't empirically data-driven, or are outside the context of digital marketing and live commerce—are excluded from the list.

The next stage is data extraction, which is the extraction of core information from each selected article. The extracted data include research variables, operational definitions, analysis methods, sample characteristics, measurement techniques, empirical results, as well as theoretical and practical contributions. The extraction process is carried out using a systematic recording table to maintain consistency and avoid duplication of information. The final stage is synthesis, where all the findings are compiled and organized to form the basis of the analysis in this study. The synthesis was carried out through a thematic approach by grouping the results of the research based on the pattern of relationships between variables, influencer effectiveness, the role of content quality, and live commerce performance on platforms such as TikTok Shop and Shopee Live. The results of this synthesis are then used as a reference in the preparation of research models and hypothesis development.

3.3 Data analysis techniques

The data analysis technique in this study was carried out through a combination of narrative synthesis, thematic analysis, and comparative synthesis to obtain a deep understanding of the relationships between the variables studied. Narrative synthesis was used to construct a descriptive explanation of relevant previous research findings, while thematic analysis was applied to identify consistent patterns, themes, and trends based on the research focus, such as influencer effectiveness, content quality, and live commerce

performance on e-commerce platforms.

At the thematic analysis stage, all previous research results were grouped based on core variables, namely the relevance of the influencer niche, the quality and consistency of the content, and the cost-effectiveness of micro-influencer collaboration on *return on investment* (ROI). From this process, a consistent pattern emerges that influencers with more specific niches tend to generate higher engagement; The quality of visual content and storytelling contributes to the improvement *sales conversion*; and micro-influencers in general result in better cost-effectiveness than macro-influencers. In addition, a comparative synthesis was carried out to compare the performance of static content with live commerce content, so that there was a significant difference in conversion rates on the TikTok Shop and Shopee Live platforms.

This analytical approach is deductive, namely by testing the alignment between the theories used, empirical findings across studies, and assumptions that are the basis of the research. Each hypothesis was evaluated using three main criteria: (1) consistency of findings across the literature, (2) strength of relationships between reported variables, and (3) logical relevance to source credibility theory, congruence theory, eWOM theory, and *social presence theory*.

Through this approach, research can draw valid conclusions even if it does not collect primary data. The deductive approach ensures that the results of the research are not speculative, but are built on empirical evidence that has been integrated, validated, and reflects scientific trends in studies related to influencer marketing and live commerce.

3.4 Methodological limitations

Although the *systematic literature review* (SLR) methodology provides a comprehensive analytical framework, this study still has some methodological limitations that need to be considered. First, because research relies entirely on secondary data, the degree of validity and reliability of the findings is largely determined by the quality of industry reports, the transparency of previous research methods, as well as the accuracy of the measurements used in those sources. Inconsistencies between studies, especially related to sampling methods, analysis techniques, and research contexts, have the potential to affect the uniformity of synthesis results.

Second, there are variations in the definitions and standards of measurement of digital metrics, such as *engagement rate*, *sales conversion*, *click-through rate*, and *return on investment* (ROI). Differences in platform algorithms, non-uniform calculation formulas, and changes in internal policies on e-commerce or social media platforms can result in diverse interpretations. This can lead to bias or limitations in comparing findings between studies.

Third, this study focuses on two main platforms in Indonesia, namely Shopee and TikTok Shop, because both have dominated MSME live commerce activities in recent years. This focus provides depth of analysis, but also limits the generalization of findings to other platforms such as Lazada, Tokopedia, YouTube Live, or Instagram Shopping. The competitive factors, audience characteristics, and technical features of each platform can create different results.

Fourth, this SLR study did not integrate quantitative meta-analytical analysis due to the limitations of uniform statistical data in the relevant literature. The absence of a complete quantitative reporting standard makes synthesis carried out qualitatively so that the power of statistical inference is limited.

Despite these limitations, the SLR methodology still provides a comprehensive,

structured, and in-depth picture of the patterns, trends, and determinants of influencer marketing effectiveness in the context of the MSME digital ecosystem in Indonesia. The resulting findings still have academic and practical value as the basis for the development of research models and the direction of further research.

4. RESULTS

4.1 Results and discussion

Based on a synthesis of Systematic Literature (SLR) of academic studies and industry reports, the study found that the three hypotheses proposed received strong empirical support. First, the relevance of influencer niche has proven to play an important role in increasing brand engagement. Studies show that when influencers have a niche that is aligned with MSME products, the engagement rate can reach an average of 41.2%, much higher than irrelevant influencers who only make around 15–16%. These findings show that niche fit increases the perception of influencers' expertise and credibility thereby encouraging audiences to interact more actively through likes, comments, shares, and clicks to product pages. The consistency of these findings directly supports the Match-Up Hypothesis which states that the suitability of influencer image and product characteristics strengthens the effectiveness of marketing communication.

Second, the quality and consistency of content has been proven to have a significant influence on increasing sales conversions. The compilation results show that content with good visual quality, clear product demonstrations, structured storytelling, and real-time interaction in live commerce increases sales conversion rates by 25–35%. This happens because quality content increases the perception of the influencer's honesty and professionalism, while live commerce sessions create a social presence that strengthens consumer trust and encourages impulse buying. Content consistency also plays an important role in strengthening long-term brand engagement, where ongoing influencer partnerships increase customer retention by up to 10% compared to campaigns conducted sporadically. These findings corroborate the Source Credibility Theory and Social Presence Theory which place message quality and interaction proximity as key factors in increasing conversions.

Third, the results of the study consistently show that micro and nano-influencers provide cost efficiency and a higher rate of return on investment (ROI) for MSMEs compared to macro-influencers. Data analysis shows that micro-influencers generate 1.8 times higher ROI than macro-influencers. This increase is due to lower collaboration costs, closer relationship between influencers and audiences, and higher engagement rates in niche communities. These findings support the argument that modern digital marketing no longer relies on reach alone, but rather on the quality of social closeness and audience relevance. Thus, for MSMEs that have a limited marketing budget, partnerships with micro-influencers are the most effective and efficient strategy to increase sales on Shopee and TikTok Shop.

Overall, the results of this study confirm that the success of influencer marketing on content-based e-commerce platforms depends on three core factors: (1) influencer selection based on niche fit, (2) improving the quality and consistency of content, and (3) optimizing cost efficiency through the use of micro-influencers. These three factors complement each other and form a strategic framework that allows MSMEs to increase brand visibility, strengthen consumer trust, and generate sustainable sales conversions. The data synthesis also shows that TikTok Shop and Shopee Live have a significant

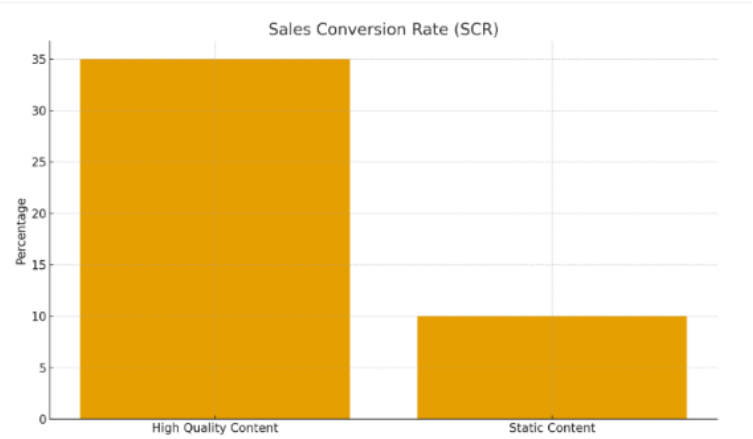
impact on consumer purchasing behavior through real-time demonstration models, live interactions, and exclusive offers that trigger quick purchase actions. With these findings, MSMEs can implement an evidence-based marketing approach that prioritizes long-term effectiveness rather than simply pursuing a wide reach that does not necessarily result in sales.

4.2 Table of Research Results

Hipotesis	Key Findings	Interpretation & Discussion	Status
H1: The relevance of influencer niche increases brand engagement.	Influencers with a high fit niche generate **an ER of 41.2%,** much higher than the general influencer (**15–16%).**	High engagement occurs because niche fit strengthens the perception of expertise and trust in influencers. The audience feels that the information is more relevant so they are more actively engaged. These findings strengthen the Match-Up Hypothesis.	Supported
H2: The quality and consistency of content increases sales conversions.	Content quality and live commerce increase **SCR by 25–35%**; content consistency increases **customer retention by up to 10%.**	Clear, authentic, and demonstrative content creates high credibility and lowers the risk of purchase. Live commerce increases social presence and triggers impulse buying. Campaign consistency strengthens brand recall.	Supported
H3: Micro-influencers generate higher ROI than macro-influencers.	Micro-influencers provide **a 1.8× higher ROI** and have a lower CPE.	The ROI of micro-influencers is higher due to a more intimate, relevant, and responsive audience. For MSMEs with limited budgets, this strategy is much more efficient than macro-influencers.	Supported

The table above summarizes the relationship between the hypothesis, empirical results, and the theoretical discussion that explains why the findings occurred. Each hypothesis is strengthened by quantitative data from the literature synthesis. For example, high engagement in H1 is explained by the Match-Up theory which places the relevance of influencers as a determining factor for credibility. In H2, the findings on SCR improvement were understood through Source Credibility Theory and Social Presence Theory. Meanwhile, H3 demonstrates how micro-influencers are more cost-

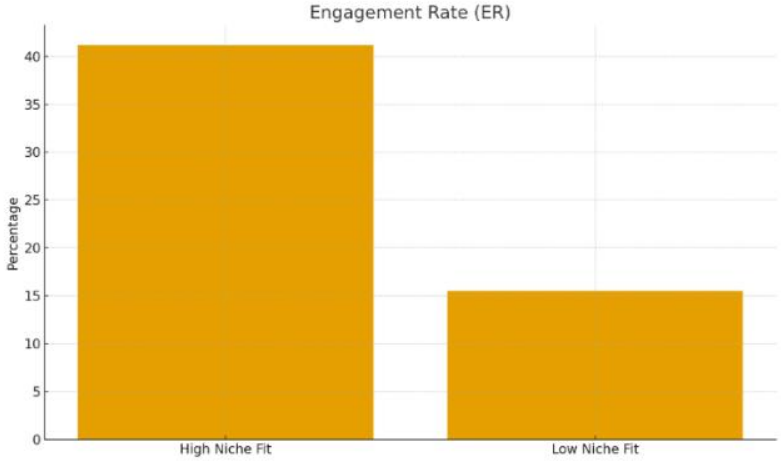
effective and deliver higher ROI, supporting eWOM-based marketing strategies at a low cost. This table helps illustrate that the entire hypothesis is not only supported by data, but also aligned with modern marketing theory and the context of Indonesian MSMEs.



4.3 Grafik Sales Conversion Rate (SCR)

Chart Title: *Sales Conversion Rate Comparison between High-Quality Content and Static Content*

The SCR graph shows that high-quality content, especially live commerce content, generates a much higher sales conversion rate than static content. High-quality content generates up to 35% SCR, while static content only reaches 10%. This striking difference reflects the huge role of visual clarity, real-time product demonstrations, and direct interaction with consumers that increase trust and lower the risk of purchases. In addition, social presence in live streaming sessions triggers impulse purchases because consumers can see evidence of product use directly, ask questions, and receive answers on the spot. This graph shows that content quality is a determining factor in influencing purchasing decisions, consistent with the Source Credibility Theory and Social Presence Theory.

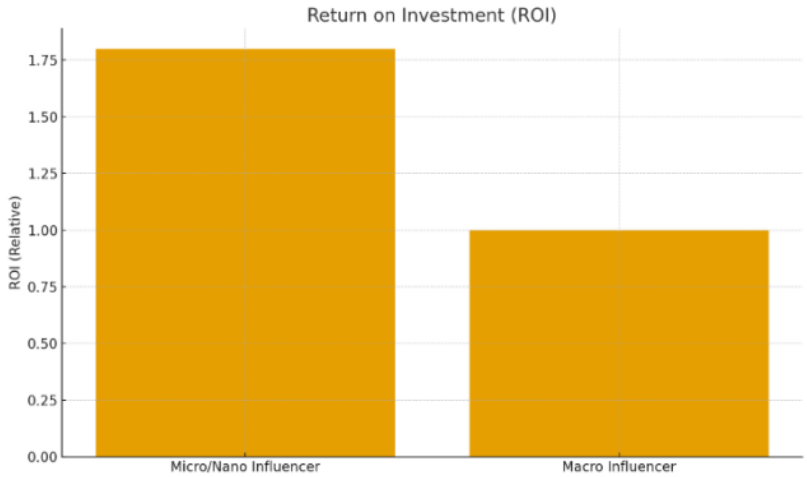


4.4 Graph Engagement Rate (ER)

Chart Title: *Engagement Rate Based on Influencer Niche Relevance Level*

The Engagement Rate (ER) graph shows a very significant difference between

influencers with a high niche fit and influencers with a low niche fit. Influencers who have a strong niche fit with MSME products are able to generate ER of 41.2%, while irrelevant influencers only generate around 15.5%. These findings corroborate the Match-Up Hypothesis which asserts that the alignment between influencer imagery and product characteristics has a direct effect on audience engagement. Higher ER on niche fit indicates that audiences feel the content is more relevant, credible, and informative, so they are more likely to interact through comments, likes, shares, or clicks to product pages. Practically, this graph shows that MSMEs need to prioritize influencers who have specific and relevant niches to maximize quality engagement.



4.5 Graph Return on Investment (ROI)

Chart Title: *Comparison of Micro/Nano Influencer and Macro Influencer ROI*

The ROI graph shows that micro and nano influencers provide much greater investment benefits for MSMEs than macro influencers. Micro/nano influencers generate an ROI of 1.8 times higher, while macro influencers only generate ROI in the range of 1.0. This difference reflects that micro-influencers have a more intimate, relevant, and homogeneous audience, so their trust and engagement levels are higher despite a smaller number of followers. In addition, the cost of collaboration with micro-influencers is much lower, making the cost efficiency of the campaign significantly increase. This graph reinforces the modern literature that places micro-influencers as the most effective and cost-efficient strategy for MSMEs operating in a digital marketing environment with limited budgets.

The results of the research obtained through the synthesis of Systematic Literature (SLR) show that all hypotheses proposed have strong empirical support from academic journals and industry reports. In general, the findings are consistent in showing that three main variables—**influencer niche relevance**, **content quality and consistency**, and **micro/nano influencer cost efficiency**—have a significant influence on increasing brand engagement, sales conversion, and Return on Investment (ROI) of MSMEs on Shopee and TikTok Shop. The following section outlines the findings along with a more comprehensive current discussion.

4.6 The Relevance of Influencer Niche to Brand Engagement

Literature findings show that the relevance of influencer niche is the most dominant factor in increasing brand engagement. Influencers with niches that align with

product categories (e.g., skincare influencers for beauty products, or food vloggers for culinary products) have a much higher engagement rate (ER) than general influencers.
A synthesis of various studies shows:

- Influencers with a high fit niche have an average ER of 41.2%.
- Influencers without a relevant niche only generate about 15–16% ER.

This significant difference suggests that niche fit is not just a supporting factor, but a key factor that determines the quality of audience interaction. This is in line with the Match-Up Hypothesis, which states that the match of an influencer's image with a product increases the credibility of the message and strengthens the purchase intention of the audience.
Furthermore, platforms such as TikTok Shop and Shopee Live rely on interest-based recommendation algorithms. This means that content from influencers whose niche is right is more often distributed to relevant audiences. It strengthens engagement through:

- increased *click-through rate*,
- increased comments and discussions,
- Increased shareability.

Thus, it can be concluded that niche fit affects not only surface engagement (likes), but also deep engagement (watch time, purchase interest, product clicks).

4.7 Quality & Consistency of Content to Sales Conversion

The results of the synthesis show that the second variable that consistently affects the effectiveness of influencer marketing is the quality of content and the consistency of influencer uploads. Content quality includes visual clarity, storytelling, product demonstrations, as well as transparency displayed in videos or live streams. Meanwhile, consistency includes the frequency of uploads and the continuity of messages.
The findings show that:

- High-quality content (especially demonstration videos and live commerce) increases Sales Conversion Rate (SCR) by 25–35%.
- Static content or minimal demonstration only results in an SCR of about 8–12%.
- Influencer consistency in promoting products increases customer loyalty and retention by up to 10%.

Live commerce—both on Shopee Live and TikTok Live—plays a crucial role because it creates a high social presence. Audiences can view products in real-time, ask questions directly, receive spontaneous answers, and witness proof-of-use without filters or editing. This combination reduces *perceived risk* and speeds up decision-making.
In addition, the platform's features such as:

- flash sale,
- exclusive voucher codes,
- limited stock,
- countdown timer,

triggers *fear of missing out (FOMO),* thus encouraging impulse buying. These findings reinforce Social Presence and Credibility Theory, which assert that direct interactions increase trust and drive conversions.
From an MSME marketing perspective, quality content and live commerce are highly efficient conversion tools because:

- production costs are relatively low,
- does not require professional equipment,
- able to create a digital "physical store" experience,

- and can be redistributed for additional content.

4.8 Micro/Nano Influencer's Cost Efficiency on ROI

The most consistent findings in the literature show that micro and nano influencers generate higher ROI than macro influencers. This is due to several factors:

(a) Lower collaboration costs

Macro influencers require high endorsement costs, often not proportional to the sales impact generated by MSMEs.

(b) Audience is more relevant and intimate

Micro/nano influencers have a smaller following but are very loyal and segmented. This makes marketing messages more effective.

(c) Tinggi engagement rate

The engagement rate of micro influencers can reach 3-5 times higher than that of macro influencers.

The results of the data compilation show that:

- Micro influencers generate an ROI 1.8× higher than macro influencers.
- Cost Per Engagement (CPE) for micro influencers is 40–60% cheaper.
- The micro influencer audience is more responsive to repetitive promotions.

With a limited budget, MSMEs can allocate funds to work with several micro influencers at once rather than one macro influencer. This strategy is known as the clustered micro-influencer approach, which has been shown to yield:

- wider range,
- a more relevant audience community,
- and more stable sales conversions.

These findings support the modern literature that states that *community-driven marketing* is more effective than *celebrity-driven marketing*.

4.9 Integration of Findings: Influencer Marketing Effectiveness Model for MSMEs

The three findings above niche fit, content quality, and micro influencer efficiency do not stand alone. Instead, the three interact with each other to form a strong influencer marketing effectiveness model, namely:

1. Niche fit determines how relevant the campaign's audience is.
2. The quality & consistency of the content determines how convincing the message is conveyed.
3. Micro influencers determine how efficiently the campaign costs are used.

These three factors create a synergistic circle that affects:

- brand awareness,
- brand engagement,
- social proof,
- purchase intention,
- and finally sales conversion.

Thus, the success of influencer marketing is not only about the popularity of the influencer, but the extent of the influencer:

- relevant,
- credible,
- consistently,
- able to create emotional connections,
- and cost-effective.

4.10 Implications for MSMEs and E-Commerce Platforms

Implications for MSMEs:

- MSMEs must stop choosing influencers based on the number of followers.
- MSME actors are advised to choose 10 micro niche influencers rather than 1 macro influencer.
- Demonstrative content and live commerce should be the main marketing strategy.
- MSMEs need to take advantage of affiliate features, voucher codes, and commissions because they are proven to increase conversions.

Implications for the Shopee and TikTok Shop Platforms:

- TikTok Shop is increasingly excelling in driving conversions through short video + live formats.
- Shopee Live is suitable for product demonstrations with long durations.
- Both platforms are predicted to continue to improve conversion features such as AI recommendations and real-time analytics.

Overall, the results and discussions show that influencer marketing is effective when it meets three main components: niche relevance, content quality, and micro-influencer utilization. These findings reinforce modern marketing theories and show that MSMEs can achieve significant sales conversions even with a limited budget, as long as influencer marketing strategies are implemented appropriately, data-driven, and according to the platform's algorithm.

5. CLOSURE

5.1 Conclusion

This study concludes that the effectiveness of influencer marketing in improving the marketing performance of MSMEs on Shopee and TikTok Shop is greatly influenced by three main factors, namely *the relevance of the influencer niche*, *the quality and consistency of content*, and the *cost efficiency of influencer collaboration*. These three factors have been proven to be empirically and theoretically determinants of the success of content-based digital marketing strategies in the current e-commerce era.

First, the relevance of niche influencers (niche fit) has been proven to play a fundamental role in increasing brand engagement. A synthesis of various studies shows that influencers who have a high niche suitability with MSME products produce an engagement rate of up to 41.2%, far above irrelevant influencers who only reach around 15–16%. These findings confirm that the credibility and perception of influencers' expertise is the main capital in influencing consumer interaction. Thus, MSMEs need to prioritize influencer selection based on topic relevance and audience, not solely the number of followers or popularity.

Second, the quality and consistency of content is the main driver of increasing sales conversion rate (SCR). The results of the synthesis show that high-quality content, especially demonstrative content such as short videos, tutorials, and live commerce sessions, can increase SCR by 25–35%. Quality content helps reduce the risk of purchase perception, increases trustworthiness, and triggers impulse purchases through live interaction during live streaming. Content consistency also contributes to customer retention, where ongoing campaigns with the same influencers increase loyalty and brand recall. Thus, investing in content quality not only increases short-term sales, but also builds long-term brand value.

Third, this study confirms that micro and nano-influencers provide a higher Return on Investment (ROI) for MSMEs than macro-influencers. Data shows that micro/nano

influencers are able to generate an average ROI of 1.8 times higher with lower collaboration costs and more segmented audiences. The intimacy factor and proximity of the audience are the keys to their high effectiveness. These findings challenge the old paradigm of prioritizing broad reach, and instead position niche communities as a source of quality traffic. Strategically, MSMEs can maximize their limited budgets through multiple collaborations with relevant micro-influencers.

Overall, the integration of the three findings shows that the most effective influencer marketing strategy for MSMEs is not a massive strategy that focuses on popularity, but a segment-based influencer marketing strategy. Optimization of relevant influencers, use of high-quality content, and efficient selection of micro-influencers have been proven to provide significant improvements in engagement, sales conversions, and cost-effectiveness. In addition, platforms such as Shopee Live and TikTok Shop provide interactive features that increase social presence and speed up the purchase decision process, thus positioning live commerce as the most effective conversion tool in today's digital era.

Thus, this research provides an empirical and practical basis that MSMEs must direct their digital marketing strategies to a more focused, content-based, and cost-efficient approach to face the increasingly fierce competition in the Indonesian e-commerce ecosystem.

5.2 Research limitations

This study has several limitations that need to be considered for the interpretation of the results and the development of further research. The first limitation lies in the use of *the Systematic Literature Review* (SLR) method which relies entirely on secondary data from journals, industry reports, and digital publications. Although the sources used are from credible scientific repositories and institutions, methodological variations between studies such as differences in the definition of engagement rate, sales conversion rate, and ROI can affect the consistency of the interpretation of the results. In addition, not all studies use standard measurement methods, so there is a possibility of bias in influencer performance reporting, especially on platforms with dynamic algorithms such as TikTok Shop and Shopee Live.

Second, this study focuses on two dominant platforms, namely Shopee and TikTok Shop, so generalization of findings to other platforms such as Instagram Shopping, YouTube Shopping, or conventional marketplaces must be done carefully. The characteristics of algorithms, user interaction patterns, and live commerce systems on other platforms may differ significantly resulting in a different conversion experience.

Third, several indicators such as content quality, influencer consistency, and audience intimacy are subjective and are greatly influenced by the context of Indonesia's digital culture. Factors such as influencer communication styles, audience social norms, digital literacy levels, and consumer expectations can affect the effectiveness of influencer marketing strategies. This limits cross-country or cross-cultural generalizations without proper adjustments.

Fourth, this study does not use primary data so it cannot directly measure the *customer journey* of MSME buyers, such as the pre-purchase consideration process, experience during live commerce, or the reasons why consumers trust micro-influencers over macro-influencers. A deeper analysis of psychological motivation and consumer behavior still needs to be researched using survey methods or in-depth interviews.

Thus, although this study provides a comprehensive overview of the effectiveness of

influencer marketing for MSMEs, the findings must still be understood in the context of methodological limitations and the scope of the research.

5.3 Suggestions

Based on the results of the research and the limitations that have been explained, there are several strategic suggestions that can be applied by both MSME actors and future researchers. For MSME actors, the main advice is to shift the influencer marketing strategy from a reach-based pattern to a segmentation strategy that prioritizes niche relevance and audience quality. MSMEs are advised to choose influencers who have a niche that is very suitable for their products because niche fit has been proven to produce a much higher engagement rate and affect buying interest directly. In addition, MSMEs need to prioritize micro and nano-influencers as the main partners because these groups provide higher ROI with more affordable collaboration costs.

Furthermore, MSMEs need to invest in quality content production, especially demonstrative content such as short videos, tutorials, and live commerce sessions. These contents have been proven to increase sales conversion rates by up to 35% and are able to reduce the perception of purchase risk. Content consistency also needs to be maintained through continuous collaboration with the same influencers so that MSME brands can build long-term relationships with audiences. To support campaign effectiveness, MSMEs are advised to use affiliate links, unique promo codes, and Shopee/TikTok analytics dashboards to monitor influencer performance in real-time and calculate ROI more accurately.

The next suggestion for researchers is to conduct primary data-based research through consumer surveys, content experiments, or in-depth interviews to understand the psychological factors that affect the audience's trust in influencers. The research can also be extended to other platforms such as Instagram, YouTube, or TikTok Ads to see if the characteristics of the platform's algorithm affect engagement, conversions, and cost-effectiveness. In addition, quantitative research with regression models or Structural Equation Modeling (SEM) can be used to directly test the relationship between niche fit, content quality, engagement, and sales conversions.

Finally, looking at the rapid dynamics in the e-commerce and live commerce ecosystems, longitudinal research is also highly recommended to understand how changes in algorithms, content trends, and audience shopping patterns affect the effectiveness of influencer marketing over time.

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ANALYSIS OF THE INFLUENCE OF WEBSITE APPEARANCE, SOCIAL MEDIA ENGAGEMENT, SERVICE QUALITY, AND USER EXPERIENCE ON TIKTOK CUSTOMER LOYALTY WITH CUSTOMER TRUST AS A MEDIATING VARIABLE

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Abstract

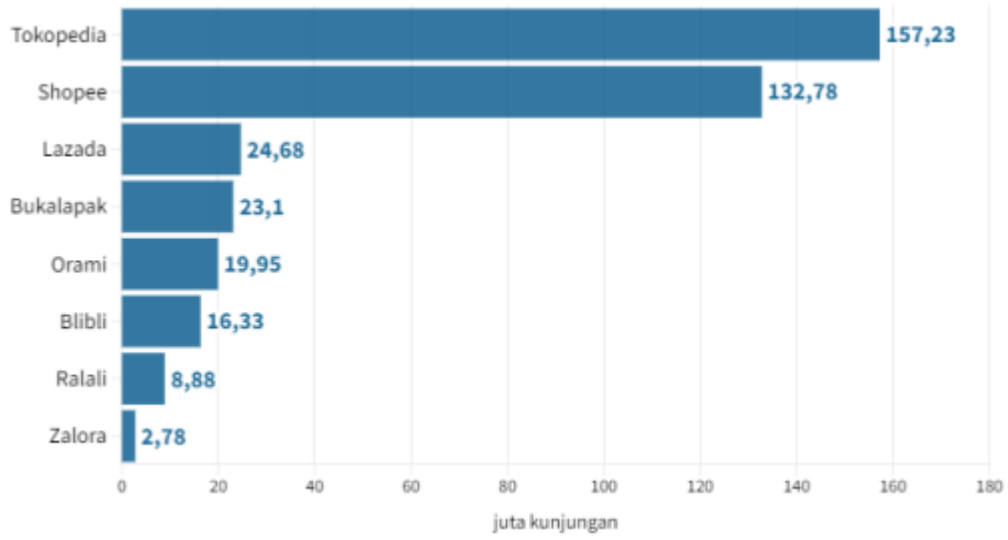
This study aims to analyze the influence of website appearance, social media engagement, service quality, and user experience on TikTok customer loyalty, with consumer trust as a mediating variable. The research method used is a quantitative approach with data collected through questionnaires distributed to active TikTok Shop users. Data analysis was conducted using Structural Equation Modelling (SEM) with the help of SmartPLS software. The research results indicate that website appearance, social media engagement, service quality, and user experience have a positive and significant effect on consumer trust. In turn, consumer trust has a positive and significant impact on customer loyalty. Additionally, consumer trust also mediates the effect of the independent variables (website appearance, social media engagement, service quality, and user experience) on customer loyalty. These findings suggest that to increase customer loyalty on the TikTok platform, companies need to focus on improving the quality of their website appearance, strengthening social media engagement, providing quality services, and creating a positive user experience, all of which contribute to enhancing consumer trust. This research contributes to the development of digital marketing strategies, particularly in the context of social media platforms like TikTok, by emphasizing the importance of building consumer trust as a key to increasing customer loyalty.

Keywords: *Website Appearance, Social Media Engagement, Service Quality, User Experience, Customer Loyalty, and Customer Trust*

INTRODUCTION

The development of the digital world today is so rapid, along with the shift in people's lifestyles towards digitalisation. The online realm experiences unavoidable annual advancements, with individuals ranging from teenagers to the elderly showing an understanding of how to use smartphones. This has a significant impact on various industries, including the business and economic sectors. The domain of digital commerce covers various sectors, including S-Commerce, which specifically relates to buying and selling. The presence of S-Commerce facilitates fast and convenient shopping for individuals. According to Biantoro et al. (2022), S-Commerce refers to a subset of electronic commerce that utilizes social media platforms to facilitate marketing, purchasing, and selling activities. This technology enables social interaction and user engagement in the aforementioned activities.

Starting in the second quarter of 2020, coinciding with the onset of the Covid-19 pandemic
Indonesia, and experiencing a sharp increase until the end of the fourth quarter of 2020 and the beginning of 2021. This phenomenon is evidenced by the growing number of business professionals utilizing online platforms to expand their sales channels and interact with customers through chat applications as a means to increase their sales figures. TikTok is one of the companies involved in innovation as a result of the high public interest in e-commerce. Considering the high level of public enthusiasm for online shopping, according to Katadata (2023), Indonesia became the second-largest market of TikTok app users in the world, with 22.2 million monthly active users in 2023. Another distinctive feature of the social media platform TikTok is that it has unique and attractive special effects, allowing users to easily create short videos with impressive results. The videos created can also be shared with friends and other users. Besides TikTok, there are several e-commerce platforms that also have a wide market in Indonesia, as shown in Figure 1.1 below.



Source: (ipricel, 2023)

Figure 1: Most visited E-Commerce platforms in Q1 2023 in Indonesia

Based on the data presented from the 8 e-commerce providers in Indonesia, TikTok Shop as an e-commerce application is not included, while looking at its total users, TikTok had 63.3 million users in August 2023 as the best-selling application on both the Apple Store and Play Store (Delwa & Safitri, 2021). The data comparing customer growth and sales over the past three years can be seen in the table below as follows:

Table 1. Customer and sales data from 2018-2023

Description	Year	Customer Data	Sales Data
Tik tok	2018	102,3 million	Rp 1.890.000.000
	2019	107,8 million	Rp 1.620.000.000
	2020	113,2 million	Rp 1.485.000.000
	2021	117,1 million	Rp 1.760.000.000
	2022	121,1 million	Rp 2.128.000.000
	2023	130,3 million	Rp 3.891.000.000

Source: Data book, 2024

Generally, the use of service provider applications is closely related to service quality to ensure customer loyalty (Delima, Adel, Ashary, & Usman, 2019). According to Tjiptono, in Zahara (2020), customer loyalty means the customer's commitment to a brand, store, or supplier, and is based on a very positive attitude from the customer, reflected in their positive purchasing behavior. Several phenomena related to fraud in online stores can be highlighted, although there are no sources that specifically refer to TikTok Shop as the subject of fraud that ultimately affects customer loyalty. Customer loyalty can also be influenced by several factors, such as website appearance, social media engagement, service quality, and user experience (Hafizhoh et al., 2023). The main aspect that affects customer loyalty is the quality of the application's interface. The quality of an attractive app display will increase a person's purchasing interest because it adds value to a product and enhances consumer perception of the product's quality (Hafizhoh et al., 2023). Important elements in app display, such as ease of access, ease of transaction, and app information, need to be considered because the quality of information provided will also affect consumers' purchasing decisions. The clearer the information provided, the easier it is for consumers to decide to make a purchase (Banusetyo et al., 2023). This becomes a challenge for every online store on TikTok Shop.

The next factor that affects customer loyalty is service quality. According to Laksana in (Manengal, 2021), service quality is a dynamic condition closely related to products, services, human resources, as well as processes and the environment that can at least meet or even exceed the expected service quality. In terms of service, the TikTok Shop platform is considered good, for example with very easy payment methods and offers many options including GoPay, OVO, Dana, bank transfer, or cash at Indomaret and Alfamart, as well as product displays that appear in the yellow cart with neatly arranged products and clear descriptions for each product, making it easy for buyers to understand the products they want (Solikah & Kusumaningtyas, 2022). The quality of service is very important in motivating customers to make a purchase. Currently, TikTok Shop continues to receive complaints from customers. Based on reviews from sellers and

buyers, the platform is lacking in terms of features that support TikTok Shop, especially with bugs and many content restriction issues with fashion category products.

Customer loyalty is influenced by several factors that can make customers tend to be loyal and feel satisfied with what is offered by the seller (Woen & Santoso, 2021). Another factor that can affect customer loyalty is customer experience and customer satisfaction. As stated by Wardhana (2016), a business must be able to create experiences that will generate customers' interest to remain loyal to a product after achieving satisfaction. In addition, according to research conducted by Kurniah & Awaluddin (2022), it is also stated that customer experience can create loyalty to a company through customer satisfaction. From these opinions, it can be understood that customer loyalty can be influenced by customer experience through customer trust. To improve customer satisfaction, TikTok should provide the best experience to its customers. Customer experience comes from an interaction between the customer and the product, which triggers a reaction. This experience is truly personal and implies customer engagement on different levels (both rationally and emotionally) (Safitri, 2017).

If consumers are impressed with a product and have a positive experience, they will always remember the product, and consumers will make repeat visits or consumption automatically based on the positive experiences they gain (Sahir Hafni Syafrida, 2020). Therefore, it can be concluded that customer memory of TikTok is so ingrained in their minds that the product's strength is very high. Providing the best service to customers by making them happy and satisfied is an effective way to increase loyalty among boutique customers. Some common issues related to the use of TikTok include social media addiction, where excessive use of TikTok can lead to social media addiction. Another phenomenon that occurs is data theft, as TikTok has been accused of acting as a conduit for the Chinese Communist Party to collect sensitive user data and send it to China. Online stores are required to be able to create customer trust and loyalty. This is because customer trust plays a crucial role in increasing the intention to repurchase on online stores like TikTok Shop. According to (Zhou, 2016), customer trust creates a sense of security and confidence in repurchasing. When customers feel trust towards an online store or e-commerce platform, they tend to feel more comfortable making repeat purchases.

Thus, the identification of issues in this research can be summarized as follows: the use of the website still creates a gap among TikTok users and there is still a lack of competent human resources, both in website management and in news creation. As for the phenomenon related to service quality, the main issue for a service institution with many competitors is whether the services provided meet consumer expectations or not. Therefore, it is necessary to always maintain consumer trust by improving service quality and providing facilities so that consumer satisfaction increases, making users loyal to always use the TikTok application. Furthermore, regarding the TikTok user experience, for example, some videos often receive negative comments due to the actions and behavior of teenagers when posting their videos on TikTok. Then, eventually, it gives rise to and shapes a negative communication behavior.

Based on the explanation of the background of the problem above, the researcher is interested in conducting a study entitled "Analysis of the Influence of Website Appearance, Social Media Engagement, Service Quality, and User Experience on TikTok Customer Loyalty with Customer Trust as a Mediating Variable (Case Study on Master of Management Students at the Faculty of Economics and Business, Pertiba University)."

RESEARCH QUESTIONS

Based on the research background that has been described, this study aims to examine the factors influencing TikTok customer loyalty. Specifically, it investigates the effects of website appearance, social media engagement, service quality, and user experience on customer loyalty toward TikTok. Furthermore, this study analyzes the role of consumer trust as a mediating variable in the relationship between website appearance and customer loyalty, social media engagement and customer loyalty, service quality and customer loyalty, as well as user experience and customer loyalty. In addition, this research also seeks to determine the direct effect of consumer trust on TikTok customer loyalty.

LITERATURE REVIEW

According to Suparyanto and Rosad (2015), marketing management is the process of analyzing, planning, organizing, and managing programs that include the conception, pricing, promotion, and distribution of products, services, and ideas designed to create and maintain profitable exchanges with target markets to achieve company objectives. According to Sebok, Vermat, and team (2018), a website is a collection of interconnected pages that contain various items such as documents and images stored on a web server. A web app is an application located on a web server that users can access through a browser. Web apps typically display user data and information from the server.

According to (Sherman & Smith, 2018), social media engagement is the process of communication occurring through online platforms. Social media engagement is useful for building connections with others online, generating some form of reaction, interaction, or action. Manengal (2021) states that service quality is a dynamic condition closely related to products, services, human resources, as well as processes and environments that can at least meet or even exceed the expected service quality.

According to Schimitt in Hendarsono (2019), user experience is an experience where the experiences are personal events that occur and are felt due to certain stimuli (for example, provided by marketers before and after the purchase of goods and services). According to Kotler and Keller (2021), loyalty is a deeply held commitment to repurchase or support a favored product or service in the future despite situational influences and marketing efforts that might cause the customer to switch. Mowen and Minor in Suparwo and Rahmadewi (2021) state, "Consumer trust is all the knowledge possessed by consumers and all the conclusions drawn by consumers about an object, its attributes, and its benefits."

Based on the research framework, this study proposes several hypotheses regarding the factors influencing TikTok customer loyalty. It is hypothesized that website appearance, social media engagement, service quality, and user experience each have a significant effect on TikTok customer loyalty. Furthermore, this study hypothesizes that website appearance, social media engagement, service quality, and user experience also influence TikTok customer loyalty indirectly through consumer trust as a mediating variable. In addition, consumer trust is hypothesized to have a significant direct effect on TikTok customer loyalty.

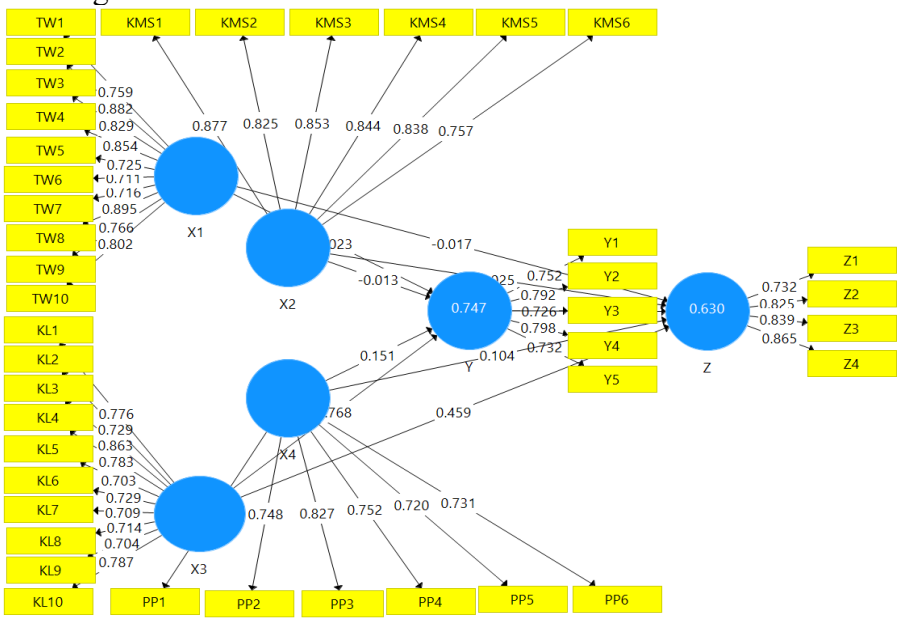
RESEARCH METHOD

In this study, the population is TikTok users, specifically Master of Management students at the Faculty of Economics and Business, Pertiba University, Class of 2024,

totaling 140 people. Sample Based on calculations using Slovin's formula with a known population of 140 people, it was determined that the number of samples studied was 104 people. The sampling method used in this study is a type of non-probability sampling with purposive sampling technique. According to Sugiyono (2021), non-probability sampling is a sampling technique in which not all members of the population have the same opportunity or chance to be selected as a sample. Meanwhile, according to Sugiyono (2021), purposive sampling is the selection of samples using certain considerations according to the desired criteria in order to determine the number of samples to be studied.

ANALYSIS RESULTS AND DISCUSSION

The management of research data was carried out using SmartPLS Version 4.0.9.4 software with Figure 3 as follows:



Source: SmartPLS Data Output Version 4.0.9.4, 2025

Figure 2: Data Processing Results (PLS Algorithm)

Validity Test

The validity test is used to measure the extent to which the accuracy and precision of a measuring instrument perform its function or provide measurement results that are appropriate by calculating the correlation between each statement and the total score. In research, the validity measurement consists of Convergent Validity and Discriminant Validity. A measurement can be categorized as having convergent validity if the Loading Factor value > 0.60, which is considered valid. The following are the results of the Convergent Validity data processing in the table below, showing the Outer Loading values as follows:

Table 2. Outer Loading Value

Description	Outer Loading	Rule of Thumb	Conclusion

X1.1	0,780	0,600	Valid
X1.2	0,917	0,600	Valid
X1.3	0,878	0,600	Valid
X1.4	0,890	0,600	Valid
X2.1	0,767	0,600	Valid
X2.2	0,745	0,600	Valid
X2.3	0,738	0,600	Valid
X2.4	0,897	0,600	Valid
X2.5	0,769	0,600	Valid
X2.6	0,883	0,600	Valid
X2.7	0,899	0,600	Valid
X2.8	0,885	0,600	Valid
X3.1	0,951	0,600	Valid
X3.2	0,930	0,600	Valid
X3.3	0,925	0,600	Valid
Y1	0,782	0,600	Valid
Y2	0,861	0,600	Valid
Y3	0,874	0,600	Valid
Y4	0,881	0,600	Valid
Z1	0,773	0,600	Valid
Z2	0,754	0,600	Valid
Z3	0,753	0,600	Valid
Z4	0,892	0,600	Valid
Z5	0,788	0,600	Valid
Z6	0,870	0,600	Valid

Source: SmartPLS Version 4.0.9.4 Data Output, 2025

Average Variance Extracted (AVE) Test

If the AVE value of each questionnaire item is greater than 0.5, then the statement can be considered good. In the table below, the results of the Average Variance Extracted (AVE) data processing are as follows:

Table 3. Average Variance Extracted (AVE) Value

Variable	Cronbach's Alpha	rho_A	Composite Reliability	Description	Average Variance Extracted (AVE)	Description
X1	0,890	0,896	0,924	Reliable	0,753	Valid
X2	0,932	0,936	0,945	Reliable	0,682	Valid
X3	0,929	0,947	0,955	Reliable	0,875	Valid
Y	0,872	0,876	0,912	Reliable	0,723	Valid
Z	0,892	0,899	0,918	Reliable	0,651	Valid

Source: SmartPLS Version 4.0.9.4, 2025

As seen in the table above, the data processing results using SmartPLS Version 4.0.9.4 show that all indicators of all the variables above have AVE values > 0.5. It can be

concluded that the AVE values above have high validity. If the measurement model is valid and reliable, the next step, which is the evaluation of the structural model (inner model), can be carried out; if not, the path diagram must be reconstructed.

Reliability Test

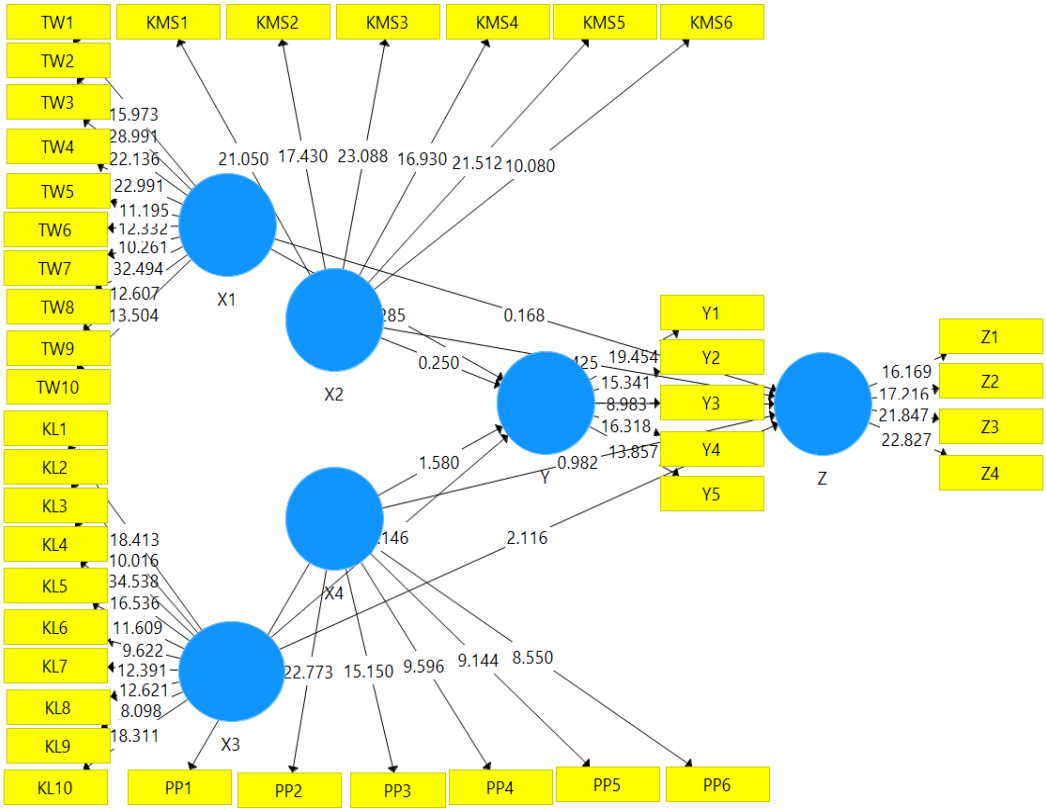
Measuring the reliability of a construct with reflective indicators can be done in two ways, namely using Cronbach's Alpha and Composite Reliability. A rule of thumb for assessing construct reliability is that the Composite Reliability value must be greater than 0.70. The Composite Reliability values for each indicator can be seen in the following table:

Table 4. Construct Reliability and Validity

Variable	*Composite Reliability*	*Cronbach's Alpha*	Conclusion
Website Appearance (X1)	0,945	0,935	*Reliable*
Social Media Engagement (X2)	0,932	0,912	*Reliable*
Service Quality (X3)	0,928	0,914	*Reliable*
User Experience (X4)	0,889	0,865	*Reliable*
Customer Loyalty (Z)	0,873	0,818	*Reliable*
Consumer Trust (Y)	0,889	0,834	*Reliable*

Source: SmartPLS Version 4.0.9.4 Data Output, 2025

Based on the Construct Reliability and Validity table above, it can be stated that the Composite Reliability value > 0.70 and the Cronbach's Alpha value > 0.70, thus it is considered reliable. It can be concluded that the variables used have met the construct reliability with values greater than the required threshold, and can be referred to as reliable.



Sumber: *Output* Data *SmartPLS* Versi 4.0.9.4, 2025

Figure 3: *Bootstrapping*

Based on the bootstrapping results shown in the figure above, the following findings were obtained:

1. Website appearance has a significant effect on customer loyalty, as indicated by a t-statistic value of 7.285, which is greater than the t-table value (1.983), and a p-value of 0.005, which is less than 0.05.
2. Social media engagement has a significant effect on customer loyalty, as indicated by a t-statistic value of 8.250, which is greater than the t-table value (1.983), and a p-value of 0.006, which is less than 0.05.
3. Service quality has a significant effect on customer loyalty, as indicated by a t-statistic value of 5.146, which is greater than the t-table value (1.983), and a p-value of 0.000, which is less than 0.05.
4. User experience has a significant effect on customer loyalty, as indicated by a t-statistic value of 2.580, which is greater than the t-table value (1.983), and a p-value of 0.015, which is less than 0.05.
5. Website appearance has a significant effect on customer trust, as indicated by a t-statistic value of 8.168, which is greater than the t-table value (1.983), and a p-value of 0.006, which is less than 0.05.
6. Social media engagement has a significant effect on customer trust, as indicated by a t-statistic value of 6.425, which is greater than the t-table value (1.983), and a p-value of 0.001, which is less than 0.05.
7. Service quality has a significant effect on customer trust, as indicated by a t-statistic value of 2.116, which is greater than the t-table value (1.983), and a p-value of 0.035, which is less than 0.05.
8. User experience has a significant effect on customer trust, as indicated by a t-statistic value of 3.982, which is greater than the t-table value (1.983), and a p-value of 0.027, which is less than 0.05.
9. Customer trust has a significant effect on customer loyalty, as indicated by a t-statistic value of 2.561, which is greater than the t-table value (1.983), and a p-value of 0.007, which is less than 0.05.

R2 (R-Square) Analysis

The R-Square values of 0.75, 0.50, and 0.25 indicate that the model is strong, moderate, and weak, respectively (Ghozali & Latan, 2015). The following are the R-Square values in the table below:

Table 5. R Square Value

Variabel	R Square	R Square Adjusted
Y	0,747	0,737
Z	0,630	0,611

Source: SmartPLS Version 4.0.9.4 Data Output, 2025

Based on Table 5 above, from the data processing results on the R-Square value, it shows that the R-Square value of the simultaneous effect (X1, X2, X3) on Y is 0.747 with an Adjusted R-Square value of 0.737. In conclusion, it can be stated that all exogenous constructs (X1, X2, X3) simultaneously influence Y by 0.737 or 73.7%, while the

remaining 26.3% is explained by other variables not included in the research model. Since the Adjusted R-Square is more than 50%, the influence of all exogenous constructs (X1, X2, X3) on Y is considered strong.

Meanwhile, the R-Square value for the simultaneous effect of X1, X2, X3, and Y on Z is 0.630, with an Adjusted R-Square value of 0.611. Therefore, it can be said that all exogenous constructs X1, X2, X3, and Y simultaneously affect Z by 0.611 or 61.1%, while the remaining 38.9% is explained by other variables not included in the research model. Since the Adjusted R-Square is more than 50%, the effect of all exogenous constructs X1, X2, and X3 on Y is considered moderate.

CONCLUSION

From the analysis and discussion presented earlier, the following conclusions can be drawn:

1. Website appearance has a positive and significant impact on TikTok customer loyalty. An attractive interface design and easy navigation enhance user comfort, which in turn strengthens their loyalty.
2. Social Media Engagement has a positive effect on customer loyalty. The presence of social media platforms increases user engagement, which strengthens their relationship with the brand.
3. Service Quality has a significant impact on customer loyalty. Responsive and professional service improves customer satisfaction, encouraging them to remain loyal to the platform.
4. User Experience Positive experiences while using the TikTok platform contribute to increased customer loyalty. Enjoyable and seamless experiences make users more likely to continue using the service. The website's appearance positively affects TikTok customers' trust (case study on all Master of Management students at the Faculty of Economics and Business, Pertiba University).
5. Website appearance has a positive and significant effect on TikTok customer trust (case study on all Master of Management students at the Faculty of Economics and Business, Universitas Pertiba).
6. Social media engagement has a positive effect on TikTok customer trust (case study on all Master of Management students at the Faculty of Economics and Business, Universitas Pertiba).
7. Service quality has a positive effect on TikTok customer trust (case study on all Master of Management students at the Faculty of Economics and Business, Universitas Pertiba).
8. User experience has a positive effect on TikTok customer trust (case study on all Master of Management students at the Faculty of Economics and Business, Universitas Pertiba).
9. Customer trust has a positive effect on TikTok Customer loyalty (case study on all Master of Management students at the Faculty of Economics and Business, Pertiba University). Customer trust mediates the relationship between independent variables (website appearance, social media engagement, service quality, and user experience) and customer loyalty. High trust strengthens the positive influence of these factors on customer loyalty.

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DIGITAL TRANSFORMATION OF GENERAL LEDGER AND FINANCIAL REPORTING SYSTEMS: EVIDENCE FROM SMES, VILLAGE ENTERPRISES, AND PUBLIC SECTOR INSTITUTIONS

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Abstract

Digital transformation in general ledger and financial reporting systems has become a strategic necessity for organizations to improve transparency, accuracy, and timeliness of financial information. This article aims to examine the implementation of digital accounting information systems in managing general ledger processes and financial reporting across small and medium-sized enterprises (SMEs), village-owned enterprises (BUMDes), and public sector institutions. The study employs a descriptive qualitative approach using document analysis, observation, and a review of accounting practices adopted by the selected entities. The findings indicate that the adoption of digital and web-based accounting systems significantly enhances the efficiency of transaction recording, reduces errors associated with manual bookkeeping, and strengthens internal control and organizational accountability. Furthermore, real-time access to financial data supports better managerial decision-making and improves reporting reliability for stakeholders. Despite these benefits, several challenges remain, including limited human resource competencies, inadequate technological infrastructure, and varying levels of digital accounting literacy. This study highlights the importance of capacity building, system adaptability, and institutional support to ensure the sustainable implementation of digital financial reporting systems. The results are expected to contribute to the development of effective digital accounting practices and provide empirical insights for policymakers, practitioners, and researchers concerned with financial reporting transformation across diverse organizational contexts.

Keywords: Accounting Information Systems; Digital Transformation; General Ledger; Financial Reporting; SMEs; Village Enterprises; Public Sector

1. INTRODUCTION

The rapid development of digital technology has significantly transformed accounting practices, particularly in general ledger management and financial reporting systems. Organizations are increasingly shifting from manual bookkeeping to digital accounting information systems to improve efficiency, transparency, and accuracy of financial information. This transformation is crucial in supporting timely decision-making and enhancing accountability across various organizational sectors. Small and medium-sized enterprises (SMEs), village-owned enterprises, and public sector

institutions face similar challenges in financial reporting, including data inconsistency, limited internal control, and delays in reporting processes. The adoption of digital and web-based accounting systems offers solutions by enabling real-time transaction recording, standardized reporting, and better financial data integration. These systems play a vital role in strengthening governance and financial management practices.

Despite the potential benefits, the implementation of digital accounting systems is not without challenges. Limitations in human resource competencies, technological infrastructure, and digital literacy often hinder effective system utilization. In some cases, resistance to change and insufficient institutional support also affect the sustainability of digital transformation initiatives in accounting and financial reporting. Therefore, this article aims to examine the digital transformation of general ledger and financial reporting systems across SMEs, village enterprises, and public sector institutions. By reviewing existing practices and empirical evidence, this study seeks to highlight the benefits, challenges, and implications of adopting digital accounting information systems, as well as their importance in improving financial reporting quality and organizational accountability.

2. METHOD

The review of selected articles on general ledger systems and financial reporting reveals a consistent pattern across SMEs, village-owned enterprises, and public sector institutions. The findings indicate that the adoption of digital accounting information systems (AIS), particularly web-based platforms and accounting software, significantly improves the effectiveness of financial recording and reporting processes. Digital systems enhance transaction accuracy, reduce manual errors, and accelerate the preparation of financial statements. In organizational practice, digital general ledger systems enable more structured financial data management and facilitate real-time access to financial information. This capability supports timely reporting and monitoring, which are critical for managerial decision-making and accountability. The results also show that standardized digital reporting formats strengthen internal control mechanisms and reduce the risk of data inconsistency.

In the public sector and village administration context, digital accounting systems contribute to improved financial transparency and compliance with reporting standards. The integration of accounting information systems with budgeting and internal control processes enhances the quality of financial reports in terms of relevance, reliability, and comparability. These systems support good governance principles by improving traceability and documentation of financial transactions. Several studies highlight the emerging role of advanced technologies such as blockchain in financial reporting. The results suggest that blockchain-based reporting systems offer potential benefits, including real-time reporting, data immutability, and enhanced security. However, their implementation remains limited due to challenges related to regulatory frameworks, technological readiness, and human resource competencies.

3. RESULT & DISCUSSION

3.1 Results

The results indicate that the adoption of digital accounting information systems significantly improves the efficiency of general ledger management and financial reporting processes. Organizations implementing web-based or application-based systems experience faster transaction recording, reduced data redundancy, and

improved accuracy compared to manual bookkeeping systems. Digital systems also enable real-time access to financial data, supporting timely reporting and monitoring activities. Furthermore, the findings show that digital financial reporting enhances transparency and accountability, particularly in SMEs, village enterprises, and public sector institutions. Standardized reporting formats and automated processes help strengthen internal control mechanisms and reduce the risk of human error and data manipulation.

The literature review further reinforces these findings by demonstrating consistent evidence across multiple organizational contexts. Previous studies report that the implementation of accounting information systems contributes to higher financial reporting quality through improved accuracy, timeliness, and reliability of financial data. In SMEs and village-owned enterprises, digital systems facilitate structured transaction recording and general ledger management, enabling more transparent and accountable financial reporting. Similarly, studies in public sector institutions indicate that the integration of accounting information systems with internal control mechanisms and budgetary processes strengthens governance and enhances the quality of financial reports. The literature also highlights that web-based systems are particularly effective in standardizing reporting formats and supporting real-time monitoring. Nevertheless, recurring challenges identified in the reviewed studies include limitations in human resource competence, insufficient technological infrastructure, and the need for continuous training and organizational support to ensure sustainable system implementation.

Table 1. Article Summary of Studies on General Ledger and Financial Reporting Systems

Author	**Article Title**	**Research Focus**	**Sector / Object**	**Key Findings**
Ashari & Dewi (2025)	Analysis of Financial Reporting Quality Viewed from Accounting Information Systems, Internal Control Systems, and Human Resource Competence	Analysis of determinants of financial reporting quality	Organization / Institution	Financial reporting quality is significantly influenced by the implementation of AIS, the effectiveness of internal control, and human resource competence.
Chandra & Poerbo (2019)	Web-Based Accounting Information System in a Labor Service Company	Design and implementation of a web-based AIS	Labor service company	Web-based AIS improves transaction recording efficiency, general ledger management, and financial statement preparation.
Dharmaw	Implementation of a Website-Based Accounting Information	Implementation	Organizati	Website-based systems simplify

an (2023)	System for Financial Management	of website-based AIS	on / SMEs	financial management and enhance the accuracy of financial reports.
Faizal et al. (2021)	Development of a Financial Management Information System for Micro, Small, and Medium Enterprises (MSMEs)	Development of a digital financial management system	MSMEs	The system assists MSMEs in transaction recording, general ledger management, and integrated financial statement preparation.
Lesmana (2021)	The Effect of Accounting Information Systems and Internal Control on Financial Reporting Quality in Pasarbatang Subdistrict	Effect of AIS and internal control	Public sector (subdistrict government)	The application of AIS and internal control positively affects the quality of subdistrict financial reports.
Maharani et al. (2025)	Determinants of Accounting Information Systems, Financial Reporting, and Budget Targets on the Quality of Government Financial Reports	Determinants of financial reporting quality	Government institutions	Accounting information systems and clear budget targets contribute to improved financial reporting quality.
Nugraha (2023)	Web-Based Financial Reporting Recording System at Suarjaya Silver Company	Web-based financial reporting system	Manufacturing company	Web-based systems accelerate recording processes and improve the timeliness of financial reporting.
Nuraini & Paramitalaksmi (2025)	Implementation of Accounting Information Systems to Enhance Financial Reporting Transparency at Panggung Lestari Village-Owned Enterprise, Panggungharjo Village	AIS implementation for financial transparency	Village-Owned Enterprise (BUMDes)	AIS implementation improves transparency, accountability, and the regularity of BUMDes financial reports.
Oktapani	The Effect of Accounting Information Systems (AIS)	Effect of AIS	Provincial	AIS and internal control systems

a (2024)	and Internal Control Systems (ICS) on Financial Reporting Quality at the Regional Financial and Asset Management Agency of South Sumatra Province	and internal control systems	government (BPKAD)	significantly affect the quality of regional government financial reports.
Rohmana & Hwihanus (2023)	The Role of Accounting Information Systems in the Utilization of Technology for Digital Bookkeeping in MSMEs	Role of AIS in digital bookkeeping	MSMEs	AIS supports the transition from manual to digital bookkeeping and improves MSME financial management efficiency.
Wulang et al. (2024)	Website-Based Financial Recording and Reporting Information System at GKS Makamenggit, East Sumba Regency	Website-based financial recording and reporting system	Religious / community organization	Website-based systems enhance recording orderliness and improve the reliability of organizational financial reports.

Source: Writer, 2025

Overall, the synthesized results presented in Table 1 confirm that the digital transformation of accounting information systems plays a critical role in strengthening general ledger management and financial reporting quality across diverse organizational settings. Regardless of sectoral differences, the adoption of web-based and application-based accounting systems consistently leads to improvements in efficiency, accuracy, transparency, and accountability of financial information. The convergence of findings from organizational, SME, village enterprise, and public sector contexts indicates that accounting information systems function not only as technical tools but also as governance instruments that support internal control, compliance, and managerial decision-making. However, the evidence also underscores that the sustainability of these improvements depends heavily on organizational readiness, human resource competence, and continuous institutional support, highlighting the need for integrated strategies that align technological adoption with capacity building and control mechanisms.

3.2 DISCUSSION

This study reinforce the view that digital transformation of accounting information systems constitutes a fundamental driver of improved financial reporting quality and strengthened organizational governance. Across organizational, SME, village-owned enterprise, and public sector contexts, the adoption of accounting information systems consistently demonstrates positive impacts on efficiency, accuracy, timeliness, transparency, and accountability of financial reporting. These outcomes are closely aligned with the core objectives of accounting information

systems, namely to provide reliable financial information that supports managerial decision-making, internal control, and accountability to stakeholders.

The evidence further suggests that digital accounting systems function not merely as operational tools for transaction processing and general ledger management, but also as strategic instruments that enhance financial governance. The integration of accounting information systems with internal control mechanisms and budgetary processes contributes to improved compliance, traceability of transactions, and overall reporting quality, particularly within public sector and village-level institutions. In the SME context, digital systems facilitate the transition from manual bookkeeping to structured and integrated financial management, enabling more informed business decisions and sustainable financial practices.

The discussion also highlights that technological adoption alone is insufficient to guarantee successful digital transformation. Recurrent challenges identified across the reviewed studies include limited human resource competence, inadequate technological infrastructure, and varying levels of organizational readiness. These constraints may reduce the effectiveness of accounting information systems and limit their contribution to financial reporting quality if not properly addressed. Consequently, the realization of full system benefits depends on continuous capacity building, targeted training programs, and strong institutional support.

Holistic approach to digital transformation is required, one that integrates technological implementation with human resource development and organizational process alignment. By synchronizing system adoption with competency enhancement and governance structures, organizations can ensure the sustainable implementation of digital general ledger and financial reporting systems and maximize their long-term value for financial management and accountability.

4.CONCLUSION

This article concludes that digital transformation of general ledger and financial reporting systems plays a significant role in improving efficiency, accuracy, transparency, and accountability across SMEs, village-owned enterprises, and public sector institutions. The adoption of digital accounting information systems reduces reliance on manual bookkeeping, minimizes recording errors, and enables real-time access to financial data for managerial and stakeholder needs. These improvements contribute to better financial governance and more informed decision-making processes. From a practical perspective, the findings highlight the importance of organizational readiness in supporting successful digital transformation. Investment in human resource capacity building, adequate technological infrastructure, and continuous system evaluation is essential to ensure sustainable implementation. Policymakers and organizational leaders are encouraged to promote standardized digital accounting practices and provide institutional support to maximize the benefits of digital financial reporting systems.

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HOW DO ESG PERFORMANCE AND BOARD DIVERSITY EVOLVE UNDER DUAL GOVERNANCE? A LONGITUDINAL DESCRIPTIVE EVIDENCE FROM SHARIAH-COMPLIANT COMPANIES

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Abstract

This study offers a longitudinal descriptive account of environmental, social and governance (ESG) performance and board diversity among Shariah-compliant public listed companies operating under dual governance arrangements in an emerging market setting. Drawing on a strongly balanced panel of 186 companies observed from 2019 to 2023, the analysis traces how ESG engagement and selected board attributes evolve over time within Islamic capital markets where market-based governance mechanisms coexist with Shariah-based oversight. The descriptive evidence points to a sustained improvement in ESG performance across the sample period. Both mean and median ESG scores rise steadily, accompanied by a clear rightward shift in the distribution of ESG outcomes. This pattern suggests that improvements in sustainability engagement are broad-based rather than concentrated among a small subset of companies. At the board level, diversity attributes exhibit uneven temporal dynamics. Gender diversity, measured using the Blau index, shows a gradual movement towards greater balance, while ethnic diversity, captured through a normalised entropy index, increases more modestly over time. In contrast, directors' religiosity, proxied by the proportion of Muslim directors on the board, remains relatively stable at the aggregate level, despite marked variation across companies. Overall, these patterns highlight the multidimensional nature of board diversity evolution within Shariah-based governance frameworks. More broadly, the observed ESG trajectory indicates that contemporary sustainability expectations can coexist with, and potentially be reinforced by, value-oriented governance principles embedded in Shariah compliance. By documenting these developments descriptively, the study establishes an empirical baseline for future research on ESG and corporate governance in Islamic capital markets and other emerging economies characterised by hybrid governance arrangements. The findings also provide a foundation for subsequent inferential and network-based analyses examining governance mechanisms and sustainability outcomes in greater depth.

KEYWORDS: Board Diversity; ESG Performance; Shariah-Compliant Companies; Dual Governance; Emerging Markets

1. Introduction

The institutionalisation of environmental, social and governance (ESG) considerations has intensified over the past decade, reshaping how corporate performance is assessed by investors, regulators and wider society. ESG engagement is increasingly understood not as a peripheral or reputational concern, but as a core element of corporate governance linked to risk oversight, organisational legitimacy and long-term resilience (Eccles et al., 2014; Khan et al., 2021). This shift reflects growing recognition that environmental and social externalities, together with governance failures, pose material risks to companies' value and systemic stability.

Despite the rapid growth of ESG-related research, empirical evidence remains disproportionately concentrated in developed economies characterised by relatively mature regulatory frameworks and stable institutional environments. Emerging markets, by contrast, operate under evolving governance regimes, uneven enforcement and heterogeneous institutional arrangements. In such settings, ESG adoption tends to occur incrementally, shaped by local learning processes and institutional constraints rather than by uniform global standards (Elamer et al., 2022). Prior studies therefore caution against directly extrapolating sustainability trajectories observed in advanced economies to emerging market contexts without careful consideration of institutional differences (Khan et al., 2021).

Beyond differences in regulatory maturity, many emerging markets are increasingly characterised by institutional hybridity, where multiple governance logics coexist within companies. This feature is particularly evident in Islamic capital markets, where conventional market-based governance mechanisms operate alongside Shariah-based oversight structures grounded in ethical principles, social justice and accountability. Shariah-compliant companies thus function under dual governance arrangements, responding simultaneously to contemporary ESG expectations and religiously informed governance norms (Haniffa & Hudaib, 2007). While policy discourse frequently highlights the compatibility between ESG objectives and Shariah principles, systematic academic evidence documenting how ESG engagement evolves within such dual governance settings remains limited.

Boards of directors play a central role in navigating these layered governance demands. As the apex internal governance mechanism, boards influence strategic orientation, oversee risk and shape the credibility of sustainability commitments. Prior research identifies board diversity as an important governance resource in this regard. Gender diversity has been associated with enhanced monitoring quality and greater sensitivity to stakeholder concerns (Adams & Ferreira, 2009), while ethnic diversity may broaden cognitive perspectives and reduce the risk of groupthink in board deliberations (Carter et al., 2010). More recently, scholars have drawn attention to directors' value orientations, including religiosity, as an additional dimension shaping ethical judgement and governance behaviour, particularly in institutional environments where religious norms are embedded within market regulation (Haniffa & Hudaib, 2007).

Notwithstanding these insights, the ESG and corporate governance literature continues to prioritise causal inference through regression-based models. While such approaches are valuable, they often presuppose relatively stable institutional conditions and well-understood variable behaviour. In emerging markets characterised by dual governance

arrangements, this assumption may be problematic. Without a clear descriptive understanding of how ESG performance and board diversity attributes are distributed across companies and how they evolve over time, causal interpretations risk being detached from their institutional context (Meyer et al., 2020).

Responding to this gap, the present study adopts a deliberately descriptive and longitudinal approach. Rather than estimating causal relationships, it documents the temporal evolution, dispersion and heterogeneity of ESG performance and board diversity attributes among Shariah-compliant public listed companies operating under dual governance arrangements from 2019 to 2023. The analysis focuses on three board diversity dimensions that are particularly salient in Islamic capital market settings: gender diversity, ethnic diversity and directors' religiosity.

By mapping levels, variability and changes over time, this study establishes an empirical baseline that clarifies how sustainability engagement and board composition evolve under institutional hybridity. In doing so, it contributes longitudinal descriptive evidence from a dual governance context that remains underexplored, enriches board diversity debates within a Shariah governance framework, and supports more informed theoretical development and future inferential research on sustainability governance in emerging markets.

2. Data and Descriptive Research Design

2.1 Sample Selection and Data Structure

This study focuses on Shariah-compliant public listed companies in Malaysia, an emerging market with a well-established Islamic capital market. Shariah-compliant firms are subject to periodic religious screening alongside conventional corporate governance and sustainability regulations, creating a governance environment in which market-based accountability coexists with faith-based ethical oversight (Haniffa & Hudaib, 2007; Grassa & Matoussi, 2018).

The sample comprises 186 Shariah-compliant companies observed over the 2019–2023 period, resulting in a strongly balanced panel of 930 firm-year observations. This timeframe coincides with intensified ESG-related regulatory guidance and growing stakeholder scrutiny in emerging markets, making it suitable for examining temporal changes in sustainability engagement.

A balanced panel structure is retained to ensure consistency across years and to distinguish cross-firm heterogeneity from within-firm temporal variation, which is particularly important for descriptive governance research aimed at documenting patterns of stability and gradual change rather than causal relationships (Wooldridge, 2010).

2.2 Variable Definition and Measurement

The analysis examines four core variables: ESG performance and three board diversity dimensions, namely gender diversity, ethnic diversity and directors' religiosity. All variables are analysed descriptively, without imposing assumptions regarding directionality or causality.

ESG performance is measured using a composite ESG score capturing firms' engagement across environmental, social and governance dimensions. Composite indicators are commonly used in descriptive sustainability research as they reflect the multidimensional nature of ESG practices while remaining neutral with respect to causal mechanisms (Berg et al., 2022). The ESG score is retained in its original scale to preserve interpretability and comparability over time.

Gender diversity is measured using the Blau index, calculated from the proportion of male and female directors on the board. For binary categories, the index ranges from 0 to 0.50, with higher values indicating a more balanced gender composition. This measure captures board heterogeneity while accounting for differences in board size (Blau, 1977; Terjesen et al., 2016).

Ethnic diversity is operationalised using a normalised entropy index bounded between 0 and 1, where higher values indicate greater heterogeneity across ethnic groups represented on the board. Entropy-based measures are particularly suitable in multi-ethnic contexts as they reflect both the number of groups present and the distribution of representation (Carter et al., 2010).

Directors' religiosity is proxied by the proportion of Muslim directors on the board, ranging from 0 to 1. In Shariah-compliant firms, this measure captures religious representation at the board level and reflects ethical orientation and accountability norms embedded in Islamic corporate governance (Farooq et al., 2021).

Firm size, measured as the natural logarithm of total assets, and profitability, proxied by return on assets, are included as contextual descriptors. These variables provide background information on firm characteristics and are not treated as explanatory controls, consistent with the descriptive focus of the study.

2.3 Descriptive Analytical Strategy

The study adopts a purely descriptive analytical design, responding to recent methodological calls to recognise descriptive analysis as a substantive and theoretically meaningful component of empirical research, particularly in complex institutional settings characterised by gradual governance adjustment (Meyer et al., 2020).

Descriptive statistics are employed to summarise central tendencies (means and medians), dispersion (standard deviations and interquartile ranges) and basic distributional features (minimum and maximum values). Temporal dynamics are examined using yearly summaries over the 2019–2023 period to capture patterns of change over time.

In addition to analysing observed levels, year-to-year variation is assessed to document the pace and variability of change within firms. This approach is especially appropriate for governance attributes, which typically evolve incrementally through board turnover and institutional learning rather than abrupt structural shifts.

Consistent with the descriptive orientation of the study, no inferential testing or causal modelling is undertaken. Instead, the analysis establishes an empirical baseline by documenting how ESG performance and board diversity attributes are distributed across firms, the extent of heterogeneity between companies, and how these characteristics evolve over time under dual governance arrangements. Recent ESG reviews emphasise the importance of such systematic descriptive mapping as a foundation for theory development and subsequent empirical testing, particularly in underexplored institutional contexts (Marie et al., 2024).

3. Findings and Discussion

Table 1 presents an integrated summary of ESG performance and board diversity attributes for Shariah-compliant publicly listed companies over the 2019–2023 period. The table combines overall descriptive statistics with start- and end-period comparisons, allowing an assessment of both central tendencies and temporal changes.

The results indicate a clear improvement in ESG performance across the sample. The overall mean ESG composite score was 36.06, with a relatively large standard deviation of 17.55, indicating substantial variation in sustainability engagement among firms. Over time, ESG performance increased markedly from a mean score of 26.32 in 2019 to 43.65

in 2023. This upward trend suggests that ESG practices became progressively more embedded among Shariah-compliant companies during the observation period.

Despite this improvement, dispersion in ESG performance remained relatively stable. The standard deviation was 14.98 in 2019 and 16.95 in 2023, indicating that firm-level differences persisted even as average ESG scores rose. This pattern suggests that improvements in ESG engagement occurred broadly across firms, but without convergence towards a uniform level of sustainability performance.

Regarding board diversity, gender diversity exhibited a noticeable upward trend. The overall mean Blau index for gender diversity was 0.29, with a standard deviation of 0.15. Gender diversity increased from a mean of 0.25 in 2019 to 0.36 in 2023. At the same time, dispersion declined from 0.16 to 0.10, indicating a degree of convergence across firms. These results suggest that female representation on boards improved gradually and became more evenly distributed across companies.

Ethnic diversity showed a more modest pattern of change. The overall mean ethnic diversity score was 0.46, with a standard deviation of 0.25. Over the five-year period, mean ethnic diversity increased slightly from 0.46 in 2019 to 0.48 in 2023, while dispersion remained largely stable. This indicates limited change in the ethnic composition of boards, with persistent heterogeneity across firms.

Directors' religiosity displayed relative stability over time. The overall mean proportion of Muslim directors was 0.33, with a standard deviation of 0.27. This value changed minimally from 0.34 in 2019 to 0.33 in 2023, suggesting that religious representation at the board level remained largely unchanged at the aggregate level. Firm-level variation, however, remained substantial throughout the period.

Table 1: Integrated Descriptive Statistics of ESG Performance and Board Diversity (2019–2023)

The results provide descriptive evidence on how ESG performance and board diversity

Measure	Overall Mean	Overall SD	2019 Mean	2019 SD	2023 Mean	2023 SD	Direction of Change
ESG Composite Score	36.06	17.55	26.32	14.98	43.65	16.95	Strong increase
Gender Diversity (Blau Index)	0.29	0.15	0.25	0.16	0.36	0.10	Gradual increase with convergence
Ethnic Diversity (Entropy Index)	0.46	0.25	0.46	0.25	0.48	0.24	Modest increase
Directors' Religiosity (Proportion Muslim)	0.33	0.27	0.34	0.28	0.33	0.26	Largely stable

evolved under dual governance arrangements in an emerging market context. The sustained improvement in ESG performance suggests that Shariah-compliant companies increasingly engaged with contemporary sustainability expectations between 2019 and 2023. This pattern aligns with broader trends observed in emerging markets, where ESG practices are gradually institutionalised through regulatory guidance, stakeholder pressure and organisational learning.

The persistence of dispersion in ESG scores indicates that improvements were uneven across firms. While average performance increased, some companies advanced more

rapidly than others. This heterogeneity reflects differences in organisational capacity, governance priorities and strategic orientation, underscoring that ESG integration under dual governance does not produce uniform outcomes.

Board diversity dynamics further highlight differentiated adjustment processes. Gender diversity showed the most pronounced improvement, accompanied by declining dispersion. This suggests that pressures to increase female board representation were increasingly internalised across firms, leading to more similar gender diversity profiles over time. The gradual nature of change is consistent with structural constraints such as director tenure and nomination practices, which typically limit rapid board reconfiguration.

In contrast, ethnic diversity evolved more slowly and exhibited persistent heterogeneity. The modest increase in mean values, coupled with stable dispersion, suggests that ethnic diversification at the board level remains constrained by entrenched recruitment networks and institutional norms. Compared to gender diversity, ethnic diversity appears less responsive to short-term governance pressures and may require longer-term structural and cultural change.

Directors' religiosity displayed a distinct pattern of stability. Despite operating under Shariah-compliant frameworks, firms did not exhibit systematic changes in religious representation at the board level. This suggests that religiosity functions as a structurally embedded governance attribute rather than a dimension subject to frequent adjustment. Importantly, the coexistence of stable religiosity and rising ESG performance indicates that improvements in sustainability engagement did not depend on changes in religious composition. Ethical orientation appears to be institutionalised through broader governance practices rather than board demographics alone.

Taken together, the findings illustrate that ESG performance and board diversity evolve through gradual and uneven processes under dual governance arrangements. Shariah-based governance principles appear compatible with strengthening ESG engagement, but they do not eliminate firm-level variation in governance practices. The descriptive patterns underscore the importance of contextualised analysis when examining sustainability and governance dynamics in emerging markets characterised by institutional hybridity.

Implications

The descriptive patterns documented in this study carry several implications for policy design, corporate practice and future academic research. Given the non-inferential nature of the analysis, these implications are framed cautiously, focusing on interpretation and relevance rather than prescription.

5.1 Policy Implications

The sustained improvement in ESG performance suggests that existing sustainability-related guidelines and disclosure initiatives have contributed to progressively stronger engagement among Shariah-compliant companies. Rather than relying on prescriptive or highly interventionist measures, the findings support a regulatory approach that emphasises consistency, transparency and gradual institutional alignment.

The gradual increase in gender and ethnic diversity at the board level further indicates that diversity-related governance reforms are taking effect over time, albeit incrementally. Policymakers may therefore prioritise disclosure-based mechanisms and long-term capacity building over rigid quota systems, particularly in contexts where board appointments remain closely tied to ownership structures and institutional norms.

Importantly, the relative stability of directors' religiosity at the aggregate level suggests that effective Shariah governance does not necessarily require uniform board composition. This reinforces the view that ESG frameworks and Shariah-based principles can be aligned through complementary governance expectations centred on accountability, ethical conduct and stewardship, rather than through additional structural constraints.

5.2 Practical Implications for Boards and Companies

From a practical standpoint, the findings highlight the central role of boards in shaping companies' sustainability trajectories under dual governance conditions. The steady upward trend in ESG performance implies that boards are increasingly engaged in overseeing sustainability-related matters, moving beyond symbolic compliance towards more integrated governance attention.

The differentiated evolution of board diversity dimensions carries practical significance for nomination committees and senior management. The gradual improvement in gender and ethnic diversity suggests that diversity initiatives are most effective when embedded within broader board renewal and succession planning processes, rather than treated as standalone governance signals. Companies may therefore benefit from adopting longer-term perspectives on board composition that align diversity objectives with strategic and sustainability priorities.

The stability of religiosity alongside rising ESG engagement further implies that ethical orientation and sustainability oversight can coexist without necessitating homogeneity in religious representation. Practitioners operating in Shariah-compliant companies may thus focus on strengthening ethical governance practices and decision-making norms, rather than equating sustainability effectiveness with specific board demographic profiles.

5.3 Implications for Future Research

This study also carries implications for future research on ESG and corporate governance in emerging markets characterised by institutional hybridity. By establishing a longitudinal descriptive baseline, the findings highlight the importance of understanding temporal variation and companies-level heterogeneity prior to engaging in causal inference.

Future studies may extend this descriptive evidence by assessing whether the documented patterns translate into systematic relationships under inferential modelling, or by investigating how board networks, committee structures and internal governance processes interact with board diversity attributes in shaping ESG outcomes. In this respect, descriptive analysis provides an essential empirical anchor for theory development in governance environments marked by institutional diversity and firm-level heterogeneity (Aguilera et al., 2018).

6. Conclusion

This study provides a longitudinal descriptive examination of ESG performance and board diversity dynamics among Shariah-compliant public listed companies operating under dual governance arrangements. Drawing on balanced panel data covering the 2019–2023 period, the findings document a clear and sustained improvement in ESG performance, indicating a gradual strengthening of sustainability engagement within this segment of the capital market.

The descriptive evidence further reveals that board diversity attributes evolve at different rates. Gender and ethnic diversity display incremental upward movements over time, reflecting gradual adjustments in board composition rather than abrupt structural change.

In contrast, directors' religiosity remains relatively stable at the aggregate level, despite substantial companies-level heterogeneity. Taken together, these patterns underscore the importance of conceptualising board diversity as a multidimensional construct, particularly in institutional environments shaped by ethical and religious governance norms.

More broadly, the findings highlight the relevance of inclusive and value-driven governance in supporting sustainability engagement within Islamic capital markets. The coexistence of ESG frameworks and Shariah-based governance principles appears to provide a conducive environment for the progressive institutionalisation of sustainability practices, rather than presenting inherent constraints.

By foregrounding descriptive mapping rather than causal estimation, this study contributes an empirical baseline for future research on ESG and corporate governance in emerging markets characterised by institutional hybridity. The longitudinal insights presented here lay the groundwork for subsequent inferential and network-based analyses that may further explore how board attributes, governance structures and sustainability outcomes interact over time.

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SUSTAINABLE CORPORATE GOVERNANCE AND THE WAR FOR TALENT: A SYSTEMATIC LITERATURE REVIEW OF THE ENGAGEMENT-RETENTION NEXUS.

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ABSTRACT

The "War for Talent" paradigm has fundamentally shifted from competitive financial incentives to a holistic demand for alignment of ethical and sustainable values. This study aims to analyze the strategic role of Sustainable Corporate Governance (SCG) in enhancing talent retention strategies through its mediating role in employee engagement. Using the Systematic Literature Review (SLR) methodology with the PRISMA 2020 protocol, this study screened data from the Scopus database using specific keywords related to ESG and human resources. A total of 663 high-quality articles published between 2014 and 2024 were analyzed using a descriptive and thematic approach supported by VOSviewer.

The analysis revealed a significant surge in publications integrating Environmental, Social, and Governance (ESG) principles into human resource management. The thematic analysis confirmed the existence of a complex nexus where the influence of SCG on retention is not direct but is fully mediated by employee engagement and perceived organizational support. Specifically, Green Human Resource Management practices and ethical leadership were identified as vital operational mechanisms that foster trust, meaningful work, and affective commitment. The study concludes that SCG is not simply a compliance metric, but rather a modern strategic component of employer branding. The implication is that organizations are encouraged to shift to stakeholder-centric governance and integrate sustainability indicators into leadership accountability to win the global talent race.

Key Words: Sustainable Corporate Governance, Employee Retention, Employee Engagement, Green HRM, Environment Social Governance, SLR

1. Introduction

The concept of the "War for Talent" has undergone a significant transformation over the past few decades, evolving far beyond its initial conception in the late 1990s as a mere competition for attracting skilled employees through financial incentives. In the contemporary global business environment, this paradigm has shifted toward a more holistic approach that fundamentally incorporates ethical values and employee goals into organizational hiring and retention strategies. While competitive remuneration remains a factor, the modern workforce increasingly demands a deeper alignment with their employers, necessitating that organizations prioritize sustainable corporate governance (SCG) and ethical leadership as central tenets of their operational philosophy. This evolution reflects a broader societal shift where organizational success is no longer viewed in isolation but is intrinsically linked to the alignment of employee values with a clearly defined corporate purpose and robust ethical standards. Consequently, the strategic focus of human resource management has expanded to encompass the creation of work environments that actively prioritize well-being and Corporate Social Responsibility (CSR), marking a departure from transactional employment relationships toward those grounded in shared values and ethical commitment.

This shift in the employment landscape is particularly pronounced among younger demographic cohorts, specifically Generation Z and Millennials, who now constitute a significant portion of the global workforce. Research indicates that the perception of Environmental, Social, and Governance (ESG) commitments among these groups significantly influences their choices regarding potential employers. These employees prioritize working for organizations that demonstrate a genuine commitment to sustainability and ethical governance, viewing such commitments as indicative of an organization's overall ethical character and legitimacy in the marketplace. For these generations, the "War for Talent" has shifted from offering high salaries to providing purpose and ethical alignment, where employees are acutely aware of corporate behavior regarding environmental and social issues (Islam et al., 2020; Macini et al., 2020). Consequently, companies that effectively communicate and embody strong ESG strategies are better positioned to attract and retain this talent, linking employer attractiveness directly to perceived commitments to sustainability and responsible governance (Islam et al., 2021).

However, the failure to align organizational values with employee expectations presents severe strategic challenges, most notably in the form of high employee turnover rates. High turnover is no longer merely an operational nuisance but a critical strategic issue that incurs substantial direct and indirect costs. Financially, the burden of replacing a single employee can exceed 200% of their annual salary, factoring in recruitment, onboarding, and training costs (Cosenza et al., 2024). Beyond immediate financial losses, high turnover rates erode institutional knowledge, decrease productivity, and can cause lasting damage to employee morale and customer satisfaction (Cosenza et al., 2024). Furthermore, organizations plagued by high turnover often struggle to maintain a cohesive corporate culture, creating a cyclic trend of dissatisfaction that further undermines organizational performance and reputation in the talent market (Macini et al., 2020; Madero et al., 2022). Thus, retention has emerged as a strategic imperative, not just an operational metric.

To address these challenges, Sustainable Corporate Governance (SCG) has emerged as a vital framework. SCG is no longer just about compliance but has become a core element of employer branding, defined by the integration of ESG into the strategic framework of Human Resource Management (HRM) (Macini et al., 2020; Madero et al., 2022). This convergence, often referred to as Sustainable Human Resource Management (SHRM), underscores the necessity for HR practices to prioritize sustainability throughout the entire employee lifecycle—from recruitment and training to development and exit (Singh et al., 2024). By fostering a workplace culture that is ethically sound and environmentally responsible, SCG initiatives aim to mitigate the risks of turnover by creating a sense of organizational loyalty and commitment. A misalignment between employee values and corporate ethics often manifests in increased turnover intentions; therefore, the implementation of SCG is critical for fostering an environment employees where feel their personal values are respected and reflected in their daily work (Macini et al., 2020).

Specific solutions found in the literature point to the efficacy of Green Human Resource Management (GHRM) as a mechanism to operationalize SCG. GHRM encompasses eco-friendly practices within recruitment, training, and employee engagement, effectively integrating sustainability into the fabric of organizational culture (Atmaja et al., 2024; Wajdi et al., 2023). Empirical studies have demonstrated that perceived strong GHRM practices correlate with improved employee commitment and

significantly reduced turnover intentions (Suleman et al., 2023). By encouraging the active participation of employees in decision-making processes and sustainability initiatives, GHRM enhances their sense of ownership and commitment to organizational goals (Madero et al., 2022). Furthermore, effective GHRM serves as a gateway to improved employer branding, establishing a competitive edge in talent acquisition by signaling a green organizational culture to prospective employees (Yasin et al., 2022; Muisyo et al., 2023).

Complementing GHRM, ethical leadership plays a critical, distinct role in cultivating green behaviors and fostering a culture of trust. Leaders who exhibit ethical values facilitate an environment where sustainable practices are integrated into everyday operations, which in turn bolsters employee engagement and aligns individual efforts with long-term sustainability goals (Hameed et al., 2024; Kanojia & Dhiman, 2025). The literature suggests that ethical leadership is the strongest predictor of affective commitment, particularly among millennials, and helps cultivate a culture of trust that enhances employee loyalty (Karakasnaki, 2024; Islam et al., 2020). Conversely, the absence of ethical governance can lead to high turnover as employees seek environments that align with their ethical standards; Thus, perceived organizational support regarding sustainability initiatives was shown to substantially reduce intentions to leave (He et al., 2020; Suleman et al., 2023).

Despite the growing body of literature on GHRM and ethical leadership individually, there remains a need to synthesize how these elements function as a cohesive system within the context of the "War for Talent." The current literature highlights that Sustainable Corporate Governance serves as a crucial pillar in the new employment paradigm, influencing employer branding and shaping organizational culture (Yasin et al., 2022; Shakil et al., 2023). However, the specific mechanisms connecting governance frameworks directly to retention strategies through the mediating role of employee engagement require further systematic exploration. The interaction between SCG practices, the psychological state of engagement, and the final outcome of retention forms a complex nexus that warrants a comprehensive review to inform future HR strategies.

Therefore, this study aims to address this gap by conducting a Systematic Literature Review (SLR) of articles published in 2025. The study specifically focuses on linking corporate governance, sustainability, and human resource management outcomes to answer two primary research questions: How does Sustainable Corporate Governance influence employee retention strategies? and what role does employee engagement play as a mediator in the SCG-Retention relationship?

By synthesizing findings on the interplay between ethical governance, engagement, and retention, this research seeks to provide a consolidated theoretical framework that establishes SCG not merely as a financial or compliance metric, but as a critical, strategic component of modern human resource management.

2. Methodology

A systematic literature review (SLR) is necessary in management studies to ensure that findings are based on the most relevant literature. The study was conducted using a methodology that adheres to best practices in the field. Research questions were designed to produce a clear and comprehensive literature analysis, and data were collected through a data synthesis process. These steps help ensure that findings are based on the most relevant sources and that the review maintains its quality. This section provides a detailed

overview of the search strategy, exclusion and inclusion criteria, and data analysis methods used.

2.1 Search Strategy and Data Sources

Developing a comprehensive search strategy is the foundation for conducting an effective SLR. This strategy must establish the use of specific keywords to accurately capture relevant literature. In this study, the search strategy was designed to cover a broad spectrum of literature by utilizing a reputable, leading academic database, Scopus. This database selection was based on its extensive coverage of high-quality management and business journals, ensuring that the study captured the most influential and relevant publications in the field. The use of this database aligns with literature recommendations to ensure that the review is not biased toward a single indexing source and encompasses a sufficient diversity of empirical evidence.

The search process was conducted using a search string incorporating key terms reflecting the study's primary variables. The search string constructed using Scopus was: ESG (Environmental Social Governance), which was then explored through the variables Employee Engagement and Retention through a literature analysis to limit the literature to the main concepts of ESG, Employee Engagement, and Employee Retention. This initial search strategy yielded a total of 19,660 documents. This number reflects the volume of available literature before the application of more stringent quality and relevance filters, indicating that this topic has received significant attention but requires systematic screening to identify the most valid empirical evidence. Subsequent filtering was performed to reduce the number of articles and make them more specific. The filtering resulted in 663 relevant articles, based on the search strategy and Scopus data sources.

The literature search used the basic keyword 'ESG' to capture a broad spectrum of globally indexed corporate sustainability practices. This literature was then systematically screened to isolate studies that specifically addressed the dimensions of Governance and its strategic implementation (SCG) in influencing employee engagement and retention.

2.2 Inclusion and Exclusion Criteria (PRISMA Protocol)

To ensure transparency and reproducibility of the study selection process, this study adopted the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. The application of the PRISMA 2020 protocol in social science research is crucial because these guidelines provide a structured reporting framework that improves reporting standards and the overall quality of systematic reviews. This includes the use of a flow diagram that visualizes the study selection process, detailing how many studies were screened, included, and excluded, along with the reasons for exclusion. This diagram enhances transparency and allows readers to follow the researchers' decision-making process throughout the review stages. The selection process from identification to final inclusion is depicted in detail in Figure 1.

The Following is a flowchart image showing depreciation article from 19,660 to 663.

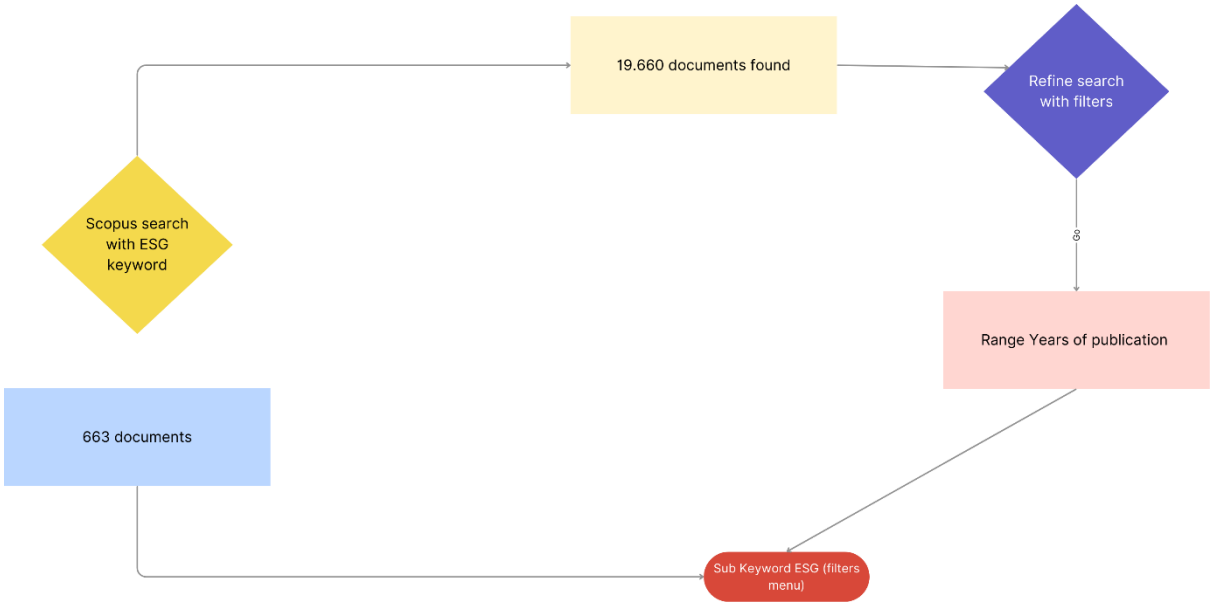


Figure 1. Scopus Screening Flow (ESG Keyword)

Figure 2. PRISMA Table detailing the selection process from identification to final inclusion (Bibliometrix)

Parameter	Criteria Inclusion (I ACCEPT if ...)	Criteria Exclusion (I REJECT if ...)
Year Rise	Article published in 2025	Article published before 2025 (because context technology / pandemic different).
Language	English	Languages other than English
Document Type	Only Journal Articles from journal accredited/reputable	Conference proceedings, Book Chapter, Thesis/Dissertatio, Review Article, or Editorial Opinion
Region	ASIA, America, Europe, Africa, Oceania	Unknown
Variables	ESG, EE, Retention	Topics besides than ESG POV
Method	Use method Quantitative (there is clear numerical data)	Qualitative Methods pure (interview) or Conceptual Paper (only) theory without data)

Strict inclusion and exclusion criteria were established to select the most relevant and high-quality articles. Inclusion criteria required articles to be written in English to ensure global accessibility and consistent terminology. Furthermore, articles had to be published in peer-reviewed journals, a standard indicator of academic quality. The publication window was limited to 2025 to capture the latest dynamics in corporate governance and human resource management (HRM) practices. Methodologically, this

review included only empirical studies, using both quantitative and qualitative approaches. PRISMA encourages the inclusion of diverse study designs to capture comprehensive perspectives, which is particularly relevant for social science research given the variety of qualitative and quantitative approaches prevalent in this field.

Conversely, exclusion criteria were applied to eliminate publication types deemed to have lower empirical validity or less specific relevance. Conference proceedings, book chapters, and white papers were excluded from the analysis to prioritize journal articles that have undergone rigorous review. Furthermore, articles that focused solely on a company's financial performance without integrating human resource (HR) variables were excluded. This step is crucial to maintaining the review's focus on the nexis between governance and the human aspects of the organization, rather than solely on the financial aspects.

The screening process was conducted in three tiered stages:

1. The first stage involved reviewing titles and abstracts to eliminate articles clearly irrelevant to the research topic using the primary keyword, ESG. This stage was conducted using Scopus, using ESG keywords and filtered as needed.
2. The second stage was a review using the Bradford Law Bibliometrics section, but still using all sources because this study analyzed articles to draw new conclusions based on demographic and thematic analysis. Because this stage is an exclusionary stage, there was some slight reduction in the bibliometric filtering of articles that passed the first stage to verify the content's suitability to the research question.
3. The third stage involved Quality Assessment (QA). As suggested in the SLR methodology literature, systematic quality assessment is crucial for evaluating the methodological quality and risk of bias in included studies. Quality assessment criteria in corporate governance reviews should consider aspects such as risk of bias, quality of study design, and relevance to the research question (Kumar et al., 2021; Aboramadan, 2020). Each study was evaluated based on the clarity of the research design, the validity of the methodology used (both qualitative and quantitative), and the clarity of participant selection and appropriate controls (Agarwal et al., 2022; Iqbal et al., 2025).

After this rigorous screening process, the final sample size for analysis was 663 high-quality articles.

2.3 Data Analysis

After article selection was complete, the next stage was data extraction and management, which employed a systematic approach to gather key information from each selected study, such as author(s), publication year, methodology, findings, and conclusions. Data synthesis and analysis were then conducted using a dual approach: descriptive and thematic analysis, supported by bibliometric analysis using VOSviewer software. Descriptive analysis was conducted to map publication trends and the geographic distribution of the 663 selected articles. The objective was to understand the evolution of research interest in this topic over the period 2025 and identify the geographic contexts in which these studies were most prevalent. This is crucial for assessing the external validity and generalizability of the findings to different contexts or sectors within the corporate governance field (Waqas et al., 2021).

Next, thematic analysis was used to synthesize the findings regarding the relationship between Governance, Engagement, and Retention. Given that the sample included both quantitative and qualitative studies, narrative synthesis was used to categorize the findings based on trends and themes emerging from the literature, enabling

the integration of rich insights from different methodologies. To strengthen the analysis, this study utilized VOSviewer for bibliometric visualization of keyword co-occurrences. VOSviewer is a specialized software tool that assists researchers in conducting bibliometric analysis to measure and visualize scientific publications and citations.

In the context of Human Resource Management (HRM), VOSviewer enables the creation of visual maps that represent the relationships between various elements in the literature, such as frequently occurring keywords. This keyword co-occurrence analysis facilitates the identification of trending topics and emerging areas in HRM (Bahuguna et al., 2022; Kumar et al., 2021). By visualizing how terms such as "Corporate Governance," "Engagement," and "Retention" are interconnected within the global literature network, this analysis can reveal patterns and connections between research themes and indicate the evolution of interest in specific topics over time (Ogbeibu et al., 2023). Additionally, VOSviewer assists in assessing publication trends by tracking the number of publications and trends over time, allowing researchers to gauge the growth of this field of study, including the impact of sustainable practices or technology on HRM practices (Hassan et al., 2023). This integration of bibliometric analysis provides additional depth to narrative reviews, allowing for more objective and visual identification of research gaps.

3. Results

This section presents empirical findings obtained from a systematic review of 663 high-quality articles that underwent a selection process. The analysis is presented in two main sections. First, descriptive findings provide a macro overview of publication trends and the geographic distribution of research related to sustainable corporate governance (SCG) and human resource management. Second, an in-depth thematic analysis examines the nexus or relationship between governance, employee engagement, and talent retention, elaborated through relevant theoretical lenses.

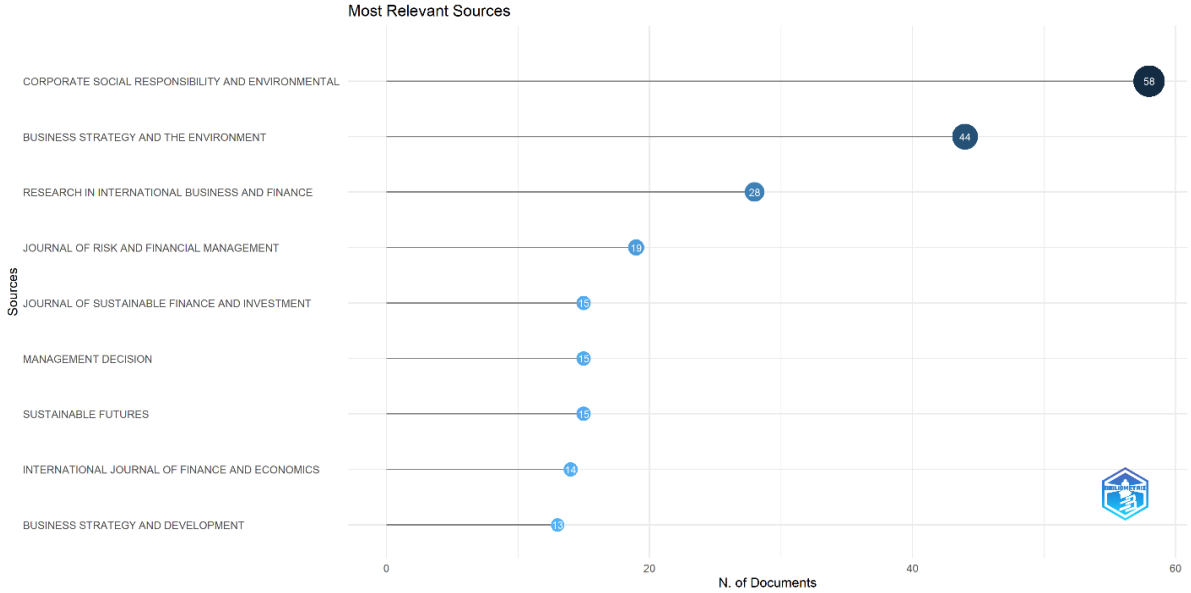
3.1 Descriptive Findings

This descriptive analysis aims to map the academic landscape of the research topic, highlighting how researchers' attention to the integration of ESG (Environmental, Social, and Governance) issues in HR management has evolved over time and how it has spread across various global contexts. Analysis of data collected by bibliometric tools reveals various dynamics in the scientific literature, particularly a surge in publications in 2025. Figure 2 shows an upward trend that developed after the pandemic ended, with momentum continuing until its peak in 2025. The term sustainability has gained widespread attention in the scientific literature, reflecting the growing recognition of environmental, social, and governance (ESG) issues by academic institutions (Liu et al., 2024). This phenomenon represents a paradigm shift in how companies view sustainability. The high number of publications also supports the notion that ESG disclosure benefits corporate reputation and attracts responsible investors (Dossa, 2025; Lu et al., 2025). This trend suggests that integrating ESG activities into strategic management processes is becoming a critical priority for organizations (Dossa, 2025; Tutar et al., 2025).

3.1.1 Publication Trend

The 2025 trend analysis reveals interesting dynamics in the volume of scientific publications in 2025. As illustrated in Figure 2, there is a significant trend in the number of publications in 2025. This phenomenon is inseparable from the global context following the COVID-19 pandemic, which has fundamentally shifted organizational priorities. Since the beginning of the pandemic, research on ESG factors, particularly in the field of Human Resource Management, has gained tremendous momentum globally.

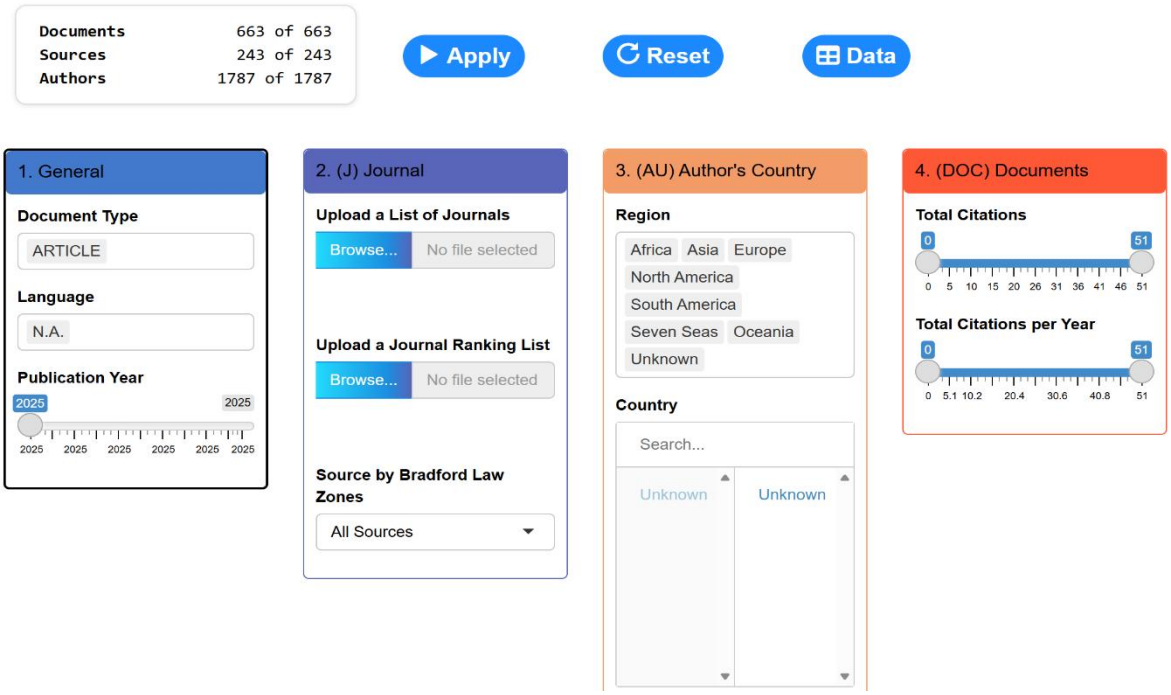
Figure 2. Yearly distribution of selected articles (20 25).



Source : Bibliometric Most Relevant Source

(Graphic image the stem shows amount article journal distributed to a number of source Journal Indexed by Scopus)

Then the filtering process in bibliometrix uses the Document Type Article, publication according to the topic, namely 2025, Source of Bradford, namely all sources, and total citations of 51. So based on the filter results, 663 documents were obtained as in figure 3 below:



Bibliometrix Filter List

Based on the filter list, 663 documents with the highest distribution of articles in 2025 were identified, with sources published in CSR and Environmental journals. According to the analyzed publication trends, the rapid emergence and evolution of green HR management practices was fueled by the pandemic. Furthermore, the increased

emphasis on corporate social responsibility also contributed to the development of more effective GHRM strategies (Gupta et al., 2025). This shift toward recognizing the importance of HR in promoting sustainable practices reflects the growing recognition of HR's role in helping organizations achieve their goals. A study by Choudhary and Datta (2023) also showed that the pandemic has sparked discussions about the importance of green creativity in management. While the pandemic has highlighted various ESG themes, it has also provided new opportunities to study them, particularly in the area of employee engagement. The shift toward digitalization and remote work also emerged during the pandemic.

A study by Setyaningrum and Muafi (2023) revealed that the integration of GHRM practices and digital skills has gained widespread popularity as companies adapt to new business realities. The study also notes that these trends support the idea that digital transformation can help organizations achieve their sustainability goals.

3.1.2 Geographic Distribution

The geographic distribution of studies shows a clear contrast between developing and developed countries. Figure 3 shows the distribution of articles across Africa, Asia, Europe, North America, South America, the Seven Seas, and Oceania. Most studies originate from North America and Europe, which are typically regions with the highest levels of ESG regulation. This is understandable, as these countries experience stronger stakeholder pressure and regulatory frameworks. Developed countries such as Europe and the US have a higher number of publications on GHRM than developing countries. This is due to the sophistication of their research institutions and the prevalence of ESG issues within corporate frameworks, contributing factors to this trend (Zhang et al., 2024).

Despite the increasing number of studies on GHRM, interest in the subject continues to grow in developing countries such as India, China, and Indonesia. Research in these regions focuses on the importance of CSR as a strategic tool for retention. According to Alenzi et al. (2023), research on the role of GHRM in the hospitality and manufacturing industries indicates that it is becoming increasingly prevalent in these sectors. This suggests that the adoption and awareness of environmentally friendly practices are increasing in developing countries due to their commitment to global sustainability goals. Research parameters and study focus vary by country. For example, studies in developed countries typically employ sophisticated methodologies and quantitative metrics. Conversely, studies conducted in developing countries tend to focus on the implementation of basic GHRM strategies and practices. Varying levels of corporate governance maturity and sustainability practices in developing countries are among the factors contributing to the slow pace of GHRM research in this region (Gholami et al., 2024). However, other factors such as lack of regulation and resource constraints also contribute to the development of nascent literature on the subject (Zaidi et al., 2025; Priyadarshini et al., 2023).

Furthermore, an analysis of the geographic distribution reveals an interesting pattern regarding the origin of published studies. Historically and empirically, the distribution of research remains heavily skewed toward North America and Europe. Recent bibliometric analyses confirm that the majority of ESG-related publications originate from these developed regions, which have more established regulatory frameworks and stakeholder pressures (Liu et al., 2024; Rasool et al., 2025). This dominance is understandable given the sophisticated research institutions and strong prevalence of ESG issues in their corporate frameworks in developed countries, such as Europe and the United States. However, there is an encouraging trend of developing

countries beginning to integrate into this global research landscape. A particularly marked increase is observed in Asia and other developing countries, such as India, China, and Indonesia, which have seen significant growth in academic attention (Rasool et al., 2025). The role of institutional frameworks in supporting ESG initiatives has also received attention, particularly in Eastern Europe and Central Asia, indicating an emerging trend of developing countries beginning to contribute substantially and actively engage with ESG-related research (Rasool et al., 2025). In these areas, research tends to focus on the implementation of basic strategies such as Green Human Resource Management (GHRM) and the importance of CSR as a strategic tool for retention in specific sectors such as manufacturing and hospitality.

3.2 Thematic Analysis: The SCG-Engagement-Retention Nexus

This thematic analysis aims to analyze the various mechanisms through which Sustainable Corporate Governance (SCG) influences talent retention strategies. The analysis was conducted through the substance of SCG, Engagement, and Retention, which were applied to "Literature Citations," resulting in core articles synthesized with their own narratives. The results of this thematic analysis are as follows:

1. This study focuses on the role of employee engagement. Furthermore, the relationship between employee retention and engagement is a central theme in efforts to improve organizational performance. According to studies conducted by Orellana, Asongu, and Yadav, employee engagement can directly influence organizational commitment and retention rates (Orellana et al., 2025; Yadav & Asongu, 2025). The relationship between employee commitment and retention can be explained by the creation of a conducive work environment. Employee intrinsic motivation can be enhanced by an effective organizational governance framework, which helps companies achieve their goals and improve their performance (Jain & Banerjee, 2025). This suggests that financial compensation is not the sole driver of employee retention. Deep psychological engagement can also be leveraged to improve employee retention rates. A well-designed framework can help enhance employee engagement. According to studies by Heubeck & Ahrens, Zakriya & Chams, and others, organizations that implement strong SCG practices are more likely to report high employee satisfaction (Heubeck & Ahrens, 2025; Zakriya & Chams, 2025).
2. These studies have shown that investing in SCG leads to better environmental, social, and governance (ESG) performance, which makes the company more attractive as a workplace (Heubeck & Ahrens, 2025). Signaling theory states that strong governance practices can help the labor market understand a company's ethical standards. This can help companies attract and retain value-conscious individuals. Employees tend to develop greater trust in a company if it has operational transparency and high governance standards. This is a crucial factor that can help them stay with the organization for a long time. Bibliometric networks indicate that ethics and trust are important elements that can be linked to retention.

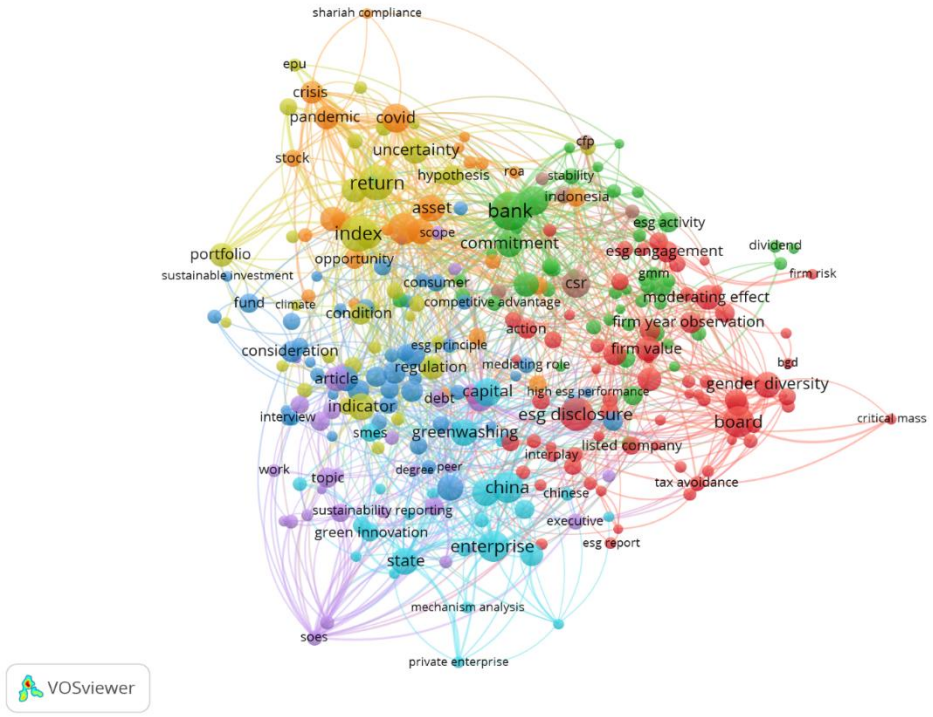


Figure 4. ***Network Visualization*** **from Keyword ESG after selected by Scopus filter**

The relationship between retention and corporate governance (SCG) can be strengthened by meaningful work and perceived organizational support. Sustainable practices can create a sense of purpose for employees, which can help them feel connected to the company. At this stage, this research also examined keyword distribution using VOSviewer, as shown in Figure 4. The keyword ESG, which generated 663 articles, was followed up through the RIS document, resulting in a distribution of topical substance as shown in Figure 4 above.

According to the analysis, conducted through a narrative literature citation process to obtain thematic analysis results, several analytical findings were obtained, including:

1. Active involvement in governance processes and investment in employee well-being are factors that can help organizations adapt to current economic conditions (Saini et al., 2025; Yadav & Asongu, 2025). One of the most effective ways to improve SCG is through the use of a green HR management system. In addition to motivating sustainable behavior, green recruitment and training can also help raise awareness of environmental issues. According to researchers, employees who feel valued and supported through ESG initiatives tend to feel more committed to the organization.

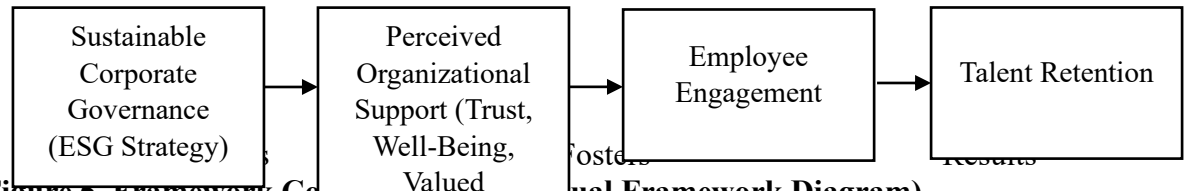


Figure 5. Framework Co ual Framework Diagram)

3. Employees who feel valued and supported through ESG initiatives tend to feel more committed to the organization. One of the most important factors that can help

improve employee retention is leadership accountability. The findings of this study indicate that ethical leadership can help employees feel more committed to their organization. This is because this type of leadership can help align employees with the company's values. This analysis also shows that the use of Sustainable Corporate Governance (SCG) can help improve employee retention rates in the face of global competition.

4. Conclusion

Through demographic analysis of research distribution, publication trends, and thematic analysis, this study demonstrates that the transformation of corporate governance from a compliance tool to a strategic imperative has transformed talent retention into a critical factor in global competitiveness. The study suggests that the influence of Sustainable Corporate Governance (SCG) is indirect, but rather mediated by perceived organizational support and employee engagement. The study also finds that ethical leadership and transparent governance practices can help organizations build trust and foster meaningful work. Green HR Management is a key operational mechanism that enables employees to perceive the benefits of these policies.

Furthermore, this study aims to provide a deeper understanding of the relationship between employee behavioral outcomes and corporate governance by integrating Signaling Theory. The research demonstrates that sustainable employee retention is associated with an organization's genuine ESG (Environmental, Social, and Governance) initiatives. The study also identifies the need for organizations to adopt a more stakeholder-centric approach to managing their talent. This can be achieved through the integration of sustainability-related performance indicators. Due to the increasing number of studies on the relationship between employee retention and corporate governance, it is important for future research to explore the validity of this theory across different industrial sectors and developing countries.

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DEVELOPING A DIGITAL ENTREPRENEURSHIP STRATEGY MODEL TO INCREASE THE COMPETITIVENESS OF MICRO, SMALL, AND MEDIUM ENTERPRISES (MSMES) INDONESIA

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Abstract

Objective: This study aims to analyze the role of Digital Entrepreneurship in strengthening the competitiveness of Indonesian Micro, Small, and Medium Enterprises (MSMEs) in the midst of accelerating digital transformation. The main purpose of the research is to formulate a comprehensive, contextual, and digital entrepreneurship strategy model that is in accordance with the needs of MSMEs that have limited resources.
Methodology: The methodology used is Systematic Literature Review (SLR) with reference to the guidelines of Petticrew and Roberts (2006), which includes the process of identifying, selecting, critically evaluating, and synthesizing findings from various international and national literature. The literature analyzed covers topics related to digital entrepreneurship, digital business models, competitiveness, dynamic capabilities, and MSME transformation.
Results: The results show that Digital Entrepreneurship has a strategic role in creating value through digital innovation, improving technology-based operational efficiency, expanding the MSME market globally through digital platforms, and building adaptive digital organizational capabilities. The findings of the study also identify four main pillars that form the Digital Entrepreneurship strategy model, namely the pillars of innovation, efficiency, digital market expansion, and strengthening organizational capabilities. These four pillars have proven to be complementary in encouraging sustainable competitive advantage.
Conclusion: The main conclusion of the study emphasizes that the implementation of Digital Entrepreneurship is a key factor for the sustainability and competitiveness of MSMEs in the digital economy era.
Limitations: This study has limitations because it only focuses on literature studies without empirical testing through field data, so the generalization of the findings still needs to be tested further.
Contribution: Nevertheless, this research makes an important contribution in the form of a conceptual model of Digital Entrepreneurship strategy that can be used as a reference for academics, policy makers, and MSME actors in designing a more targeted digital transformation strategy.

Keywords: *Digital Entrepreneurship, MSMEs, sustainable competitiveness, dynamic capabilities, digital transformation,*

1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) have long been the main foundation of the Indonesian economy. The vital role of MSMEs is reflected in their contribution to the national economic structure, including a contribution of more than 60 percent to the Gross Domestic Product (GDP) and the provision of jobs for the majority of the

productive population (Central Statistics Agency, 2024). The dominance of this sector in the economy is an indicator that MSMEs are not only small-scale business entities, but also strategic actors that support economic resilience, income equity, and community independence (Tambunan, 2019). However, MSMEs still face various structural challenges such as limited access to capital, low managerial capacity, minimal mastery of technology, and human resources who are not competent in data-based decision-making. These challenges are increasingly complex with the presence of the Industrial Revolution 4.0 which brings fundamental changes to the global business landscape. The development of digital technology ranging from *cloud computing*, artificial intelligence, *big data analytics*, to *the Internet of Things* has changed the way organizations create value, manage processes, and interact with customers (Schwab, 2017). In this context, companies are no longer just competing locally, but must deal with global competitors who utilize digital technology as a competitive advantage. As geographical boundaries are blurring due to digitalization, MSMEs are in a position that demands adaptability faster than ever before. Business actors who fail to carry out digital transformation have the potential to lose relevance, lagging far behind competitors who are more technologically adaptive (Porter & Heppelmann, 2015).

The change in landscape requires MSMEs to not only partially adopt digital technology, but also carry out a comprehensive strategic transformation through the Digital Entrepreneurship approach (Nambisan, 2017). Digital Entrepreneurship is not just an online-based business activity, but an entrepreneurial paradigm that positions digital technology as the core of the process of creating value, innovation, and exploiting new market opportunities. Thus, digital transformation is not only related to the ability to use social media or marketplaces, but concerns how MSMEs redesign business models, strengthen organizational structures, improve customer experience, and create unique value propositions (Kraus et al., 2020). In the framework of modern competition, the competitive advantage of MSMEs is no longer enough to be maintained through physical product differentiation or location advantage alone. Excellence is now formed through technology integration, customer data processing, the ability to provide fast and personalized services, and consistent cross-channel connectivity or omnichannel experience (Chaffey & Ellis-Chadwick, 2019; Verhoef et al., 2015). Through this approach, MSMEs can expand the market, improve operational efficiency, and create stronger customer relationships. Digital transformation brings great opportunities for MSMEs to penetrate the global market through technology platforms, thus providing opportunities for small businesses to become part of the international value chain (Oviatt & McDougall, 1994). Although these opportunities are wide open, not all MSMEs have the same readiness to carry out digital transformation. Many MSMEs are still in the basic digitalization stage, which is using technology only for marketing or communication needs, without integrating it into core business processes. This condition illustrates that there is a significant digital gap between the technological capabilities of MSMEs and the demands of the digital market (World Bank, 2021).

Therefore, it is important to examine how Digital Entrepreneurship can be applied as a relevant, structured, and appropriate strategy for the limited resources of Indonesian MSMEs. This research is here to answer these needs by formulating a Digital Entrepreneurship strategy model based on the four main pillars of Digital Innovation, Technological Operational Efficiency, Digital Global Market Expansion, and Digital Organizational Capabilities. These four pillars are formulated based on thematic analysis of relevant academic literature and consider the factual conditions of Indonesian MSMEs.

The strategy model is expected to be an applicable strategic framework for MSME actors, policy makers, and academics in designing programs to strengthen MSMEs in the era of digital transformation. By integrating the perspectives of competitiveness, digital entrepreneurship, and dynamic capability theory, this study emphasizes that digital transformation is a strategic imperative for MSMEs, no longer an option. The ability of MSMEs to survive and thrive in the digital economy is highly dependent on their readiness to adopt technology, utilize data as a source of competitive advantage, and increase internal capacity to adapt quickly and sustainably (Teece, 2007; Westerman et al., 2014). This view shows that Digital Entrepreneurship is the main foundation in building the competitiveness of Indonesian MSMEs in the future.

2. Literature Review

This literature review is compiled to provide an in-depth theoretical foundation on the main concepts that form the research framework, namely MSMEs, competitiveness, Digital Entrepreneurship, digital transformation, digital business models, and dynamic capabilities that are the foundation for the success of MSMEs in facing the digital economy era. The literature analyzed ranges from classical theory to the latest developments in digital entrepreneurship research.

2.1 MSMEs and Their Strategic Role in the Economy

MSMEs have a vital contribution to the Indonesian economy. Its role can not only be seen from its large contribution to GDP, but also in the provision of jobs and economic equity (Central Statistics Agency, 2024). According to Tambunan (2019), MSMEs function as important instruments in regional economic development, poverty alleviation, and the creation of national economic stability. However, the characteristics of small-scale MSMEs with limited resources often make them vulnerable to external pressures, market changes, and technological disruptions. The organizational structure of MSMEs which is generally simple with centralized decision-making on business owners causes their adaptability to be limited. A World Bank study (2021) shows that the digital divide is still a significant obstacle for MSMEs in Indonesia, especially in adopting more advanced technologies such as cloud computing, data analytics, or modern business management software.

2.2 Competitiveness Theory in a Digital Context

The concept of competitiveness has become a major concern in the science of strategic management. Porter (1985) emphasized that competitiveness is created when a company is able to produce higher value or lower costs than competitors. In the context of digital MSMEs, competitive advantage does not only come from physical products, but also from customer experience, the quality of digital interactions, and the company's ability to manage data (Kotler & Keller, 2016). The Resource-Based View (RBV) theory developed by Barney (1991) states that continuous competitive advantage is obtained through resources that are VRIO: Valuable, Rare, Inimitable, and Organized. In the digital age, RBV is experiencing an expansion of meaning as valuable resources are no longer limited to physical factors such as capital or labor, but also digital assets such as customer databases, recommendation algorithms, digital brands, and innovation capabilities. In the era of digital transformation, companies that are able to effectively integrate digital resources will have a greater chance of maintaining a competitive advantage. This is in line with the view of Teece (2007) who introduced the theory of dynamic capabilities as

the ability of companies to sense opportunities (sensing), seizing, and transform resources (transforming) in a rapidly changing environment.

2.3 Digital Entrepreneurship as a Strategic Concept

Digital Entrepreneurship (DE) is a new development in the entrepreneurship literature. Nambisan (2017) defines DE as an entrepreneurial activity that makes digital technology the foundation for creating opportunities, innovation, and developing business models. In contrast to e-business which only relies on the digitization of conventional processes, DE emphasizes fundamental overhauls in business structures by utilizing technology as the core. Kraus et al. (2020) added that DE includes not only the use of digital platforms such as marketplaces or social media, but also the exploration of business models based on artificial intelligence, big data, predictive analytics, and interplatform integration in the digital ecosystem. The use of this technology allows MSMEs to create new value propositions that are more competitive. In the realm of MSMEs, Digital Entrepreneurship provides a great opportunity to expand the market and reduce operational costs. For example, MSMEs can utilize automated sales systems, data-driven customer preference mapping, digital content personalization, and the use of live streaming as a medium of direct interaction. With digital, MSMEs are no longer limited by narrow geographical space like in the pre-digital era.

2.4 Digital Transformation of MSMEs

Digital transformation is a process of strategic and structural change that involves the integration of technology into all aspects of the business. Westerman et al. (2014) explain that digital transformation is not just the use of digital tools, but involves the evolution of the way companies operate and deliver value to customers. In MSMEs, digital transformation often takes place in stages, starting from the digitization process, then progressing to the digitization of business processes (digitalization), to full digital transformation that has an impact on business models and organizational structures. Many MSMEs in Indonesia are currently only in the early stages of transformation, such as using social media for promotion or marketplace for sales, but have not yet integrated digital into operational management such as CRM, simple ERP, or data analytics. The success of MSME digital transformation is greatly influenced by the readiness of human resources. Rogers (2003) explained that the adoption of innovation is highly dependent on the perception of benefits, ease of use, and organizational readiness. This explains why many MSMEs have not carried out optimal digital transformation, even though the necessary technology is available at affordable prices.

2.5 Omnichannel and Channel Integration in Digital Business

The development of increasingly digital consumer behavior requires companies to provide consistent experiences across multiple platforms. Verhoef et al. (2015) introduced the concept of omnichannel as an approach that integrates all communication, marketing, and distribution channels to create a well-rounded customer experience. In the context of MSMEs, an omnichannel strategy is relevant because it can improve the quality of customer interaction, expand market reach, and provide convenience in managing transactions. Chaffey and Ellis-Chadwick (2019) emphasize that data integration between channels is key to the success of this strategy. For example, customer information obtained from marketplaces can be linked to data from social media to improve digital marketing accuracy.

2.6 Dynamic Capabilities in Digital MSMEs

Dynamic capabilities are an important concept that explains the ability of organizations to adapt and change to follow the dynamics of the rapid digital environment (Teece, 2007). In MSMEs, dynamic capabilities are realized through the ability to learn new technologies, respond to changes in platform algorithms, experiment with digital marketing models, and manage customer data effectively. Eisenhardt and Martin (2000) affirm that dynamic capabilities are not just assets, but are an iterative process that allows organizations to acquire continuous learning. In the context of MSMEs, this learning can come from customer interaction, market response, changes in digital trends, and evaluation of content performance on social media. Dynamic capabilities are the main foundation for MSMEs to maintain a competitive advantage in the digital era. Without adaptability, MSMEs will find it difficult to adapt to the rapid changes in the digital ecosystem, especially with the emergence of new technologies such as generative AI, machine learning, and global platforms.

2.7 Digital Business Model for MSMEs

Digitalization not only changes business processes, but also encourages the creation of new, more innovative business models. Osterwalder and Pigneur (2010) explain that digital business models create value through the more effective use of technological resources, networks, and customer interactions. In MSMEs, digital business models can include direct sales through social platforms, subscription-based services, bundling digital products with physical ones, or content monetization. Digitalization provides opportunities for MSMEs to create new value through service personalization, fast delivery, real-time interactivity, and digital logistics integration. This enriches the value proposition of MSMEs and increases the attractiveness of the business in the eyes of modern consumers.

2.8 Synthesis of Literature Review

Based on the literature analysis, it can be seen that Digital Entrepreneurship is a strategic approach that is able to help MSMEs face the challenges of the digital era. The DE concept combines the theory of competitiveness, RBV, dynamic capabilities, and digital transformation into one unified framework. These findings are the basis for the preparation of the Four Pillars Digital Entrepreneurship Strategy Model, which consists of digital innovation, technological efficiency, global market expansion, and digital organizational capabilities. The four concepts cannot stand alone, but interact with each other to form the foundation of the transformation of MSMEs towards sustainable competitiveness.

3. Research Methods

This study uses a qualitative approach with *the Systematic Literature Review (SLR)* method to examine the concept of Digital Entrepreneurship and its relevance to increasing the competitiveness of MSMEs. SLR was chosen because it provides a systematic, transparent, and replicable literature review process in the future. This approach is in line with the guidelines put forward by Petticrew and Roberts (2006), who assert that SLR not only summarizes the literature but also synthesizes findings to generate a deeper understanding. The research process began by determining the focus of the study, namely how the Digital Entrepreneurship strategy can help MSMEs transform and increase competitiveness. This research question was then directed to the literature

search process using various scientific databases such as Web of Science, ScienceDirect, and Google Scholar. To strengthen the local context, several national journals indexed by SINTA and institutional reports such as World Bank and Ministry of Cooperatives reports are also used. The use of various types of sources is carried out in accordance with Creswell's (2018) view that qualitative research requires rich and varied data sources. Literature search was conducted using keywords such as *Digital Entrepreneurship*, *MSMEs*, *digital transformation*, *competitive advantage*, *resource-based view*, and *dynamic capabilities*.

These keywords reflect the big concepts that are the basis of the research. The publication time range from 2010 to 2024 is set to ensure relevance to the development of digital technology. Despite this, classical theories such as Porter (1985), Barney (1991), and Teece (2007) remain included because of their significant contributions to the theory of competitiveness and dynamic capabilities. The literature obtained was then selected based on the relevance of the title and abstract. Next, the researcher reads the entire content of the article to assess its contribution to the research objective. The selected literature is one that directly discusses aspects of digital entrepreneurship, digital transformation of MSMEs, digital business strategies, competitiveness, and organizational capabilities. Of the hundreds of initial sources, only about forty articles are considered the most relevant and adequate to be analyzed in depth. Data analysis was carried out by thematic analysis**,** as explained by Guest et al. (2012). Thematic analysis allows researchers to identify recurring themes, patterns, and concepts in the literature. Through this process, various main themes were found, such as digital innovation, the use of technology as operational efficiency, omnichannel integration, dynamic capabilities, and strengthening the digital market.

Each theme is analyzed to see its contribution to the formation of Digital Entrepreneurship strategies. The literature synthesis was carried out by combining various theories of strategic management and digital entrepreneurship. Porter's (1985) theory of competitive advantage, Barney's (1991) Resource-Based View theory, and Teece's (2007) theory of dynamic capability are important foundations in formulating a research framework. In addition, the concept of Digital Entrepreneurship introduced by Nambisan (2017) provides a modern perspective on how digital technology not only supports operations, but also creates new business opportunities. This cross-theoretical integration allows research to produce comprehensive and applicable conceptual models. The validity of the research is maintained through the selection of credible academic sources, a transparent literature selection process, and the consistent application of thematic analysis methods. Meanwhile, the reliability of the research is strengthened by the systematic use of SLR procedures so that they can be replicated by other researchers.

This approach follows the guidance of Denyer and Tranfield (2009), who emphasize the importance of consistency and transparency in literature review to improve academic quality. The scope of research is limited to literature focusing on MSMEs and digitalization, digital entrepreneurship strategies, competitiveness, digital business innovation, and relevant management theories. The research does not involve primary data, so the entire findings are conceptual and serve as the basis for future empirical research. However, SLR-based research still has strategic value because it is able to provide a strong theoretical foundation for the development of a targeted and systematic Digital Entrepreneurship model. Through structured research procedures and in-depth literature analysis, this research provides a theoretical foundation to understand how Digital Entrepreneurship can increase the competitiveness of MSMEs. This approach

provides a holistic picture of the role of digital technology, innovation, and organizational capabilities in dealing with the dynamics of the modern business environment.

4. Results and Discussion

The results of this research come from the Systematic Literature Review (SLR) process of more than 40 scientific sources regarding Digital Entrepreneurship, MSMEs, digital transformation, competitiveness, and strategic management theory. The thematic analysis yielded four major interconnected themes: digital innovation, technological efficiency, digital market expansion, and digital organizational capabilities. These findings form a strategic framework that emphasizes that Digital Entrepreneurship is a key factor in strengthening the competitiveness of Indonesian MSMEs. To support the discussion, this section also presents a table of data summaries, findings patterns, and a literature map as a basis for interpretation.

4.1 Summary of Research Findings Based on the Literature

The results of the analysis of the literature show that MSMEs are in an increasingly strategic and challenging position in the digital era. The majority of studies illustrate that the digital adoption rate of Indonesian MSMEs is still in the early stages, which is characterized by the dominance of the use of social media and marketplaces as the main means of marketing and sales. These findings are consistent with the Central Statistics Agency report (2024) and the Kraus et al. (2020) study, which show that most MSMEs have not yet leveraged more complex business management technologies such as Customer Relationship Management (CRM), simple Enterprise Resource Planning (ERP), or data analytics. The literature also identifies a number of structural challenges that hinder the digital transformation of MSMEs. The World Bank (2021) revealed that the main obstacles lie in low digital literacy, limited access to capital for technology investments, limited knowledge about digital marketing strategies, and lack of skilled human resources in operating modern technology. These challenges show that there is a clear gap between the availability of technology and the ability of MSMEs to adopt it. On the other hand, almost all literature highlights that digitalization opens up very wide opportunities for MSMEs to develop.

Nambisan (2017) shows that Digital Entrepreneurship not only provides new tools for business actors, but also forms new ways of creating value, building customer relationships, and developing business models. Through digital platforms, MSMEs can reach a wider range of customers, expand the market to the national and global levels, and reduce dependence on traditional distribution channels. In addition to market expansion opportunities, the literature also emphasizes that digitalization can increase the competitive advantage of MSMEs through faster innovation processes, production flexibility, and the ability to update products according to consumer preferences in real-time. This concept is in line with Porter's (1985) view of the importance of differentiation and Barney's (1991) view of the Resource-Based View, which emphasizes that competitive advantage comes from a company's ability to develop unique resources, including digital assets and technological capabilities.

Literature analysis also found that the success of Digital Entrepreneurship in MSMEs is highly dependent on organizational capabilities, especially the ability to learn and adapt to technological changes. Teece (2007) refers to this ability as *dynamic capabilities*—namely the company's capacity to sens, seizing, and transform resources effectively. MSMEs that have dynamic capabilities are better able to respond to technological changes, understand shifts in consumer behavior, and make rapid operational

adjustments. Overall, the literature findings show that MSMEs are at a critical point in the digitalization process. Despite the significant structural challenges, the opportunities provided by digital technologies are far greater. These findings show the urgent need for MSMEs to adopt a comprehensive Digital Entrepreneurship strategy, especially in digital innovation, technology integration, strengthening digital markets, and building organizational capabilities. These four major themes then form the basis of further discussion in this study.

Table 1. Summary of Key Findings on MSMEs and Digitalization

Aspects of the Findings	Key Findings	Source
Digital adoption of MSMEs	Dominated by the use of social media and marketplaces; Adoption of management technology is still low	Kraus et al. (2020); BPS (2024)
Digital Challenges	Limitations of digital literacy, technology capital, skilled human resources	World Bank (2021)
Digital Opportunities	National-global market expansion, operational efficiency, product innovation	Smashing Pumpkins (2017)
Factors that determine competitiveness	Digital innovation, technology integration, organizational capabilities, digital ecosystem	Teece (2007); Porter (1985)

4.2 Digital Innovation as a Key Driver of Competitive Advantage

The results of the literature analysis show that digital innovation is a fundamental factor in increasing the competitive advantage of MSMEs. Innovation does not only refer to the creation of new products, but includes process innovation, service innovation, and business model innovation. In the digital age, innovation often has to do with the use of technology to facilitate interaction with customers or create new, more personalized experiences. Porter (1985) asserts that differentiation is one of the important strategies for competitive advantage, and the modern literature shows that digital innovation reinforces that differentiation. MSMEs that are able to develop creative content, utilize live streaming, use big data to understand trends, or create responsive digital services tend to gain a better competitive position. Research by Liu et al. (2022) even found that the integration of digital innovations in marketing can significantly increase customer trust and conversion rates. Digital innovation also provides space for *value co-creation* between MSMEs and customers. Customers are not just passive consumers, but part of the innovation process through real-time feedback, digital preferences, and engagement in the digital community. This condition is in line with the concept of sensing in Teece's (2007) theory of dynamic capabilities, which is the ability of organizations to read market opportunities and needs quickly through digital indicators.

Table 2. Forms of MSME Digital Innovation

Types of Digital Innovation	Implementation Examples	Benefits

Product Innovation	Creative design, new variants, digital products	Market differentiation
Service Innovation	Live commerce, online consultation	Improved customer experience
Process Innovation	Order automation, digital stock management	Cost efficiency
Business Model Innovation	Subscriptions, product curation, digital collaboration	New sources of income

4.3 Technology Efficiency and System Integration Increase Productivity

The second theme reveals that digital technology plays a big role in improving the efficiency and operational performance of MSMEs. Digitalization helps MSMEs simplify business processes, speed up services, and lower production costs. The use of digital bookkeeping applications, electronic payment systems, order automation, inventory applications, and the use of *chatbots* has been proven to reduce manual errors while increasing service speed. According to Chaffey and Ellis-Chadwick (2019), digitizing operational processes improves the quality of business decisions because the available information is more accurate and real-time. Similar findings were mentioned by McAfee and Brynjolfsson (2012), who stated that companies that effectively utilize digital data have higher organizational performance than companies that rely solely on intuition. The integration of this technology not only increases productivity, but also increases *responsiveness*, which is the ability of MSMEs to respond quickly to consumer demand. In the instant digital era, the ability to respond quickly is an important factor in maintaining customer satisfaction. Thus, technology is no longer just an aid, but an essential foundation in building efficiencies that bring competitive advantage.

Table 3. MSME Technology That Increases Efficiency the Most

Technology	Function	Impact on Performance
Digital payment system	Automated Transactions	Increased transaction speed
Financial Management Apps	Digital bookkeeping	Financial statement accuracy
Marketplace tools	Stock & order management	Smoother operational management
CRM (Customer Relationship Management)	Customer segmentation & retention	Customer loyalty increases

Technology integration not only reduces costs, but also increases *responsiveness*, which is the ability of businesses to respond quickly to market demand. McAfee and Brynjolfsson (2012) emphasized that data-driven companies perform better than traditional companies.

4.4 Digital Market Expansion and Branding Strengthening

The third theme shows that digitalization opens up great opportunities for MSMEs to expand the market. Before the digital era, the market reach of MSMEs was generally limited geographically. However, through marketplaces, social media, websites, and digital collaboration, MSMEs can now reach consumers throughout Indonesia and

abroad. UNCTAD (2021) emphasized that digital platforms provide three to five times greater opportunities for MSMEs to enter the international market. Social media is becoming a very powerful branding tool, while marketplaces provide ready-to-use infrastructure for distribution and transactions. Websites provide higher credibility, while collaborations with influencers increase brand trust and exposure. In addition to expanding the market, digitalization provides opportunities for MSMEs to build *a strong brand identity*. Kotler et al. (2021) explain that in the digital age, branding is not only about products, but also about stories, values, and emotional connections built through content. MSMEs that succeed in building a consistent digital narrative will have greater appeal in the eyes of modern consumers.

Table 4. Digital Channels and Their Impact on MSME Market Expansion

Digital Channels	Main Functions	Impact
Marketplace	Direct sales	Wide market reach
Social Media	Branding and Promotion	Increased awareness
Website	Business credibility	Consumer trust
Influencing collaborations	Digital marketing	Sales increase significantly

According to UNCTAD (2021), MSMEs connected to digital platforms have a 3-5 times greater chance of penetrating the global market than conventional MSMEs. Digital branding also plays an important role in this process, especially through storytelling and engaging content (Kotler et al., 2021).

4.5 Digital Organizational Capabilities as a Foundation for Transformation

The results of the literature show that digital transformation is not only made possible by technology, but is largely determined by organizational capabilities. These capabilities include digital learning skills, change management skills, creativity in facing challenges, and flexibility to adapt to technological dynamics. Teece (2007) explains the three dimensions of dynamic capabilities: sensing, seizing, and transforming. In the context of MSMEs, sensing capabilities can be seen from the ability to read changes in consumer trends through digital data. Seizing capabilities can be seen from the ability of MSMEs to take advantage of digital opportunities such as maximizing online sales, creating content, or implementing digital marketing strategies. While transforming is related to the ability to adjust the internal structure of the business, such as changing work processes, updating systems, or improving workforce competencies to match digital demands. Bharadwaj et al. (2013) emphasize that digital capabilities are not only technical capabilities, but also strategic capabilities. Adaptive leadership, an organizational culture that supports innovation, and digital HR readiness are key factors for the success of long-term digital transformation

Table 5. Form of MSME Digital Organization Capabilities

Capabilities	Description	Contribution of Strategy
Sensing	Ability to read trends and changes	Quick response to the market
Seizing	Ability to take advantage of opportunities	Product innovation, business model
Transforming	Ability to customize internal processes	Long-term adaptation

Digital capabilities include the ability to learn new technologies, manage internal changes, develop digital human resources, and build a culture of innovation. Research by Bharadwaj et al. (2013) confirms that digital capabilities are a source of strategic advantage that is difficult for competitors to replicate.

4.6 Integration of Findings: Digital Entrepreneurship as a Strategic Framework

The integration of all findings shows that Digital Entrepreneurship is a strategic framework that is able to unite innovation, efficiency, market expansion, and organizational capabilities. These four aspects do not stand alone, but are mutually reinforcing systems. Digital innovation provides MSMEs with a new source of value; technological efficiency strengthens the operational foundation; the expansion of the digital market expands growth opportunities; and organizational capabilities to ensure MSMEs remain adaptive in the long term. The literature confirms that MSMEs that successfully combine these four elements tend to gain a sustainable competitive advantage. The Four Pillars Digital Entrepreneurship model found in this study shows that a comprehensive digital strategy can increase the competitiveness of MSMEs in a changing business ecosystem.

Table 6. Synthesis of Findings: The Four Pillars of Digital Entrepreneurship

Pillar	Key Focus	Impact on MSMEs
Digital innovation	Products, services, business models	Differentiation & added value
Technology Efficiency	Automation, data analytics	Increased productivity
Digital market expansion	Marketplace, social media	Wider reach
Organizational capabilities	Digital learning adaptation	Long-term durability

This model shows that MSMEs must implement all four pillars simultaneously to gain a sustainable competitive advantage. If one of the pillars is ignored, the digital transformation process is likely to be less than optimal.

4.7 Critical Discussion: Challenges and Implications

Further analysis shows that MSMEs not only face opportunities, but also significant challenges in digital transformation. Key challenges include limited digital literacy, resistance to change, technology costs, and lack of skilled human resources support. These findings are consistent with a World Bank report (2021), which shows that MSMEs in developing countries often lag behind in technology adoption due to structural barriers and technical competence. Despite this, the opportunities for digitalization remain enormous. MSMEs that are able to overcome these obstacles have the potential to enter a wider market, increase efficiency, and build a competitive advantage that is difficult to replicate. Implicitly, ecosystem support such as digital training, business mentoring, access to technology financing, and pro-transformation government policies are very important. From a theoretical perspective, this research strengthens the understanding that digital capabilities, technological innovation, and digital market strategies are important pillars in increasing the competitiveness of MSMEs. From a practical perspective, these findings provide strategic direction for MSMEs to formulate digital transformation steps in a more targeted and measurable manner.

5. Conclusion

This study examines the role of Digital Entrepreneurship in strengthening the competitiveness of Indonesian MSMEs through *the Systematic Literature Review approach*. The results of the analysis show that digital transformation is no longer an option, but a strategic need for MSMEs to be able to survive and thrive in an increasingly competitive business ecosystem. Digital Entrepreneurship emerged as a comprehensive strategic framework because it not only emphasizes the use of digital technology, but also reframes business processes, product innovation, marketing strategies, and organizational capabilities as a whole. The main conclusion of this study shows that the four pillars of Digital Entrepreneurship, namely digital innovation, technological efficiency, digital market expansion, and organizational capabilities, serve as key foundations in encouraging MSMEs to increase their competitive advantage.

Digital innovation strengthens product differentiation and enables the creation of new value for consumers through creative content, digital interactions, and products that are more relevant to market needs. Technology efficiencies increase productivity, reduce operational costs, optimize production processes, and support data-driven decision-making. The expansion of the digital market opens up opportunities for MSMEs to reach consumers beyond geographical boundaries, both at the national and global levels, through marketplaces, social media, websites, and digital collaborations. Meanwhile, the capabilities of digital organizations ensure the continuity of long-term adaptation to technological changes, build a culture of innovation, and develop competent digital human resources.

In addition to identifying the strengths of Digital Entrepreneurship, this study also shows significant challenges, ranging from low digital literacy, limited capital for technology investment, lack of digital training, to resistance to change. Nevertheless, the research concludes that the opportunities for digitalization for MSMEs are much greater than the challenges. When MSMEs are able to integrate the four pillars of Digital Entrepreneurship consistently, they have the potential to build a competitive advantage that is difficult for competitors to replicate and can survive in the long term. Thus, this study emphasizes that Digital Entrepreneurship is a fundamental strategy for MSMEs to face digital market dynamics, increase efficiency, expand market share, and strengthen competitiveness in the global ecosystem.

Research Contributions

This research makes an important contribution both theoretically and practically to the development of MSME and Digital Entrepreneurship studies in Indonesia. Theoretically, this study enriches the literature on MSMEs and competitiveness by integrating various strategic theories such as *Resource-Based View* (Barney, 1991), *Dynamic Capabilities* (Teece, 2007), and Porter's theory of competitive advantage (1985) with the modern concept of Digital Entrepreneurship (Nambisan, 2017). This theoretical synthesis results in a holistic understanding of how digital technology does not only function as a tool, but as a strategic component that shapes the competitive structure of MSMEs.

This research conceptually introduces the Four Pillars Digital Entrepreneurship Model, which can be used as a basis for further research, evaluation models, and empirical measurements of the digital readiness of MSMEs. The practical contribution of this research lies in the provision of strategic recommendations that can be directly applied by MSME actors to improve their business performance. The findings on digital innovation, digital market strategies, and technology integration provide a clear picture

of digital transformation measures that are realistic and appropriate to the Indonesian context. This research also provides guidance for MSME actors to develop adaptive organizational capabilities through training, change management, and internal team strengthening. In addition, this research contributes to policies by highlighting structural issues that need to be considered by the government, such as the digital divide, lack of technological literacy, and lack of access to financing for the adoption of digital technology. Thus, the model and findings of this research can be the basis for making more inclusive and comprehensive policies in supporting the digitalization of national MSMEs.

6. Suggestions

Practical Advice for MSME Actors.

MSMEs need to strengthen digital innovation capabilities as the main strategy in facing market competition. This can be done through the exploration of more creative product design, the use of *live commerce*, and the improvement of the quality of digital content that is able to build emotional relationships with customers. MSMEs are advised to develop simple data analysis skills in order to understand consumer behavior based on the insights available on digital platforms. Business owners also need to utilize digital technology in a more integrated manner. It is not enough to just use social media, MSMEs must start utilizing digital bookkeeping applications, cloud-based inventory systems, and structured digital marketing strategies. The use of digital data for decision-making needs to become a new habit. Thus, MSMEs can significantly increase operational efficiency and competitiveness. In addition, MSMEs need to improve organizational capabilities, especially in terms of digital literacy and adaptability. Digital training and workshops should be carried out regularly, both through government programs and independent initiatives. Business owners must be open to change and encourage team members to be actively involved in the digital transformation process.

Policy Advice for Governments and Stakeholders.

The government needs to strengthen the ecosystem that supports the digitalization of MSMEs through more targeted policies. First, it is necessary to provide structured and sustainable large-scale digital literacy training. Today's training programs tend to be short and in-depth, making them less effective in creating long-term transformations. Digital training should include strategic aspects such as digital marketing, content design, data analysis, cybersecurity, and marketplace management. The government also needs to increase MSMEs' access to technology financing through low-interest loans, tax incentives for digital investments, and software subsidy support for MSMEs. By reducing the cost burden of digital transformation, the government can accelerate the massive adoption of technology in the MSME sector. Furthermore, collaboration between the government, universities, and digital platforms is needed to build a digital incubator for MSMEs. These incubators can provide mentoring, content training, and mentoring in the use of advanced digital technologies such as data analytics, SEO, or simple artificial intelligence. In addition, the government can expand digital infrastructure evenly throughout Indonesia, especially in rural areas. Without strong internet access, the digitalization of MSMEs cannot run optimally and the digital divide risks widening further.

Suggestions for Further Research.

Future research is recommended to conduct an empirical analysis using surveys or direct interviews with MSMEs to measure the level of digital readiness and empirical impact of the Four Pillars Digital Entrepreneurship Model. Quantitative research can test the relationship between digital innovation, technological integration, and the competitiveness of MSMEs statistically. In-depth qualitative research can also provide a contextual understanding of the digital challenges faced by MSMEs in certain sectors such as culinary, fashion, and handicrafts.

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DETERMINANTS OF CUSTOMERS' DECISIONS TO SELECT MURABAHAH-BASED HOME FINANCING: EVIDENCE FROM PT BSI TBK., KCP PALEMBANG A RIVAI

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Abstract

The development of Islamic banking in Indonesia shows a positive trend from year to year, but its market share is still far behind conventional banking. This condition shows that public interest in sharia financing products, including home financing based on murabahah contracts, has not been maximized. This study was conducted to analyze the factors that affect customers' decisions in taking murabahah financing, especially product knowledge, margin levels, and service quality at PT BSI Tbk., KCP Palembang A Rivai. This study uses a quantitative approach with multiple linear regression analysis, t-test, and f-test. Data was obtained from the distribution of questionnaires to home financing customers based on murabahah contracts. The results showed that product knowledge had no effect on financing decision-making, while margin level and service quality had a significant positive effect on financing decision-making.

Keywords: *Product Knowledge, Margin, Service Quality, Murabahah, Decision Making.*

1. INTRODUCTION

Housing is a basic human need as well as a long-term asset for society. However, the high price of residential property in Indonesia is not comparable to people's purchasing power, so Home Ownership Credit (KPR) financing is the main solution to own a residence. The development of Islamic banking, especially PT Bank Syariah Indonesia (BSI) Tbk., presents an alternative to sharia-based home financing through *murabahah* contracts. The increase in BSI's consumer financing shows the high need of the public for financing facilities, especially home purchases.

However, the market share of sharia mortgages is still relatively small when compared to conventional mortgages. OJK data until 2023 shows that sharia mortgage financing is only around 15% of the total conventional mortgage financing (Aulia et al., 2025). This condition raises questions about the factors that affect people's decisions in choosing sharia financing products, especially financing based on *murabahah* contracts.

The community's decision to take financing is not only driven by the need for housing, but also by several important factors, including product knowledge, margin levels, and service quality. Product knowledge is a major factor in customer decision-making. Product knowledge is defined as the knowledge that customers or consumers have about the products and services used (Wahyudhi, 2022). Product knowledge plays a role in shaping customer trust and confidence in the characteristics and financing mechanisms. The margin level is also the main consideration because it affects the amount of installments and total customer financing. A high margin level will affect customers' preferences to choose these financing products (Putri et al., 2024). In addition, service quality plays a role in building customer satisfaction and loyalty in choosing financing products. Services are contacts that occur between consumers and every aspect of an organization that can shape consumer opinions regarding the quality of services provided by the organization (Sari & Kasidin, 2024).

Product knowledge is an important factor in the customer's decision to take home financing based on *the murabahah contract,* including at PT Bank Syariah Indonesia (BSI) Tbk., KCP Palembang A Rivai. Customers' understanding of the characteristics of *murabahah* financing, contract mechanisms, installment schemes, and differences between margins and conventional interest play a role in shaping customer trust and confidence in the financing products offered. Previous research has shown that product knowledge has an effect on customer decisions (Syahvindra & Sari, 2024; Wahyudhi, 2022). However, this study shows that product knowledge has no effect on customer decisions because decisions are more driven by the need for housing, trust in banking institutions, and recommendations from other parties (Siahaan et al., 2023; Susanti et al., 2023). This difference shows that the influence of product knowledge on the decision to take home financing based on *murabahah* at BSI KCP Palembang A Rivai still needs to be studied theoretically.

The margin level is also the main consideration for customers in choosing home financing based on *the murabahah* contract at PT Bank Syariah Indonesia (BSI) Tbk., KCP Palembang A Rivai. Margins that are considered reasonable and competitive can increase customer interest in taking home financing based on *murabahah* contracts. However, other findings show that the margin level doesn’t affect customer decisions, because customers emphasize more ridiculous sharia principles, contract transparency, and trust in banks (Furwanti, 2020; Susilawati et al., 2025)

Service quality is also one of the factors that is no less important in influencing the decision to take financing by customers. Fast, home-based, informative, and reliable service for employees in explaining financing products can increase customer comfort and trust. Previous research has stated that the quality of services affects financing decisions (Elyghasyah et al., 2025; Nursafitri & Hafizh, 2024; Susanti et al., 2023).However, this study found that service quality does not affect customer decisions, as these decisions tend to be influenced by financing needs, trust in banks, and religious considerations (Sari & Kasidin, 2024).

Based on the background that has been presented, the formulation of the problem in this study is:

1. Does product knowledge affect the decision to take home financing based on *the murabahah* contract at PT Bank Syariah Indonesia Tbk., KCP Palembang A Rivai?

2. Does the margin level affect the decision to take home financing based on *the murabahah* contract at PT Bank Syariah Indonesia Tbk., KCP Palembang A Rivai?
3. Does the quality of service affect the decision to take home financing based on *the murabahah* contract at PT Bank Syariah Indonesia Tbk., KCP Palembang A Rivai?
4. Does product knowledge, margin level, and service quality together affect the decision to take home financing based on *the murabahah* contract at PT Bank Syariah Indonesia Tbk., KCP Palembang A Rivai?

2. METHODOLOGY

This study uses a quantitative approach with the type of associative research, which aims to analyze the influence of product knowledge, margin level, and service quality on the decision to take home financing based on *murabahah* contracts. This research was conducted at PT Bank Syariah Indonesia (BSI) Tbk., KCP Palembang A Rivai, with the object of research in the form of customers who have taken or are taking home financing based on *the murabahah* contract.

The population in this study is all murabahah contract-based home financing customers at PT Bank Syariah Indonesia (BSI) Tbk., KCP Palembang A Rivai during the 2023 – 2025 intake period, which totals 46 customers. Given the relatively small population, the sampling technique used was total sampling, so that all members of the study were 46 respondents.

The types of data used in this study are primary data and secondary data. Primary data was obtained directly from respondents through the distribution of questionnaires prepared based on the indicators of each research variable, namely product knowledge, margin level, service quality, and financing decision-making. Meanwhile, secondary data is obtained through literature studies, in the form of textbooks, scientific journals, reports, and relevant supporting documents. Data analysis in this study uses the help of the SPSS Version 27 application, and is carried out with 3 (three) methods, namely:

1. T-test
   The t-test is used to test the significant degree of influence of a partially independent variable on a dependent variable. If the significance probability value is < 0.1, then Ha is accepted. On the other hand, if the significance probability value is > 0.1, then Ha is rejected.
2. F-test
   The f-test is used to test the significant degree of influence of independent variables simultaneously or together on dependent variables. If the significance probability value is < 0.1, then Ha is accepted. On the other hand, if the significance probability value is > 0.1, then Ha is rejected.
1. Coefficient of Determination (R^2)
   The coefficient of determination (R^2) is used to determine how much variation occurs in the dependent variable (Y) that can be explained by the independent variable (X).

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Partial Test (t-test)

The t-test was carried out to determine the influence of each independent variable on the dependent variable. The results of the t-test can be seen in the table below.

Table 1. T-Test Results

Independent Variables	t Hitung	Sig.	Remarks
Product Knowledge (X_1)	-1,506	0,139	No significant effect
Tingkat Margin (X_2)	1,768	0,084	Significant effect
Kualitas Layanan (X_3)	1,998	0,052	Significant effect

(source: SPSS Version 27 processed, 2025)

3.1.2 Simultaneous Test (f-test)

After a simultaneous test (f-test), a fcal value of 4,230 and a significance value of 0,011 were obtained. This means that product knowledge (X_1), margin level (X_2), and service quality (X_3) have a simultaneous and significant effect on the decision to take home financing based on *the murabahah* contract (Y).

3.1.3 Coefficient of Determination

The results of the determination coefficient test showed an *R Square* (R2) value of 0.232. Thus, the variation of all independent variables (X) can affect the change of the bound variable by 0.232 (23.2%). While the rest, 76.8% (100%-23.2%) were influenced by other variables outside the study.

3.2 Discussion

Based on the results of the study, product knowledge (X_1) did not have a significant effect on the decision to take home financing based on the murabahah contract (Y). These findings are in line with research conducted by Alfikaromah & Nurhidayati, (2023); Andriani, Maknuun, & Ulumudin, (2022) that product knowledge has no effect on customer decisions. Customers tend to be interested in taking financing at PT BSI Tbk., KCP Palembang A Rivai because of the set margin level, the quality of services provided, and the influence of persuasion from family or friends who have used this financing before.

Furthermore, the results of this study show that the margin level (X_2) has a significant effect on the decision to take financing (Y). This finding is the same as the results of research by Fatimah et al., (2024); Istiqomah Sujono & Wahyu Wibowo, (2020) which show that the margin level has a significant effect on the decision to use murabahah financing products. Financing with the principle of murabahah is quite in demand by customers of PT BSI Tbk., KCP Palembang A Rivai. Because of the margin set by PT BSI Tbk., KCP Palembang A Rivai is easy to fulfill, does not burden customers, can compete with other banks, and is superior in quality. In addition, the amount of margin set by the bank makes it easier for customers to plan their finances.

In addition, the findings in this study show that the quality of service (X_3) has a significant effect on the decision to take financing (Y). The results of this study are the same as the research that has been conducted by Rizki, (2021); Thoharudin, Suriyanti, & Amirul Huda, (2020) which states that the quality of service has a significant effect on the decision to take murabahah financing. The quality of service depends on the attitude of the employee, and the existing facilities and infrastructure. employees of PT BSI Tbk., KCP Palembang A Rivai have a high level of reliability, quick response in responding to customers, and have sufficient knowledge related to home financing products based on murabahah contracts. The competence and positive attitude possessed by employees of

PT BSI Tbk., KCP Palembang A Rivai are able to create a comfortable, convincing, and trusted experience by customers.

The results of the study show that product knowledge, margin level, and service quality together influence customer decisions in taking home financing based on *murabahah* contracts. Financing decisions are not determined by one factor alone, but are the result of relevant considerations. The value of the determination coefficient showed that the three variables were able to explain 23,2%, while the rest were influenced by other factors outside the study.

4. CONCLUSION

Based on the results of the study, it can be concluded that product knowledge does not have a significant effect on the decision to take home financing based on the murabahah contract. This is because the significance value is 0,139 > 0,1. The level of margin and service quality have a positive and significant effect on the decision to take home financing based on *the murabahah contract*. This is because the significance value of the margin level is 0,084 < 0,1 and the quality of service is 0,052 < 0,1. Simultaneously, the value of Fcal (4,230) > Ftable (2,2190), and the significance value of 0,011 < 0,1 are known. Thus, product knowledge, margin level, and service quality together have a positive and significant effect on the decision to take home financing based on *the murabahah* (Y) contract at PT BSI Tbk., KCP Palembang A Rivai. These results show that the three independent variables used in the study have the ability to explain the variation of dependent variables when tested together (simultaneously). This means that although not all variables have a significant influence partially, collectively these variables still play an important role in influencing the decision to take financing by customers.

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DETERMINING FACTORS FOR GOLD INVESTMENT DECISIONS AT PT PEGADAIAN PALEMBANG BRANCH

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Abstract

This study aims to analyze the role of price, knowledge, and risk perception in determining gold investment decisions at PT Pegadaian Palembang Branch. The background of this study stems from the increasing public interest in gold investment, which is not always accompanied by a comprehensive understanding of the factors that influence it. The study used a quantitative approach with a survey method of 96 active customer respondents, and multiple linear regression analysis as a data processing technique. The results show that partially, the variables of price, knowledge, and risk perception have a positive and significant influence on investment decisions. Simultaneously, these three variables also have a significant influence, contributing 83,2% to investment decisions, while the remainder is influenced by other factors outside the model. Risk perception was found to be the dominant variable in influencing investment decisions. These findings reinforce the importance of financial literacy, perceived security, and access to accurate price information in shaping public investment decisions. This study has implications for PT Pegadaian to improve price transparency, expand investment education, and strengthen the credibility of gold products as a safe and profitable investment instrument.

Keywords: price, knowledge, risk perception, investment dicisions

1. Introduction

Over the years, gold investing has been a popular method of managing wealth and assets. For many years, gold was considered a sign of economic stability and was considered a refuge in the face of inflation and market turmoil (Khoiriyah & Resyita, 2023). In times of global economic uncertainty, geopolitical conflict, or financial crisis, gold is the best choice.

Gold investment trends are undergoing a major shift due to technological advancements and changing investor preferences. There are now more flexible and cheap digital options such as gold savings and gold installments through digital pawnshop

applications. Previously, people only knew about investing in gold in physical form such as jewelry and gemstones (Cahyani & Darmawan, 2025). These digital platforms have not only become more accessible, but also encourage the younger generation to invest.

PT Pegadaian and Bank Syariah Indonesia launched "Bank Billion", driven by an increase in public interest in gold and jewellery investment by 7.9% annually until January 2025, according to Bank Indonesia data. The goal of this initiative is to increase the amount of gold stored domestically and to expand gold-based investment options domestically.

According to Janah (2025), the price of gold will increase significantly in early 2025; it rose to $2,917.7 an ounce, close to its previous high of $2,942.5. The uncertainty of the United States' monetary policy and the potential spike in global trade tariffs, which prompted investors to look for hedge assets such as gold, led to this price increase.

PT Pegadaian is a state-owned financial institution that markets gold investment products through various types of services. Digital services such as savings and gold installments, as well as products such as Antam, UBS, and Galeri 24 gold are available in a variety of sizes, so they can reach a wide range of demographics. Historical data shows a continuous increase in gold prices at Pegadaian in the last ten years, showing a positive trend for gold investment in Indonesia.

But for some investors, fluctuations in the price of gold can raise doubts when making a decision. Conversely, investors' understanding and analysis in choosing a good time to buy or sell gold is also influenced by investment knowledge. Individuals who have good financial knowledge can make investments wisely, especially when choosing gold savings products that fit their risk profile (Muga et al., 2022).

Risk perception is very important when making investment decisions. The level of risk tolerance varies for each person. Conservative investors are more likely to consider gold as a safe asset. On the other hand, other investors consider the volatility of gold prices (Pakpahan & Nasution, 2023). Understanding risk perception helps investors choose investment strategies and make logical decisions based on market and expected outcomes.

Some previous studies have shown mixed results on how investment knowledge, risk perception, and gold prices influence gold investment decisions. For example, Priantika, Wulandari, and Habra (2021) found that gold prices significantly affect interest in investing in gold, and Ariska, Agus, and Marpaung (2022) found that customers are not always affected by changes in gold prices. In addition, research on investment knowledge shows mixed results depending on the respondents' situation and demographics (Rumayaan & Tanusi, 2025; Darmawan, Kurnia, & Rejeki, 2019).

Risk perception also affects investment interest, according to Manik, Fadillah, and Jannah (2021). However, Ripada (2020) argues the opposite. These different results suggest that research needs to be conducted in a local context, especially in the Palembang area, which has unique social and economic characteristics.

This study aims to examine how gold prices, investment knowledge, and risk perception affect PT Pegadaian Palembang Branch's investment decisions in gold. The purpose of this study is based on empirical phenomena and disparities in the findings of previous research. It is hoped that this research will add to the literature on the investment behavior of the Indonesian people and become a reference for making gold investment policies that are more inclusive and in accordance with customer needs.

2. Literature Review

This research is based on relevant economic theories and investment behavior, and refers to previous research to explain the relationship between price, knowledge, and risk perception in determining gold investment decisions. These three variables are important to understand because they affect an individual's decision to choose gold as an investment instrument.

2.1. Gold Investment

Because gold has the ability to maintain its value against inflation and global economic instability, it is considered a safe investment instrument. Paydia (2023) describes gold investment as the process of buying physical gold or gold-based financial instruments to maintain value and manage wealth. The types of gold investments at Pegadaian include digital arisan, installments, savings, and gold bars.

2.2. Gold Price

The exchange rate of gold in the market that is influenced by various macroeconomic variables, such as inflation, exchange rates, and interest rates, is called the price of gold. Hidayatullah and Aristiwati (2021) state that the price of gold is always changing, which means that investors have both profit opportunities and risks. Gold prices consist of three categories, namely rising (due to high inflation), falling (due to the strengthening of the rupiah against the dollar), and stable (due to relatively stable economic conditions). The price of gold greatly influences investment decisions, especially among conservative investors who avoid high risk. However, the dynamics of unstable gold prices in the short term have not been fully explained in the context of investment decisions in financial institutions such as pawnshops.

2.3. Investment Knowledge

Investment knowledge is a person's level of understanding of the concepts, strategies, and risks associated with investing. According to Muga et al. (2022), investors can more easily choose investment instruments that align with their goals, and risk profile if they have good financial knowledge. This knowledge includes a basic understanding of investing, previous experience, and an understanding of the potential benefits and risks of various investment instruments. Investors who have enough knowledge will be more likely to make rational investment decisions. However, there has not been much research that links investment knowledge specifically to the decisions made about investing in gold through pawnshop schemes.

2.4. Risk Perception

Risk perception is a personal assessment of how likely an investment action is to result in losses. Pakpahan and Nasution (2023) state that risk perception greatly influences people's interest in choosing certain types of investments, especially volatile instruments such as gold. Hidayat and Nurhayati (2022) explain that risk perception includes acceptance of price fluctuations, market uncertainty, and possible capital loss.

Investors' perception of risk can be irrational and influenced by their own personal emotions and experiences. When it comes to investing in gold at Pegadaian, this perception of risk can affect investors' tendency to choose gold savings over physical gold.

2.5.Investment Decision

The process of allocating funds by investors into certain instruments with the aim

of making a profit is known as an investment decision. The level of risk, the period of return, and the return affect investment decisions, according to Putri and Hamidi (2019). In pawnshops, this includes choosing gold investments, such as savings or installments, based on risk and profit considerations.

3. Methodology

This research was conducted to analyze the influence of gold price, investment knowledge, and risk perception on gold investment decisions. The research was conducted empirically at PT Pegadaian Palembang Branch, which is located on Jalan Merdeka No. 11, 19 Ilir Village, Bukit Kecil District, Palembang. The subjects in this study are active customers at PT Pegadaian Palembang Branch. The focus of the study was to find out how much influence the three independent variables (price, knowledge, and risk perception) had on gold investment decisions. Research Design This research uses a quantitative approach with associative methods and surveys. The quantitative approach was chosen because it allows the measurement of relationships between variables through statistical techniques. The associative method is used to determine the relationship between two or more variables, while the survey method is used to obtain primary data through the distribution of questionnaires (Sujarweni, 2015).

3.1. Data Types and Sources

1. Primary Data: Obtained from respondents through interviews and the distribution of questionnaires to gold investment customers at PT Pegadaian Palembang Branch (Sugiyono, 2022).
2. Secondary Data: Derived from internal documents of PT Pegadaian Palembang Branch, such as the number of active customers. This data is collected without the need for additional processing (Sugiyono, 2022).

3.2. Data Collection Techniques

1. Questionnaire: An instrument in the form of a list of written questions given to respondents to collect data on their perceptions and experiences related to gold investment (Sujarweni, 2015).
2. Interview: The process of collecting data through face-to-face with PT Pegadaian employees to obtain more in-depth information (Sugiyono, 2022).

3.3. Population and Sample

The population in this study consists of all active customers of PT Pegadaian Palembang Branch as many as 2,571 people. The number of samples based on calculations using the Slovin formula with an error rate of 10% was 96 respondents. Sample Sampling Techniques are determined by non-probability sampling methods, especially accidental sampling techniques, which are sampling based on who happens to be found and qualified as respondents.

3.4. Data Analysis Techniques

The data obtained was analyzed using the SPSS application. Some of the stages of testing carried out include:

1. Test Instruments
    a. Validity: Using Pearson Product Moment correlation. The instrument is considered valid if the value r is calculated > r of the table (Sujarweni, 2015).

b. Reliability: Using Cronbach Alpha. The instrument is considered reliable if the alpha value > 0.60 (Sugiyono, 2012).

2. Classic Assumption Test
   a. Normality Test: To test whether residual data is normally distributed (Ghozali, 2018).
   b. Multicollinearity test: To test whether there is a relationship between independent variables (Ghozali, 2018).
   c. Heteroscedasticity Test: To find out the similarity of residual variance between observations (Ghozali, 2018).
3. Multiple Linear Regression Analysis is used to determine the influence of gold price variables (X_1), investment knowledge (X_2), and risk perception (X_3) on gold investment decisions (Y) simultaneously or partially (Sugiyono, 2012). Regression model:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + e \quad (1)$$

4. Hypothesis Test
   a. t-test: To see the influence of each independent variable individually on the dependent variable with a significance level of 5% (Sujarweni, 2015).
   b. F test: To test the influence of all independent variables together on dependent variables (Sujarweni, 2015).
   c. Coefficient of Determination (R2): To measure how much of the proportion of variation of the dependent variable is described by the independent variable.

Table 1. Research Variables

Variables	Variable Indicators	Scale
Variable X_1 (Price)	1. When gold prices are high 2. When gold prices are low 3. When the price of gold stabilizes	Likert 1 – 5
	4.	
	5.	
Variable X_2 (Knowledge)	1. Basic knowledge of investing 2. Have experience before making an investment 3. Profit-level knowledge	Likert 1 – 5
Variable X_3 (Risk Perception)	1. Perceived level of risk 2. Perception of experiencing investment loss risk 3. Perception of market certainty	Likert 1 – 5
Variable Y (Gold Investment Decision)	1. Expected rate *of return* 2. Risk level 3. Term	Likert 1 – 5

Source : Previous Development and Research

4. Results and Discussion

4.1 Validity and Reliability Test Results

Based on the results of the validity test, all statement items from the gold price variables, investment knowledge, risk perception, and investment decisions had a

calculated r value greater than the r of the table (0,201), indicating that all statement items were valid. Meanwhile, the results of the reliability test showed that Cronbach's Alpha value for each variable was above 0,6, which means that all research instruments are reliable and consistent to use.

4.2 Classical Assumption Test Results

1. Normality Test

The normality test was carried out using the Kolmogorov-Smirnov test. The results showed a significance value (Sig.) > 0,05, then the data was normally distributed.

Table 2. Normality Test Results

Variables	Sig.	Remarks
Residual Unstandardized	0,200	Data Normal

Source : Primary data processing results, 2025

In addition to using the Kolmogorov-Smirnov test, normality testing was also carried out with the P-Plot probability normal test which showed that the data in this study was normally distributed.

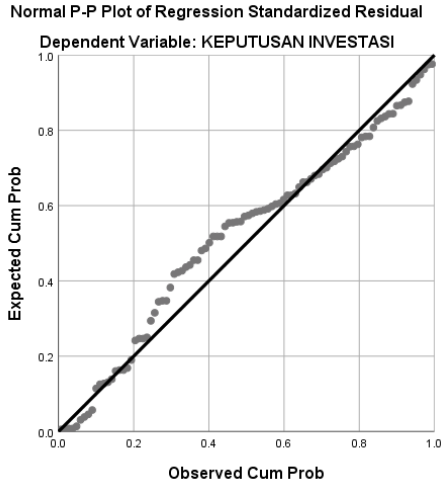


Figure 1. Normality Test Results P-P Plot
Source: Data processing results, 2025

2. Multicollinearity Test

Multicollinearity test to determine whether there is a high correlation between independent variables. The criteria in this test are that if the tolerance is > 0,10 and VIF is < 10, then there is no multicollinearity problem.

Table 3. Multicollinearity Test Results

Independent Variables	Tolerance		Remarks
Price (X_1)	0,819		No symptoms of multicollinearity

Knowledge (X_2)	0,852		No symptoms of multicollinearity
Risk Perception (X_3)	0,862		No symptoms of multicollinearity

Source : Primary data processing results, 2025

3. Heteroscedasticity Test

The Heteroscedasticity test was carried out with *the Glacier test* and the test in a pattern on the graph (*Scatterplot*).

Table 4. Heteroscedasticity Test Results

Independent Variables	Sig.	Remarks
Price (X_1)	0,223	Heteroscedasticity does not occur
Knowledge (X_2)	0,246	Heteroscedasticity does not occur
Risk Perception (X_3)	0,708	HetSeroscedasticity does not occur

source : Primary data processing results, 2025

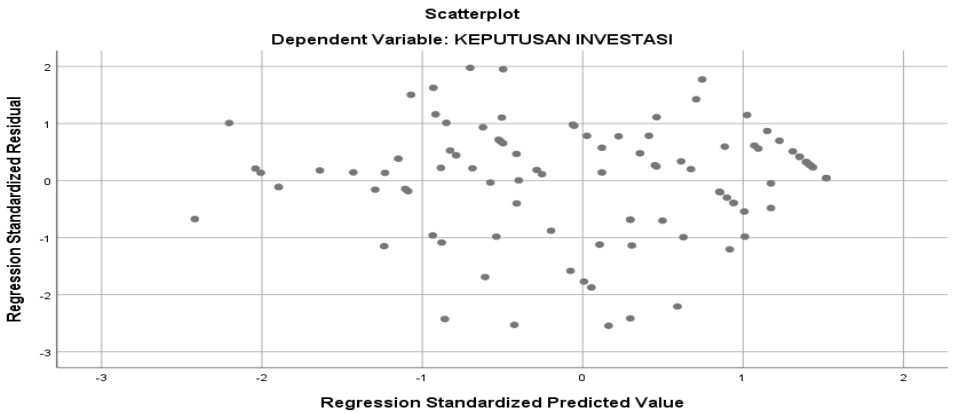


Figure 2. Heteroscedasticity Test Results Graphically
Source: Primary data processing results 2025

4.3 Hasil Uji Hipotesis

1. Results of the t-test (Partial)

In this test, it is used to determine whether each dependent variable has an independent effect on the independent.

Table 5. Multicollinearity Test Results

Independent Variables	t hitung	Sig.	Remarks

Price (X_1)	4,530	0,000	Significant effect
Knowledge (X_2)	2,119	0,037	Significant effect
Risk Perception (X_3)	6,780	0,000	Significant effect

Sumber : Hasil pengolahan data primer, 2025

Since the significance value of the three variables is less than 0,05, it can be concluded that price, knowledge, and risk perception each have a significant partial effect on gold investment decisions.

2. Results of the F-test (Simultaneous)

The results of the F test were seen that the Fcal value obtained was 157,946 while the Ftable value was 2,70, then the Fcal value > Ftable and the significance level was 0,000 < 0,05. Therefore, it can be concluded that the hypothesis has been tested and there is an investment decision accepted (H_0 rejected and H_4 accepted), meaning that all price variables, investment knowledge, and risk perception have a positive and significant effect together or simultaneously on investment decisions at PT Pegadaian Palembang Branch.

3. Determination Coefficient (R^2)

The results of the determination coefficient (R^2) showed that the ability of the variables of price (X_1), knowledge (X_2), and risk perception (X_3) to investment decisions (Y) of investment in PT Pegadaian Palembang Branch was 83,2% while the remaining was 16,8% which was explained in other variables that were not discussed in this study.

4.1.Discussion

The results of this study show that the price of gold has a great influence on investors' decisions about what they want to invest. This is in line with commodity exchange rate theory, which states that prices play a crucial role in attracting investors to the commodity. These findings reinforce the investor behavior theory that understanding investment knowledge will increase confidence and propensity to invest, as investment knowledge has also been shown to influence investment decisions. A person's perception of risk greatly influences their decision about investing in gold. This perception supports the theory of prospects, which states that people tend to avoid investments that are considered safer, such as gold. The decision of PT Pegadaian Palembang Branch on gold investment is greatly influenced by these three factors at the same time. This shows that in the local market, investment decisions are influenced by financial literacy levels and subjective perceptions of investment risks, as well as price factors.

5. Conclusions and Suggestions

5.1. Conclusions

Based on the formulation of the problem, the results of data analysis, and the hypothesis testing that has been carried out, a number of important findings were obtained related to the factors that affect the decision to invest in gold at PT Pegadaian Palembang Branch, which are as follows:

1. Price (X_1) has a positive and partially significant impact on gold investment decisions (Y). The t-test results showed a value of 4,530 with a significance level of 0,000 (< 0,05), which suggests that the greater the perception of the movement of the price of gold, the greater their inclination to invest.

2. Product Knowledge (X_2) has a positive and partially significant impact on gold (Y) investment decisions. The t-value of 2,119 and the significance of 0,037 indicate that knowledge (X_2) has a positive and partially significant influence on investment decisions (Y). In other words, it is more likely for investors to make investment decisions if they have a better understanding of investment instruments.
3. Risk perception (X_3) had a positive and partially significant impact on investment decisions (Y), with a t-value of 6,780 and a significance of 0,000. This suggests that investors with a good perception of risk tend to be more confident in making investment decisions.
4. Gold price, investment knowledge, and risk perception affect gold investment decisions simultaneously, with an F value of 157,946 and a significance of 0,000. The determination coefficient (R^2) of 83,2% indicates that the three variables may be responsible for the difference in investment decisions, while the remaining 16,8% is influenced by other variables that are not included in this study model.

5.2. Sugestions

Based on the results of the study, the researcher conveyed the following suggestions:

1. For PT Pegadaian Palembang Branch, it is recommended to provide real-time and competitive gold price information to help customers make the right investment decisions. The provision of profit simulations based on price fluctuations can also be a plus. In addition, it is necessary to strengthen the image of investment security through transparency, testimonials, and protection features. Financial literacy programs are also important, especially targeting the younger generation and the informal sector, through training, webinars, or collaboration with local communities. A sustainable promotion and education strategy, both digitally and face-to-face, is also needed to expand the reach and increase interest in gold investment among the general public.
2. For future researchers, it is recommended to develop this research by adding other variables, such as personal motivation, social influence, level of trust in financial institutions, and the use of digital technology. This aims to obtain a more comprehensive picture of the factors that influence gold investment decisions.

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THE IMPACT OF AI-DRIVEN PERSONALIZATION ON USER RETENTION IN SPOTIFY: THE MEDIATING ROLE OF EMOTIONAL ATTACHMENT

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Abstract

The increasing use of artificial intelligence (AI) in digital platforms has transformed how personalized user experiences are delivered, particularly in music streaming services. This study examines the effect of AI-driven personalization on user retention, with emotional attachment as a mediating variable, within the context of Spotify users in Palembang city, Indonesia. Using a quantitative approach, data were collected through a survey of 110 Spotify users in Palembang city and analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS). The results indicate that AI-driven personalization has a strong and significant effect on emotional attachment, while emotional attachment significantly influences user retention. Although AI-driven personalization also has a direct effect on user retention, the effect is relatively weaker. Furthermore, emotional attachment is found to partially mediate the relationship between AI-driven personalization and user retention. These findings confirm that emotional attachment plays a central role in translating AI-driven personalized experiences into sustained user behavior. This study contributes to the literature by extending the Stimulus–Organism–Response framework in the context of AI-based digital services and offers practical insights for streaming platforms to enhance user retention through emotionally driven personalization strategies.

Keywords: AI-driven personalization; emotional attachment; user retention; S-O-R framework

1. INTRODUCTION

The development of digital technology has driven a major transformation in the global music industry where previously the conventional way of consuming music has changed to *online* platforms via *streaming*. With the presence of artificial intelligence technology (*AI*), which is a music service that is able to adjust to the preferences of each user, it causes fundamental changes in finding, choosing, and enjoying songs. Streaming music platforms now not only provide an extensive catalog of songs but also provide a personalized song listening experience through AI algorithms. One of the most aggressive and successful platforms to integrate AI-driven personalization technology is Spotify, which later became a pioneer and leader of the modern digital music ecosystem.

In Indonesia, the development of digital music platforms is getting stronger, according to a report from We Are Social and Kepois In 2024, it was recorded that more than 78% of active internet users access music streaming services both for free and with a subscription. Based on the Populix survey (2023), Spotify is used by 66% of music streaming service users in Indonesia, far outperforming You Tube Music with 38% achievements, Joox by 17% and Apple Music by 6%. Spotify's dominance lies not only from the music catalog offered but also in its ability to deliver a personalized listening experience through AI technology. This approach makes Spotify not only an entertainment service provider, but also a listener partner which is able to understand the emotions and character of its users through personalized and relevant music recommendations, namely features such as *Discover Weekly, Daily Mix, Release Radar* and *Playlist Made for You* which are specifically designed with each user's unique preferences in mind so that they are able to touch the psychological side of the user. Not only that, at the end of each year, Spotify also presents an annual summary with *the Spotify Wrapped* feature that compiles music listening data into a personalized music journey view that makes users feel recognized, appreciated, and emotionally connected to the platform. The combination of AI algorithms in recommendations and behavioral analysis allows Spotify to create a music listening experience that is similar but not uniform so that it feels exclusive to each individual (Gomathy, 2022).

Music listening activities are often related to mood, personal preferences, self-identity and social experiences. When digital platforms are able to present songs that suit individual psychological conditions and tastes, the relationship created is no longer transactional but emotional. A consistent personalization experience makes some users feel "recognized" and "understood" by the platform, resulting in an *emotional attachment* to the services they use (Agil Anderson & Malik Mutoffar, 2024). This attachment is one of the factors that has the potential to strengthen user loyalty and the tendency to stick to one particular platform in the long term(Bansal & Pruthi, 2021) .

Although the Spotify platform has managed to attract millions of users in Indonesia, most of them are still classified as non-premium users who enjoy the service for free with ads as the main source of income. This situation poses its own challenges for Spotify in keeping users active and encouraging them to switch to paid services. A report from *We Are Social* (2024) notes that around 82% of internet users in Indonesia have multi-platform *behaviour* where users use more than one music streaming application at the same time which increases the risk of users moving to competing platforms when they feel that music recommendations, listening experiences, or emotional value obtained are no longer satisfactory so that it will affect sustainability platform business in the long run.

In that context, AI personalization research is seen as an important factor that can create a more relevant listening experience and improve user convenience (Holtz et al., 2020; Sepnandito & Suharyati, 2024). However, the personalization effect on customer retention doesn't always happen immediately without a strong emotional connection between the user and the platform. Emotional attachment acts as a psychological element that is able to strengthen the relationship (Grönroos, 1996). When users feel emotionally connected to the platform because of personalization that suits their personality, they are more likely to stick around and stay loyal to the service (Darmayasa & Yasa, 2021).

2. THEORETICAL FOUNDATION

Stimulus–Organism–Response (S-O-R) Theory

The *Stimulus–Organism–Response* (S-O-R) model proposed by Mehrabian and Russell (1974) explains that environmental stimuli can affect the internal conditions of individuals *(organisms)* which further determine behavioral responses . In the context of digital services, artificial intelligence-based music personalization acts as a stimulus that creates a personalized experience for users. The experience gives rise to emotional attachment as an internal affective response, which ultimately drives Spotify user retention behavior (Hajcak & Foti, 2020).

Customer Retention Theory

Retention is a consequence of customer loyalty that develops gradually through cognitive, affective, conative, and behavioral processes. In this context, user retention arises when users have a positive attitude and emotional attachment to a brand or platform, thus encouraging the intention to continue using the service despite the availability of other alternatives (Oliver L, 1980). User retention is reflected in behaviors such as intent to repeat use, willingness to stay subscribed, and resistance to moving to competitor services (Parasuraman et al., 1994). In digital-based services, retention is an important indicator of the success of the platform because the cost of retaining users tends to be lower than acquiring new users (Salem, 2021).

In the perspective *of Stimulus–Organism–Response* (S-O-R) put forward by Mehrabian and Russell (1974), user retention is positioned as a response, which is a behavioral response that arises as a result of the user's internal reaction to a certain stimulus. The personalization of AI-based services as a stimulus affects the user's affective state (organism), such as emotional attachment, which ultimately drives the user's decision to continue using the Spotify service on an ongoing basis.

Hypothesis

- *H1* There is a positive and significant influence of AI Personalization on the Emotional Attachment of Spotify users in Palembang city.
- *H2* There is a positive and significant influence of Personalisai AI on Spotify User Retention in Palembang city.
- *H3* There is a positive and significant influence of Emotional Attachment on Spotify User Retention in Palembang city
- *H4* There is a positive and significant influence of AI Personalization on Spotify User Retention in Palembang city through Emotional Attachment as a mediation variable.

3. RESULTS AND DISCUSSION

Respondent Profile

The respondent profile which is presented in this study is to find out the basic characteristics of the research participants, so that they can provide an overview of the results obtained. The results of the respondent profiles showed that most of the respondents were female (57.7%), and the male respondents were 42.3%. Based on age, respondents were dominated by the age group of 20–30 years (43.6%), followed by the age group under 20 years old (31.8%) and the age over 30 years old (24.6%). In terms of employment, the majority of respondents were workers (62.7%), while students were 37.3%. In addition, most respondents use the Spotify application for more than an hour per day (61.9%), indicating a relatively high intensity of use among respondents.

Data Analysis
Uji Outer Model
Convergent Validity Test

To test the validity of the convergence, the *outeir loading* value is used. An indicator is declared to meet the convergence validity if *the outer loading* value > 0.708 (Hair, 2022)

Table 2. Outer Loading Test Results

Variabel		Indicator	Statement Items	Outer Loading
AI Driven Personalization (X)	PA1	Relevance	Suitable music recommendation	0,789
	PA2	Ease of Exploration	Ease of finding music you like	0,775
	PA3	Preference Accuracy	Understanding the user's music genre	0,782
	PA4	System Adaptability	Ability to adapt to the changing of music preferences	0,705
Emotional Attachment (Z)	KE1	Emotional Comfort	Feel comfortable when listening to music on Spotify	0,714
	KE2	Emotional Closeness	Feeling familiar with music in Spotify	0,786
	KE3	Emotional Meaning	Feeling nostalgic when listening song on spotify	0,778
	KE4	Feeling Understood	Spotify understanding the changing of user's feelings	0,697
User Retention (Y)	RP1	Intention to Continue Using	Intend to stay on Spotify	0,853
	RP2	Consistency of Using	High intensity using Spotify	0,844
	RP3	Replacement Resistance	Reluctant to move to another app	0,792

Source: SmartPLS data processing, 2025

Based on Table 2 the values *outer loading* of each indicator has a value of > 0.7 so that the eleven indicators studied in the study are valid.

Table 3. Average *Variance Extracted* (AVE) Test Results

	Average Variance Extracted (AVE)
AI Driven Personalization (X)	0.583
User Retention (Y)	0.554
Emotional Attachment (Z)	0.689

Source: SmartPLS data processing, 2025

Based on Table 3, all research variables have a value *average variance extracted* (AVE) of > 0.50. Thus, all indicators in this study are able to explain the latent variables well and are suitable for use at the next stage of analysis.

Composite Reliability Test

The variable is declared reliable if the CR value > 0.70. The higher the CR value, the better the consistency of the indicator in measuring the variable in question (Hair, 2022). The results of the CR test for each variable in this study can be seen as follows:

Table 4. Composite Reliability Test Results

	Composite Reliability
AI Driven Personalization (X)	0.848
User Retention (Y)	0.832
Emotional Attachment (Z)	0.869

Source: SmartPLS data processing, 2025

Based on Table 4, it can be seen that all variables in the study have a CR value of > 0.7. Thus all variables are declared reliable. With the fulfillment of the criteria for the validity and reliability of the research instrument, the model can be continued at the structural testing stage (*inner model*). The configuration of the relationship between variables in this study is shown in the diagram of the algorithm path schema as follows:



Figure 2 SmartPLS Algorithm Test Results
Source: SmartPLS data processing, 2025

Uji Inner Model

Collinearity Test (VIF)

If the VIF value is 5 or high then it indicates a critical collinearity problem among the indicators of the formatively measured variables. Ideally, the VIF value is close to 3 or lower (Hair, 2022).

Table 5. Results of the Collinearity Test (VIF)

	VIF
PA1	1,576
PA2	1,604
PA3	1,689
PA4	1,288
KE1	1,612

KE2	1,766
KE3	1,473
KE4	1,356
RP1	1,652
RP2	1,663
RP3	1,497

Source: SmartPLS data processing, 2025

Based on the table of 5 indicators, all the variables in this study have a VIF value of < 5, so it can be concluded that there is no multicollinearity between indicators in each variable so that all indicators can be used in the study.

Determinant Coefficient Test (R2)

The Determinant Coefficient (R^2) is tested to see how well the independent variable is able to explain the dependent variable. The results of the R^2 test can be seen in the following table:

Table 6. R^2 Test Results

	R Square	R Square Adjusted
Emotional Attachment(Z)	0.645	0.641
User Retention (Y)	0.595	0.587

Source: SmartPLS data processing, 2025

Based on Table 6. The R-square value shows that the AI driven personalization variable is able to explain 64.5% of the variation in emotional attachment ($R^2 = 0.645$). which indicates the model has strong explanatory abilities. Meanwhile, the variables of AI driven personalization and emotional attachment simultaneously accounted for a 59.5% variation in user retention ($R^2 = 0.595$).

Uji *Effect Size* (F2)

Effect *Size* (F2) testing was performed to see how much influence each predictor variable had on endogenous variables. The results of the F^2 test can be seen in the following table:

Table 7. F^2 Test Results

	Emotional Attachment (Z)	User Retention (Y)
AI Driven Personalization (X)	1,814	0.059
User Retention (Y)		
Emotional Attachment (Z)		0.262

Source: SmartPLS data processing, 2025

Based on table 7. The effect *size* value (f^2) indicates that AI driven personalization has a very strong influence on emotional attachment ($f^2 = 1,814$), indicating that AI driven personalization is a major determinant in the formation of emotional attachment of Spotify users. In contrast, the direct effect of AI driven personalization on user retention was relatively weak ($f^2 = 0.059$), suggesting that AI driven personalization did not predominantly affect retention without intermediary psychological mechanisms. Meanwhile, emotional attachment had a moderate effect on user retention ($f^2 = 0.262$),

which confirms the important role of emotional attachment as a key factor in driving the sustainability of Spotify use, while also strengthening its position as a mediating variable in the research model.

Relevance Test (Q2)

The Q-Square (*Predictive Relevance*) test is used to find out if the model has good predictive ability against endogenous variables. If $Q^2 > 0$ indicates that the model has predictive relevance. The results of the Q^2 test can be seen in the following table:

Table 8. Q^2 Test Results

	SSO	SSE	Q^2 (=1-SSE/SSO)
AI Driven Personalization (X)	61.036	61.036	
Emotional Attachment (Z)	64.065	39.193	0.388
User Retention (Y)	45.708	25.096	0.451

Source: SmartPLS data processing, 2025

Based on Table 8. The *predictive relevance* value (Q^2) indicates that the model has good predictive capabilities. The emotional attachment variable has a Q^2 value of 0.388, which indicates that the model is able to predict emotional attachment constructs with an adequate level of accuracy. Meanwhile, the user retention variable showed a Q^2 value of 0.451, which signifies strong predictive ability in explaining the retention behavior of Spotify users.

Significance and Influence Test

A relationship is declared significant if the T-Statistic > 1.96 or the P-Value < 0.05 at a 95% confidence level. The results of the significance test on direct relationships are shown as follows.

Table 9. Results of the Direct Relationship Significance Test Results

	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
AI Driven Personalization (X) -> Emotional Attachment (Z)	0.803	26.229	0.000
AI Driven Personalization (X) -> User Retention (Y)	0.260	2.408	0.016
Emotional Attachment (Z) -> User Retention (Y)	0.547	5.463	0.000

Source: SmartPLS3 data processing, 2025

Based on Table 9 the results of the structural pathway test showed that AI driven personalization had a positive and significant effect on emotional attachment ($\beta = 0.803$; $t = 26.229$; $p < 0.001$), indicating that AI driven personalization is a major determinant in the formation of emotional attachment of Spotify users. In addition, AI driven personalization also had a positive and significant effect on user retention ($\beta = 0.260$; $t = 2.408$; $p = 0.016$), albeit with a relatively weaker power of influence. Meanwhile, emotional attachment had a positive and significant effect on user retention ($\beta = 0.547$; $t = 5.463$; $p < 0.001$), which confirms the important role of emotional attachment in driving sustainable use of Spotify.

Table 10. Indirect Relationship Significance Test Results

	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
AI Driven Personalization (X) -> Emotional Attachment (Z) AI Driven Personalization (X) -> User Retention (Y) Emotional Attachment (Z) -> User Retention (Y)	0.439	5.271	0.000

Source: SmartPLS3 data processing, 2025

Based on Table 10 the results of direct and indirect pathway testing, emotional attachment is categorized as *partial mediation*. This is demonstrated by the direct effect of AI driven personalization on user retention that remains significant ($\beta = 0.260$; $p = 0.016$), as well as an indirect effect through emotional attachment that is also significant ($\beta = 0.439$; $p < 0.001$). These findings indicate that AI driven personalization affects user retention both directly and through emotional attachment, so emotional attachment acts as a partial mediator in the relationship between AI driven personalization and Spotify user retention.

Test Model Fit

The *Model Fit* test is used to assess how well the model is generated at matching existing data. The assessment of model suitability in this study was using the value indices from *the Standardized Residual Root Mean Square* (SRMR). The test results of the fit model are as follows:

Table 11. Model Fit Test Results

	Saturated Model	Estimated Model
SRMR	0.095	0.095

Source: SmartPLS3 data processing, 2025

Based on Table 11the SRMR value of 0.095 at saturated model or estimated model which is below the threshold of 0.08 indicates that the model has a good level of compatibility.

Discussion

The Effect of AI Driven Personalization on Emotional Attachment

The results of the study show that AI driven personalization has a positive and significant effect on the emotional attachment of Spotify users. This finding is evidenced by the path coefficient value of $\beta = 0.803$ with a t-statistical value of 26.229 and a p-value of < 0.001, which indicates that the higher the level of AI driven personalization that users feel, the stronger the emotional attachment formed to the Spotify application. The magnitude of the R-square value in the emotional attachment construct ($R^2 = 0.645$) also suggests that AI driven personalization has a strong ability to explain the variation in users' emotional attachments (Agil Anderson & Malik Mutoffar, 2024).

The Effect of AI Driven Personalization on User Retention

The results show that AI driven personalization has a positive and significant effect on Spotify user retention. This is evidenced by the path coefficient value of $\beta = 0.260$ with a t-statistical value of 2.408 and p-value = 0.016, which indicates that the improvement in the quality of AI driven personalization directly drives the tendency of

users to continue using the Spotify app. These findings confirm that AI driven personalization has an important role in shaping continuous usage behavior on music streaming services (Ramadhani & Salisah, 2024).

The Effect of Emotional Attachment on User Retention

The results of the study show that emotional attachment has a positive and significant effect on Spotify user retention. This is shown by the path coefficient value of $\beta = 0.547$ with a t-statistical value of 5.463 and a p-value of < 0.001, which indicates that the stronger the user's emotional attachment to Spotify, the higher their tendency to continue using the app. These findings confirm that affective factors have an important role in driving continuous usage behavior on music streaming services (Zhang et al., 2025).

The Effect of AI Driven Personalization on User Retention through Emotional Attachment

The results show that AI driven personalization has a positive and significant effect on user retention through emotional attachment. This is evidenced by an indirect influence value of $\beta = 0.439$ with a t-statistical value of 5.271 and a p-value of < 0.001, which indicates that emotional attachment plays an important role in explaining the relationship between AI driven personalization and Spotify user retention. These findings suggest that AI driven personalization not only affects retention directly, but also indirectly through the formation of users' emotional attachment to the platform.

Furthermore, the test results showed that the direct effect of AI driven personalization on user retention remained significant ($\beta = 0.260$; $p = 0.016$) even though emotional attachment was included in the model. This condition indicates that emotional attachment acts as a partial mediator, where AI driven personalization affects user retention both through direct and affective channels. These findings confirm that the technical aspects of personalization and the emotional aspects work simultaneously in driving sustainable use behavior (Albérico & Joaquim A, 2023; Eboseremen et al., 2022; Panya et al., 2025; Widjaja, 2023).

4. CONCLUSION

The results of this study support the application of *the Stimulus–Organism–Response* (S-O-R) model in the context of AI-based digital services, especially on music streaming platforms. AI personalization as a stimulus is able to influence the affective state of users and encourage behavioral responses in the form of user retention, thus reinforcing the importance of integration between technology and emotional aspects in managing long-term user relationships.

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GROWTH RESPONSE AND PLANT YIELD SWEET CORN (*ZEA MAYS* SACCHARATA STURT) AGAINST BIOLOGICAL ORGANIC FERTILIZERS AND PLANTING SPACING

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Abstract

The use of biological organic fertilizers is currently highly recommended because the content of macro and micronutrients can be immediately available to plants and obtain high yields by adjusting the spacing. The purpose of this study was to determine the effectiveness of biological organic fertilizers on the growth and yield of sweet corn plants to support food security programs by providing quality and safe potential food products for the community while maintaining environmental sustainability. This study was conducted on land owned by farmers in Sukajaya Sub-District Sukarame Palembang city. The method used is a randomized design group (RAK) factorial consisting of 2 factors, namely: the first factor is biological organic fertilizer H1: biological organic fertilizer 200kg/ha, H2: biological organic fertilizer 300kg/ha, H3: biological organic fertilizer 400kg/ha, the second factor is the planting distance consists of 3 levels, namely: J1= 50 cm x 30 cm, J2= 60 cm x 30 cm, J3= 70 cm x 30 cm. The results showed that the biological organic fertilizer treatment can have the best effect on the growth and yield of sweet corn. Planting distance of 60 cm x 30 cm can have the best effect on the growth and yield of sweet corn. Interaction between biological organic fertilizer and planting distance can have the best effect on the growth and yield of sweet corn.

Keywords: Biological organic fertilizer, Spacing, Sweet corn

Introduction

Along with the emergence of the food industry and supermarkets whose needs are quite large both nationally and internationally for sweet corn, it is necessary to increase the production of sweet corn until it reaches sufficient potential. So that the government followed up the direction of economic development policies in the agricultural sector, then Agropolitan was established as a leading development program with corn-based competencies. In practice, there are still many obstacles faced by both farmers and the government (Adijaya, 2014).

Considering that the economic value of sweet corn is quite high, it is necessary to make efforts to increase the production of sweet corn. An important factor in increasing sweet corn production is fertilization (Marajo, 2016). The low production of sweet corn is partly due to land degradation due to the continuous and excessive use of inorganic materials such as fertilizers and pesticides. Therefore, to restore the quality of degraded land, it is necessary to add organic matter to the soil (Rinata, 2016).

The fact shows that to pursue high production, farmers often use inorganic fertilizers continuously and even excessively without returning crop residues and organic matter to the soil. This will lead to a decrease in land quality which results in a decrease in crop productivity. Besides that, public awareness of quality and chemical-free food products is a consideration for reducing the use of inorganic fertilizers. Efforts are needed to overcome the above by maintaining soil fertility and health which play a role in increasing plant productivity so that they can produce good quality safe food products and be able to compete in the global market, namely by using biological organic fertilizers. Biological organic fertilizers are biological products that can increase fertilizer efficiency, fertility, and soil health. Biological organic fertilizers contain bacteria that are useful for stimulating plant growth so that crop production remains high and sustainable (Chusnia *et al*., 2012). The application of this biological organic fertilizer can provide NPK nutrients, increase soil CEC and increase soil P solubility.

The nutrients needed by sweet corn plants are nitrogen, phosphorus, and potassium. The requirement for N nutrients ranges from 31.41 – 39.39 kg/ha, P nutrients range from 6.03 – 12.54 kg/ha, and K nutrients range from 37.50 – 41.70 kg/ha (Priyanto, 2016). This is supported by the research results of Marlina *et.al*., (2016), that the application of biological organic fertilizers (chicken manure enriched with Azospirillum bacteria and 400 kg/ha phosphate solubilizing bacteria with 50% NPK organic fertilizer can increase the production of rice plants in the soil. ups and downs of 57.79 g/pot. Furthermore, Marlina and Asmawati (2017), that the application of a combination of 400 kg/ha biological organic fertilizer with 25% NPK inorganic can increase NPK nutrient absorption and rice production per plot by 1.46 kg/plot.

In addition to fertilization, spacing is one of the factors that can affect crop production. Increasing corn production can be done by improving the level of planting density to increase the yield of corn plant seeds. Increasing the level of planting density per unit area to a certain extent can increase seed yields, but increasing the number of plantings will result due to competition for nutrients, water, solar radiation, and space to grow so it will reduce the number of seeds planted. Plant population (planting distance) is one of the factors that can affect crop yields. Planting with spacing aims to population plants get an equal share of the necessary nutrients and sunlight, and facilitate maintenance (Probowati, 2014). Maximum production is achieved when using the appropriate spacing. The higher density level of a plant results in a higher level of competition between plants in terms of getting nutrients and light. To get the right spacing, several things need to be considered soil fertility, proper spacing, and balanced use of fertilizers. The purpose of this study was to determine the effect of biological organic fertilizers and spacing on the growth and production of sweet corn (*Zea mays saccharata* Sturt).

Materials and methods

The methods used in this study are experimental methods with field trials belonging to farmers in Sukajaya Village, Sukarame District, Palembang Municipality. The research was conducted from July to November 2022. The materials used in this study were sweet corn seeds, biological organic fertilizers, urea fertilizer, KCL, SP-36, Furadan-3G, Azodrin-15WSC, Dithane M-45-80 WP, and dolomite. The tools used were: hoes, machetes, sickles, knives, buckets, dippers, raffia rope, bamboo, plastic sheets, tape measure, scales, calipers, scissors, and stationery. The experimental design

used was a randomized block design which was arranged in a factorial manner consisting of 2 treatment factors, namely the treatment of biological organic fertilizers and the treatment of spacing, with 3 replications. The first is biological organic fertilizer H1 = 200 kg/ha biological organic fertilizer, H2 = 300 kg/ha biological organic fertilizer, and H3 = 400 kg/ha biological organic fertilizer. The second factor is the spacing consisting of 3 levels, namely: J1 = 50 cm x 30 cm, J2 = 60 cm x 30 cm, and J3 = 70 cm x 30 cm. Based on the treatment factors obtained as many as 9 treatment combinations. Each combination was repeated 3 times, resulting in a total of 27 experimental units or plots. Land preparation was cleared of weeds after that the soil was smoothed and plots were made with a size of 2 m x 3 m with a distance of 50 cm between plots, while the distance between groups which were replicates was 100 cm. Making biological organic fertilizer using 200 kg of chicken manure and 100 kg of straw incubated for 1 month, once every 4 days it is stirred back and forth then the manure and straw that have been incubated are added with bran and sugar then given Azospirillum and phosphate solubilizing bacteria after that the fertilizer is ready to be used.

Planting the planting hole is made by digging. Three seeds were planted per hole at a depth of 3 cm-5 cm, with spacing according to the treatment, namely: 50 cm x 30 cm (36 tons/plot), 60 cm x 30 cm (21 tons/plot), 70 cm x 30 cm (15 tons/plot). After two weeks of age the plants were selected, leaving two plants per hole. At the time of planting, the seeds were given Furadan-3G at a rate of 2 g/plant. Giving this furadan is to prevent pest attacks, watering is done twice a day, depending on weather conditions. The first weeding is done simultaneously with the second urea fertilization accompanied by growth when the plants are three weeks old. The second weeding is done when the plants are six weeks old accompanied by heaping. To protect plants from disease, given Dithane M-45 80 WP with a concentration of 2 g/l water. In eradicating pests, sweet corn is used, ready to be harvested at the age of 60 days to 70 days after planting or when the corn silk is brown and the cobs are full. Observation of plant growth is carried out every week. Variables observed included plant height, flowering age, cob length, cob diameter, net cob weight per plant, and dry weight.

Results and Discussion

The results of the analysis of variance showed that biological organic fertilizers had a very significant effect on net cob weight per plant, had a significant effect on cob length, and cob diameter, but had no significant effect on plant height, flowering age, and dry matter weight. The spacing treatment had a significant effect on plant height and net cob weight per plant while flowering age, cob length, cob diameter, and dry cob weight had no significant effect. The application of several doses of biological fertilizers showed no significant effect on plant height, flowering age, or dry matter weight. From the administration of biological organic fertilizer doses of 200 kg/ha, 300 kg/ha, and 400 kg/ha, it turned out that the doses of biological organic fertilizers were 400 g/ha, also gave the highest average consistency showing positive linear (increase) in all parameters of growth and production of corn plants where biological organic fertilizers contain macro, micronutrients, hormones, humic acids, and microorganisms that benefit the soil. The benefits of the presence of microorganisms in the soil can increase soil fertility, produce important compounds such as nutrient solvents, microbial solubilizing phytohormones, fix N2, dissolving P so that it becomes more available changing organic matter thereby increasing the availability of nutrients in the

soil (Saraswati and Purwani, 2009). In the treatment, spacing affects the nutrients and growth space obtained by plants which in turn influences plant growth and production. Plant population affects the efficiency of water and nutrient use which affects plant growth and production.

The treatment of several spacings showed no significant effect on flowering time, cob length, cob diameter, and dry weight. This is presumably because the spacing between plants is very small so that the growth in height of the three spacings is almost uniform and always increases, then the spacing of 50 cm x 30 cm (J3) in sweet corn plants causes competition between plants in absorbing sunlight, water, extracting nutrients, and causing crowns and roots to overlap so that plants cannot grow properly and give maximum results. According to Bakkara (2010) which states that maximum production is achieved when using the appropriate spacing. The higher the level of density of a crop, the higher the level of competition between plants in terms of getting nutrients and light. Conversely, if the spacing is too far, evaporation of nutrients and water will occur and the processes of transpiration, evaporation, and respiration will be quite high so that the need for water and nutrients will decrease. The interaction had a significant effect on plant height and cob weight but had no significant effect on flowering time, cob length, cob diameter, and dry weight.

Table 1. Results of the analysis of the variation in the effect of biological organic fertilizers and spacing on all observed parameters

Observed Parameters	F count			KK (%)
	H	J	I	
Plant height (cm)	2,15^{tn}	4,24*	1,96^{tn}	4,00
Age of flowering (days)	2,85^{tn}	0,69^{tn}	8,72**	3,09
Cob length (cm)	5,14*	2,73^{tn}	3,00*	7,57
Ribbed cob diameter (cm)	4,23*	2,28^{tn}	1,59^{tn}	3,49
Net cob weight per plant (g)	6,27**	4,73*	3,72*	3,90
Dry chest weight (g)	2,90^{tn}	0,20^{tn}	0,82^{tn}	9,50

Description: * = Significant impact, ** = Very significant impact, tn = not significant effect, H = Bio-organic fertilizer, J = Spacing, I = Interaction, KK = Coefficient of diversity

Table 2, the J2 treatment gave the best results for plant height, which was 182.98 cm. At this spacing, there was no significant competition between plant leaves in getting the sunlight needed for the photosynthesis process and providing ideal growing space for the growth of corn plants. sweet. Plants with wider spacing get enough sunlight and nutrients because the competition between plants is smaller. Spacing is closely related to factors that play a role in plant growth, such as the efficient use of sunlight, especially for photosynthesis. If the spacing is too tight, the canopy leaves will lose the opportunity to receive light, so the amount of light absorbed is reduced, resulting in a reduced rate of photosynthesis. Likewise with spacing that is too rare, even though there is no competition for nutrients, the number of plant populations will affect crop production.

Table 2. Results of the analysis of the variation in the effect of spacing on plant height (cm)

Treatment	Average plant height (cm)	BNJ test 0,05 = 8,76	0,01= 11,47
J3	173,88	a	A
J1	175,05	ab	A B
J2	182,98	b	B

Note: Numbers followed by the same letter mean no significant difference at the 5% and 1% LSD test level

The results of the honestly significant difference test Table 3 shows that the dose of biological organic fertilizer and spacing has a very strong relationship between the treatment of biological organic fertilizer and the population of soil bacteria where the higher the dosage of biological organic fertilizer, the higher the number of bacterial populations the presence of the total population of bacteria in the soil influenced by the dose of fertilizer while the rest comes from other factors. Thus spurring faster release of flowers and this can accelerate the process of fruit formation. Biological organic fertilizers have a function as a material that contains living cells that can fix nitrogen and so on to increase soil fertility and help plant growth through increasing microbial activity in the soil and helping plant growth through increasing microbial activity in the soil (Simangunkalit et al., 2006). While the spacing shows the best effect so that in the absorption of nutrients, sunlight will be maximized. This situation is made possible by a well-developed plant root system because the area of root development is sufficiently available and does not overlap so that the plant gets the adequate scope to achieve maximum growth and production. The honest significant difference test results for the treatment of biological organic fertilizers and spacing are mutually influential treatments, in line with Syarief's statement (2005) which states that adequately available nutrients can stimulate plant growth, stimulate root system growth, increase production yields, and increase plant growth. leaves to increase the process of photosynthesis.

Table 3. Effect of biological organic fertilizers and Spacing on flowering age (days)

Treatments	Average age of flowering (days)	BNT test 0,05 = 2,79	0,01= 3,46
H1J3	30,66 a		A
H3J1	31,00 a		A
H1J2	31,33 a		A
H2J3	31,33 a		A
H3J2	31,66 a		AB
H1J1	32,33 ab		AB
H2J2	32,33 ab		AB
H2J1	33,00 ab		AB
H3J3	35,03 ab		B

Note: The numbers followed by the same letter mean that they are not significantly different at the 5% and 1% BNT test levels

Table 4 shows that the treatment of biological organic fertilizers besides being able to change the physical properties of the soil, there is also a change in chemical properties with an increase in the elements N, P, and K as a source of nutrients for plant growth and yield (Sari *et al*., 2016; Dinesh *et al*., 2010). In addition, the provision of nutrients needed by plants can be carried out by bacteria in biological fertilizers which can fix N from the air and phosphate solubilizing microbes which can increase P in the soil to become available P for plant growth, thereby affecting growth and yield components. besides that, it can save the use of chemical fertilizers (Moelyohadi *et al*., 2012). contains beneficial bacteria and fungi such as *Azotobacter chococcum, A. vinelandi, Azospirilum sp, Pseudomonas cepacia, Penicillium sp, Acinetobacter sp* with each population e" 10^{7} CFU/mL. Azotobacter, known as N2-fixing rhizobacteria in plant roots, can produce phytohormones including cytokinins and gibberellins (Hindersah and Simarmata., 2004).

Table 4. Interaction of the effect of biological organic fertilizers and spacing on cob length parameters (cm)

Biological Organic Fertilizer	Spacing			Biological Organic Fertilizer
	J1	J2	J3	
H1	20,48a AB	19,64a AB	19,70a AB	19,94ab AB
H2	20,42ab AB	24,58b B	19,83a AB	21,61b AB
H3	19,57a A	19,42a A	19,03a A	19,34a A
BNJ	H and J 0,05 = 19,90 0,01 = 2,48		HJ 0,05 = 4,47 0,01 = 5,41	

Note: The numbers followed by the same letter mean that they are not significantly different at the 5% and 1% BNT test levels

Table 5 shows that the diameter of cobs with H2 treatment has larger diameter than other treatments, this is in line with Habibi L (2008) which states that biological organic fertilizers can decompose chemical residues, bind heavy metals, supply part of the N requirements for plants, dissolving phosphate compounds, releasing K compounds from soil colloidal bonds, producing natural enzymes, producing anti-pathogenic substances (specific to each type of microorganism). Biofertilizers function to increase production yields, increase the efficiency of the use of artificial fertilizers, reduce the dosage of artificial fertilizer use, improve the physical, chemical, and biological structure of the soil, suppress pest and disease attacks, create a good balance of flora and fauna in the soil which in turn brings goodness to all aspects of agriculture. This is the opinion of Palungkun and Budiarti (2012) that if there is a balance between the cobs in sweet corn plants in obtaining nutrient requirements, sunlight, water, and humidity, the cobs produced will have a large size.

Table 5. The effect of biological organic fertilizers on the diameter of cobs (cm)

Treatments	Average cob diameter (cm)	BNT Test	
		0,05 = 0,18	0,01 = 0,24
H1	13,26	a	A
H3	13,70	b	B
H2	13,90	c	B

Note: The numbers followed by the same letter mean that they are not significantly different at the 5% and 1% BNT test levels

The honest significant difference test results for the H2 biological organic fertilizer treatment had a net cob weight per plant, which was 190.63 grams, higher than the other treatments. This shows that the application of H2 biological organic fertilizer at a rate of 300 kg/ha can create better soil texture and structure conditions, and support the formation of crumb structure and soil aggregate stability. According to Suwahyono (2011), the microbes contained in biological fertilizers when applied to plants can bind nitrogen from the air, dissolve phosphate bound in the soil and break down complex organic compounds into simpler compounds and stimulate plant growth. Then according to Soemarno (2011) that if the plant has conditions that support it with the appropriate nutrients and mineral elements, the plant will experience upward growth and become taller. Microbes contained in biological organic fertilizers such as Azotobacter and Azospirillum which are capable of fixing nitrogen to produce good plant height, Endophytic microbes which are capable of producing growth hormones, and phosphate solubilizing microbes capable of fixing P elements to increase the height growth of maize plants better thus affecting production. Spacing of 60 cm x 30 cm still gave better results in the growth of corn plants even though some plant parameters had a significant effect and some had no significant effect at $\alpha = 5\%$, but for all plant growth and production parameters, it gave the highest average consistency at the spacing plant 60 cm x 30 cm. This is because the corn plant is a C4 plant that is adaptive to sunlight so the spacing of 60 cm x30 cm is the ability of the plants to get full sunlight and sufficient nutrients to carry out the assimilation process better. The spacing system affects light, CO_2, wind, and nutrients obtained by plants so it will affect the photosynthesis process which in turn has a different effect on the growth parameters and corn production.

Table 6. Interaction of the effect of biological organic fertilizers and spacing on the parameter of net cob weight per plant (g)

Biological Organic Fertilizer	Spacing			Biological Organic Fertilizer
	J1	J2	J3	
H1	174,07ab A	176,83a AB	182,49a AB	177,79ab A
H2	177,48ab AB	204,58b B	189,83a AB	190,63b AB
H3	182,57a A	182,42a A	188,03a A	184,34a A
Average spacing	178,03a A	187,94b A	186,78ab A	
BNJ	A and J 0,05 = 8,72		AJ 0,05 = 20,82	
	0,01 = 11,42		0,01 = 25,75	

Note: The numbers followed by the same letter mean that they are not significantly different at the 5% and 1% BNT test levels

The dry weight of each treatment tabulated showed that the biological organic fertilizers produced the highest body weight of 90.82 g. While the treatment of J1 spacing was 86.46 g. The interaction between biological organic fertilizers and H1J3 spacing resulted in the highest weight of 94.64 g while the lowest was achieved in the H3J3 treatment of 70.27 g.

The process of photosynthesis will determine the accumulation of photosynthate which is beneficial for plant growth. Plant growth is strongly influenced by the high and low photosynthate produced through the process of photosynthesis. In fertile soils, the spacing should be somewhat narrowed, and in infertile soils, the spacing should be extended, so that there is no competition for nutrients in the area around the roots with other plants, which can affect optimum plant growth and yields. The application of biological organic fertilizers can create better soil texture and structure conditions, and support the formation of crumb structures and the stability of soil aggregates. Steady soil aggregates will provide good aeration so that sufficient oxygen is available for plant respiration, besides that it can increase the soil's ability to store water. Quansah (2010) states that the provision of organic matter can increase the quality and quantity of crop production. Fertilization of biological organic fertilizers can increase yields quantitatively and qualitatively. Lingga and Marsono (2007) stated that fertilizer is the key to soil fertility because it contains one or more elements to replace elements that have been absorbed by plants. Availability of nutrients which are essential elements needed by plants, because if one of the elements is not present, the metabolic process and plant growth will be disrupted and even result in death. Sufficient nutrient content in the soil will lead to good vegetative growth of corn plants (Retno and Darminanti, 2009). Corn plants give maximum yields when there are sufficient nutrients available for the plant because the vegetative phase also requires nutrients, no different from the generative phase. Plant yields will be optimal if the conditions are met, such as the availability of sufficient nutrients and appropriate environmental factors.

In other treatments, the results were low because, at the beginning of growth, the fertilizer had not been completely absorbed, so the results were not visible. The biological organic fertilizers that are given can make solid soil aggregates which will provide good aeration so that sufficient oxygen is available for plant respiration, besides that it can increase the soil's ability to store water. Physically it can improve soil structure to make it more friable making it easier for sweet corn plants to absorb nutrients, chemically this biological organic fertilizer can contribute nutrients and biologically can activate microorganisms in the soil in decomposing organic fertilizers.

Microorganisms present in biological organic fertilizers produce active compounds that play a role in decomposing organic matter, to accelerate the solubility of available nutrients in the soil. Plants that were given biological fertilizers gave a positive linear response with an increase in the dose given, this was suspected to be a phosphate solubilizing microorganism Streptomyces sp. contained in biological fertilizers help the availability of P. The element Phosphorus (P) is an essential macronutrient but slow release in the soil, with the application of biological fertilizers, so that the phosphate solubilizing microorganisms will break down the unavailable (potential) phosphate into available phosphate for plants where phosphate functions in

seed formation. Agung and Rahayu (2004) stated that biological fertilizers have been able to increase the efficiency of nutrient uptake, improve growth and yield, and increase resistance to pests and diseases. Generally used microbes that can live together (symbiosis) with the host plant. Benefits are obtained by both parties, the host plant gets the additional nutrients needed, while the microbe gets organic matter for its activity and growth.

Conclusions

Based on the results of this study it can be concluded as follows:

1. Treatment of 300 kg/ha biological organic fertilizer can give the best effect on the growth and yield of sweet corn (*Zea mays saccharata* Sturt).
2. Treatment spacing of 60 cm x 30 cm can give the best effect on the growth and yield of sweet corn (*Zea mays saccharata* Sturt).
3. Interaction treatment between biological organic fertilizers with a dose of 300 kg/ha and a spacing of 60 cm x 30 cm will have the best effect on the growth and yield of sweet corn (*Zea mays saccharata* Sturt).

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THE EFFECT OF PHOSPHATE DOSAGE ON THE GROWTH AND PRODUCTION OF PEANUT PLANTS

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ABSTRACT
Peanut is a food crop with economic value and high fat and protein content. This study aims to determine the effect of phosphate dose on the growth and production of peanuts. This study used a Randomized Block Design, with six treatments and four replications. One treatment consisted of 4 sample plants. The treatments used were as follows: A: 0 grams of TSP per plant (control); B= 0.22 grams of TSP per plant; C= 0.33 grams of TSP per plant; D= 0.44 gram TSP per plant; E= 0.55 grams of TSP per plant; F= 0.66 grams of TSP per plant. The parameters observed in this study were: plant height, number of branches, flowering age, percentage of filled pods, percentage of cipo pods, the weight of 100 seeds, and weight of seeds for each plant. Based on the results of the research that has been carried out, it is concluded that: Phosphate fertilizer affects the growth and production of kidang variety peanuts in the Lebak swamp land, meanwhile, treatment D, i.e. treatment with a phosphate dose of 0.44 grams of TSP per plant, was the best treatment.
***Keywords*:** Phosphate, Dosage, Peanut

1. Introduction

Peanuts are a food crop with high economic value due to their nutritional content, particularly their high protein and fat content (Arianti et al., 2021). Peanut demand continues to increase annually in line with population growth, community nutritional needs, food diversification, and the increasing capacity of the Indonesian food and feed industry. However, domestic peanut production is insufficient to meet Indonesia's needs, which still requires import substitution.

Peanut production in Sumatra reached 12,074 tons in 2012, declining to 11,351 tons in 2013. This decrease in production was due to a decrease in harvested area of 1,066 hectares, a decrease of 0.34 kW/ha, or 2.81%. In 2014, it decreased again to 9,778 tons (Central Statistics Agency, 2015).

The application of biofertilizers in groundnut cultivation can supply essential nutrients such as nitrogen and/or phosphorus to plants without leaving chemical residues in the environment, while also enhancing the microbial population associated with plant roots (Bargaz et al., 2018) (Munyari et al., 2025). Biofertilizers are products that contain beneficial living microorganisms capable of inhabiting the rhizosphere or plant tissues, where they enhance the availability and uptake of essential nutrients, thereby supporting and improving plant growth (Krska et al., 2022) (Asoegwu et al., 2020). Biofertilizers are available in various formulations, such as dry products and liquid suspensions, and can

be applied through seed treatment or delivered via irrigation water (Amenaghawon et al., 2021) (Allouzi et al., 2022). To achieve high production, fertilizer is a crucial factor in advanced agricultural efforts. Fertilizer is needed to maintain soil fertility and reduce crop production costs by increasing yields per hectare.

One of the essential nutrients for peanut plants is phosphorus (P), which accelerates plant growth and increases grain production (El-All et al., 2024). P is found in the soil as mineral phosphate in the form of plant debris and organic matter. Peanut plants require essential nutrients such as N, P, and K for growth and production, particularly for flower, pod, and seed formation (Fitriana et al., 2015). P is the second primary nutrient after N, playing a role in soil metabolism and microbiological processes and is absolutely essential for both soil microbes and plants (Gusmiatun et al., 2019) (Mohamed et al., 2024). Phosphate itself plays an active role in the generative phase, such as accelerating flowering and fruit ripening.

Tidal and swampy areas in South Sumatra currently and in the future play a significant role in the success of the rice self-sufficiency program. Additionally, non-rice crops (secondary crops and horticulture) have long been traditional commodities, significantly increasing farmers' incomes.

Based on field observations in the Ogan Ilir area of Inderalaya District, peanut production ranged from 7 to 10 pods per plant. This is thought to be due to the low soil fertility of these swampy areas and the presence of toxic compounds such as Al, Mn, and Fe, which can bind other nutrients such as N, P, K, and others.

The swampy areas of South Sumatra, despite challenges such as poor water management and low natural fertility, have the potential to develop various agricultural enterprises. Several efforts have been and are being undertaken to address these challenges, including the construction of primary and secondary canals, liming, fertilization, and pest and disease control.

Previous study further explained that peanuts require phosphate fertilization at a rate of 45 kg per hectare. This will stimulate pod growth, fill unfilled pods, and accelerate fruit maturity.

Based on the above description, fertilization plays a role in increasing the fertility of swampy soil. Therefore, further research is needed to investigate the effect of phosphate fertilization on peanut growth and production in swampy soil.

2. Methodology

The research was conducted over three months on the grounds of the University of Palembang, Jl. Dharmapala No. 1A, Palembang, from March 2025 to June 2025.

The materials and tools used in this study were peanut seeds, urea, KCl, TSP, CaO lime, manure, swamp soil, polybags, pesticides, hoes, saws, machetes, hammers, nails, thatch roofing, measuring tape, scales, sprayers, sieves, gelam wood, raffia rope, and stationery.

This study used a Randomized Block Design (RBD), with 6 treatments and 4 replications. Each treatment had 4 sample plants. The treatments used were as follows: A: 0 grams of TSP per plant (control); B = 0.22 grams of TSP per plant; C = 0.33 grams of TSP per plant; D = 0.44 grams of TSP per plant; E = 0.55 grams of TSP per plant; F = 0.66 grams of TSP per plant.

2.1. Procedures

The procedures implemented in this research were as follows:

1. Prepare a 4 m x 6 m plot of land. Clear the land of vegetation using a hoe and machete, and construct a fence from thatch.
2. Prepare the substrate by taking the topsoil from the swamp and drying it. Next, sift the soil and apply lime at a dose of 13.5 grams per 10 kg of soil. The soil is placed in polybags and arranged according to the research chart.
3. Prepare the treatment, using TSP fertilizer, weighed according to the treatment. This is applied at planting by sprinkling it on the soil surface and watering it with water.
4. Planting is carried out simultaneously with the application of TSP fertilizer as a treatment, along with urea at a dose of 0.20 grams per plant and KCl at a dose of 0.19 grams per plant as a base fertilizer. After applying the fertilizer, cover it with soil and water it with water. 5. Maintenance, including watering in the morning and evening if there is no rain, weeding, and pest and disease control.

2.2. Parameters

1. Plant Height (cm)
   Plant height was measured two weeks after planting, until flowering, at weekly intervals. Measurements were taken from the soil surface to the growing point.
2. Number of Branches
   The number of branches was counted from all branches formed on the sample plants. Observations were made after harvest.
3. Flowering Age (days)
   Flowering age was observed after 50 percent of the plant population for each treatment had flowered.
4. Percentage of Filled Pods
   The percentage of filled pods was taken from each sample plant and calculated after harvest.
5. Percentage of Unfilled Pods
   The percentage of unfilled pods was taken from each sample plant and calculated after harvest.
6. Weight of 100 Seeds
   The weight of 100 seeds was taken from each sample plant and calculated after harvest.
7. Seed weight per plant
   The seed weight per plant is measured based on the seed weight of each sample plant after harvest.

3. Results and Discussion

3.1. Effect of Variables

Based on observations in this study, it was found that the effect of phosphate dosage on plant height, number of branches, flowering time, percentage of filled pods, percentage of unfilled pods, weight per 100 seeds, and seed weight per plant were significantly different compared to the other treatments. The effect of phosphate dosage on plant height can be seen in Table 1.

1. Plant Height

The analysis of variance (ANOVA) results showed that treatment D was significantly different from the other treatments. The BNJ test showed that treatment D was significantly different from treatments F, A, E, and B, and significantly different from treatment C.

2. Number of Branches

The analysis of variance (ANOVA) results showed that the treatments were not significantly different. However, tabulation showed that treatment D had the highest number of branches, with 7.31, and treatment A had the lowest number of branches, with 5.06.

3. Flowering Time

The analysis of variance (ANOVA) results showed that the treatments were not significantly different. However, tabulation showed that treatment D had the fastest flowering time, with 27 days, followed by treatments E, C, F, E, and A, each with 27.75 days. 28.00 days; 28.25 days; 28.75 days; and 29.50 days.

Table 1. Effect of phosphate dosage on plant height (cm)

Parameters	Average (cm)	BNJ	
		0.05=3.21	0.01 = 4.06
F	14.83	a	A
A	15.78	a	AB
E	16.20	ab	AB
B	17.35	ab	AB
C	19.26	b	BC
D	22.98	c	C

Note: Numbers followed by the same letter are not significantly different.

4. Percentage of Filled Pods (%)

The results of the analysis of variance showed that each treatment was significantly different from the other treatments. The BNJ test showed that treatment D was significantly different from treatments F, A, E, and B, but not significantly different from treatment C. Table 2 shows the percentage of filled pods with various phosphate levels.

Table 2. Effect of phosphate levels on the percentage of filled pods.

Parameters	Average (cm)	BNJ	
		0.05=0.32	0.01 = 0.41
A	8.98	a	A
F	9.07	a	A
E	9.19	a	A
B	9.23	a	A
C	9.26	a	AB
D	9.66	b	B

Note: Numbers followed by the same letter are not significantly different.

5. Percentage of Cipo pods (%)

The results of the analysis of variance showed that the treatment was significantly different from the other treatments. The BNJ test showed that treatment D was significantly different from treatments C, B, E, F, and A. Table 3 shows the effect of phosphate dosage on the percentage of Cipo pods.

Table 3. Effect of phosphate dosage on the percentage of filled pods.

Parameters	Average (cm)	BNJ	
		0.05=0.78	0.01 = 0.99
D	2.59	a	A
C	3.75	b	B
B	3.84	b	B
E	3.91	b	B
F	4.21	b	B
A	4.37	b	B

Note: Numbers followed by the same letter are not significantly different.

6. Weight of 100 seeds (grams)

The results of the analysis of variance showed that treatment D was significantly different from the other treatments. The BNJ test showed that treatment D was significantly different from treatments C, B, E, F, and A. Table 4 illustrates the effect of phosphate dosage on the weight of 100 seeds.

Table 4. Effect of phosphate dosage on the weight of 100 seeds

Parameters	Average (cm)	BNJ	
		0.05=6.15	0.01 = 7.77
A	38.05	a	A
F	40.35	a	A
E	42.23	a	A
B	50.38	b	B
C	51.00	b	B
D	61.41	c	C

Note: Numbers followed by the same letter are not significantly different.

7. Seed weight per plant (grams)

The results of the analysis of variance showed that each treatment was significantly different from the other treatments. The BNJ test showed that treatment D was

significantly different from treatments C, B, E, F, and A. The effect of phosphate dosage on seed weight per plant can be seen in Table 5.

Table 5. Effect of phosphate dosage on seed weight per plant

Parameters	Average (cm)	BNJ	
		0.05=19.46	0.01 = 24.59
A	43.79	a	A
F	51.55	a	A
E	56.21	a	A
B	60.94	a	A
C	62.34	a	A

Note: Numbers followed by the same letter are not significantl different.

The analysis of variance showed that the phosphate application on the growth and yield of the Kidang variety of peanuts in swampy areas significantly affected plant height, percentage of filled pods, percentage of unfilled pods, weight per 100 seeds, and weight of seeds per plant. The effect was insignificant on the number of branches and flowering time.

Changes in the number of branches and flowering time were insignificant, but tabulated differences were observed. Treatment D had the highest number of branches compared to the other treatments. For flowering time, treatment D had the fastest flowering compared to the other treatments. Treatment A also produced the lowest yields for both number of branches and flowering time.

Although TSP fertilizer is water-soluble, it is easily washed away by irrigation. This indicates that TSP fertilizer fails to meet the required P nutrient requirements during the plant's reproductive phase, such as the stem, and the remainder is stored as protein and carbohydrates.

Phosphate treatment significantly impacted plant height, the percentage of filled pods, the percentage of unfilled pods, and the weight of 100 seeds per plant. This is thought to be because phosphate is useful for plants in stimulating the growth of early roots, especially the roots of seeds and young plants. The faster the root growth, the more readily the plants absorb water and nutrients available in the soil, resulting in better plant growth and a better response to photosynthesis. Consequently, the plants thrive and produce high yields (Faza et al., 2019).

This is because TSP fertilizer is slightly soluble in water, allowing it to provide more P nutrients to the culture medium to stimulate the initial growth of peanut plants. P taken up by the roots is used in plant metabolic processes such as photosynthesis. Adequate P leads to optimal photosynthesis. Some of the assimilates produced are used in the formation and construction of plant organs, while the remainder is stored as protein and carbohydrates.

Treatment D performed best compared to the other treatments. This is thought to be because the phosphate required by peanut plants is optimally available, resulting in good and fertile plant growth (Rizki et al., 2016). Phosphate can accelerate root growth,

stimulate and strengthen plant growth, and increase grain production (Faza et al., 2019) (Fathi and Afra., 2023). Plant P uptake and utilization are crucial for crop yield (Afra and Mozafar, 2017). Phosphorus deficiency will result in a poor and stunted plant system, poor fruit formation, and reduced seed (fruit) yield (Malhotra et al., 2018). Phosphate (P) is needed by plants for new cell formation in growing tissues and stem strengthening (Rafique et al., 2020).

Furthermore, Arwansyah et al., 2019, stated that soil deficient in phosphorus will result in poor plant growth. Visible symptoms include the leaves turning completely dark and often appearing shiny red. The edges of the leaves, branches, and stems develop a purplish-red color that gradually turns yellow. When the plant bears fruit, the fruit is stunted, ugly, and ripens quickly (Wijaya and Syawal, 2015). Phosphorus is an essential nutrient for supporting reproduction, and a deficiency in P inhibits flower and cob formation, and grain formation (Rahmawati et al., 2018).

4. Conclusions

The conclusions drawn from the research results are:

1. Phosphate fertilizer affects the growth and production of the Kidang variety of peanut plants in swampy areas.
2. Treatment D, with a phosphate dose of 0.44 grams of TSP per plant, was the best treatment.

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FREEDOM OF EXPRESSION IN THE DIGITAL ERA AN EXAMINATION OF HUMAN RIGHTS AND LEGAL REGULATIONS

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Abstract

Freedom of expression is one of the fundamental human rights guaranteed by both the constitution and international law. In the digital era, this right has taken a new form through social media as a primary platform for expressing public opinion. However, technological advancements also bring new challenges, such as the misuse of free speech through the spread of hoaxes, hate speech, and defamation. This study aims to analyze how the concept of freedom of expression is guaranteed in national law, the challenges of law enforcement related to violations of free speech on social media, and the efforts made by the government and society to create responsible freedom of expression. The research method used is a normative juridical approach by examining relevant legislation and legal literature. The findings indicate that although freedom of expression is protected by the 1945 Constitution and Law Number 39 of 1999 on Human Rights, its implementation in social media remains hindered by the application of the Electronic Information and Transactions Law (UU ITE), which often leads to multiple interpretations. Therefore, synergy among the government, law enforcement authorities, and society is essential to strengthen digital literacy and reform existing regulations so that freedom of expression can be realized fairly and responsibly in the digital space.

Keywords: *freedom of expression, social media, law, human rights*

1. INTRODUCTION

Freedom of expression is one of the most fundamental human rights guaranteed by both national constitutions and international legal instruments. Article 19 of the *Universal Declaration of Human Rights (UDHR)* states that everyone has the right to freedom of opinion and expression, including the right to seek, receive, and impart information through any media without interference. A similar guarantee is found in the *Constitution of the Republic of Indonesia of 1945*, particularly Article 28E paragraph (3), which affirms every person's right to express their opinions. Freedom of expression serves as a

cornerstone of democracy, enabling public participation in decision-making processes and providing oversight of government actions.

In the digital era, the meaning and scope of freedom of expression have undergone significant transformation. The development of information and communication technology has given rise to social media as a new public sphere where individuals can express ideas, share information, and interact without geographical boundaries. Platforms such as X (Twitter), Facebook, Instagram, and TikTok have become the primary channels for people to voice opinions and shape public discourse. The emergence of social media expands access to freedom of expression and strengthens the democratization of information, as noted by Sabubun and Ruslak Hammar (2023) in their study on the protection of freedom of expression in digital spaces (*Eduvest Journal*).

However, the advancement of digital technology also brings various new challenges. The wide-open space for expression is often misused to spread false information (hoaxes), hate speech, and defamation, which can lead to social conflict and threaten public order. Wisanjaya and Widodo (2023) point out that in Indonesia, the misuse of freedom of expression on social media often conflicts with regulations such as *Law No. 19 of 2016 on Electronic Information and Transactions (UU ITE)*, which in practice is often viewed as restricting the right to free expression. This situation reflects a dilemma between protecting freedom of expression and safeguarding other rights such as dignity, reputation, and public security.

Therefore, freedom of expression in the digital era is not only about the right to speak but also about the responsibility to exercise that freedom ethically and constructively. Balanced regulation and social awareness are needed to ensure that social media remains a healthy democratic space without infringing on human rights. Further research is essential to understand how national and international law can adapt to the dynamics of digital communication while upholding the principle of responsible freedom of expression.

Based on the above background, the research problems can be formulated as follows:

1. How do national legal regulations guarantee freedom of expression in the digital era, particularly through social media?
2. What are the challenges in law enforcement related to violations of freedom of speech on social media?
3. How do the government and society promote responsible freedom of expression in cyberspace?

2. METHODOLOGY

This study employs a normative legal research method, which focuses on the analysis of positive legal norms in the Indonesian legal system. This approach is used to understand how the principle of freedom of expression is normatively guaranteed in national legislation and how it is implemented in the digital space, particularly on social media. The study uses a normative legal approach, which examines written legal materials (*law in books*) to identify principles, doctrines, and legal norms regulating freedom of expression. According to Soerjono Soekanto and Sri Mamudji (2015), normative legal research is conducted on secondary sources or library materials, consisting of primary, secondary, and tertiary legal materials. This approach is appropriate because the research focuses on analyzing legal norms rather than empirical practice.

The research utilizes three types of legal materials: Primary legal materials, which are statutes and regulations serving as the legal foundation for freedom of expression, including: The 1945 Constitution of the Republic of Indonesia (especially Articles 28E(3) and 28F); Law No. 39 of 1999 on Human Rights; Law No. 11 of 2008 on Electronic Information and Transactions, as amended by Law No. 19 of 2016. Secondary legal materials, which include literature supporting the analysis of primary legal sources, such as books, scholarly journals, and prior research. Tertiary legal materials, which provide explanations or guidance regarding primary and secondary sources, such as legal dictionaries, encyclopedias, and official government websites.

Legal materials were collected through library research, as suggested by Peter Mahmud Marzuki (2017), which is a primary method in normative legal research aimed at gathering relevant legal materials. The data were obtained by reviewing legal documents, books, scientific journals, and government reports related to freedom of expression and digital media regulations. The collected legal materials were analyzed using qualitative descriptive analysis, interpreting and comparing the norms in legislation to evaluate their consistency with human rights principles. This analysis identifies gaps between the written law (*law in books*) and its application in practice on social media (*law in action*). As noted by Johnny Ibrahim (2018) in *Theory and Methodology of Normative Legal Research*, qualitative analysis aims to uncover the legal meaning embedded in regulations and assess their alignment with justice and legal certainty.

Through this methodology, the study aims to: Systematically examine how freedom of expression is guaranteed in national law and international law ratified by Indonesia; Identify challenges in law enforcement regarding the misuse of freedom of expression on social media and Provide normative recommendations for regulatory improvement and digital literacy enhancement so that freedom of expression can be realized in a fair, proportional, and responsible manner.

3.RESULTS AND DISCUSSION

1.1 National Regulations Guaranteeing Freedom of Expression in the Digital Era

In Indonesia, the guarantee of freedom of expression has a strong foundation in the 1945 Constitution of the Republic of Indonesia (UUD 1945), which serves as the highest legal authority. Article 28E paragraph (3) explicitly states that *"every person shall have the right to the freedom of association, assembly, and expression of opinion."* This constitutional provision affirms that citizens are free to express their ideas and opinions, both in traditional public spaces and in digital environments, as part of democratic participation. In addition, Article 28F of the 1945 Constitution strengthens the right to communicate and to obtain information, thereby establishing the legal basis for freedom of information in the digital age. This constitutional guarantee is further reinforced by Law No. 39 of 1999 on Human Rights, particularly Article 23 paragraph (2), which emphasizes that everyone has the right to freely express their opinions in public.

In the context of digital communication, the Law No. 11 of 2008 on Electronic Information and Transactions (the ITE Law)—as amended by Law No. 19 of 2016—plays a crucial role in regulating the use of digital media. The ITE Law aims to provide legal certainty in cyberspace and to protect users from

harmful content. However, in practice, it often intersects with the issue of freedom of expression. Certain provisions, such as Articles 27–28, prohibit the dissemination of content containing defamation, false information, or hate speech. Although these provisions are intended to maintain public order and protect individual dignity, their application has been criticized for being overly broad and potentially restrictive of free expression (Wisanjaya & Widodo, 2023). Recognizing this concern, the government has taken corrective measures through revisions of the ITE Law and the issuance of a Joint Decree by the Minister of Communication and Information Technology, the Chief of Police, and the Attorney General in 2021, which provides guidelines to ensure that law enforcement is not misused to suppress legitimate expression.

Furthermore, Indonesia's commitment to freedom of expression is also reflected in its ratification of the International Covenant on Civil and Political Rights (ICCPR) through Law No. 12 of 2005. Article 19 of the ICCPR affirms the right of every individual to hold opinions without interference and to seek, receive, and impart information and ideas through any media. By ratifying this treaty, Indonesia is legally bound to align its national legislation with international human rights standards, ensuring that any restriction on freedom of expression is lawful, necessary, and proportionate.

In conclusion, Indonesia's national regulations provide constitutional and legal protection for freedom of expression, including in digital spaces. However, their implementation must continue to be refined to achieve a balanced approach between protecting individual rights and maintaining public order amid the rapid development of digital technology.

1.2 Challenges in Law Enforcement Related to Violations of Freedom of Expression on Social Media

Law enforcement concerning violations of freedom of expression on social media in Indonesia faces complex and multidimensional challenges. One of the main challenges is the imbalance between protecting freedom of expression and maintaining public order as well as the rights of others. In practice, several provisions within *Law No. 11 of 2008 on Electronic Information and Transactions (ITE Law)*, as amended by *Law No. 19 of 2016*, are often used to prosecute individuals who express their opinions online. For instance, Article 27 paragraph (3) concerning defamation and Article 28 paragraph (2) concerning hate speech are frequently interpreted broadly and subjectively, leading to potential criminalization of expressions that should fall under the legitimate exercise of free speech (Wisanjaya & Widodo, 2023).

Another major challenge lies in the capacity of law enforcement officers to understand the context of digital communication. Limited digital literacy and insufficient understanding of human rights principles among law enforcement authorities often result in disproportionate handling of cases. In many instances, reports concerning social media posts are processed without careful assessment of their motives, context, or social impact. This situation has led to a public perception that the law is being used as a tool to suppress criticism, particularly against those opposing political or governmental interests. According to *Setiawan and Prakoso (2022)*, this condition has fostered a phenomenon known as "self-censorship," where individuals refrain from expressing opinions due to fear of legal repercussions.

Furthermore, technical and juridical challenges also complicate law enforcement in the digital sphere. Identifying offenders online can be difficult due to anonymous accounts, data encryption, and cross-border information dissemination. The evidentiary process in court requires specialized digital forensic expertise and inter-agency coordination. *Putra (2023)* notes that weak digital tracking systems and a lack of human resources in the cyber sector often hinder fair and transparent resolution of cases related to freedom of expression.

Another challenge involves the regulatory imbalance and government policy practices in managing digital spaces. On one hand, the government aims to safeguard cybersecurity and curb the spread of disinformation; on the other hand, measures such as website blocking, content takedowns, and internet restrictions are sometimes perceived as excessive and contrary to the constitutional guarantee of freedom of expression. *Human Rights Watch (2023)* highlights that such policies risk undermining the digital democratic space by instilling fear and limiting public participation in socio-political discourse.

Law enforcement related to violations of freedom of expression on social media requires not only firmness in legal implementation but also a deep understanding of democratic values and human rights principles. A more precise and proportional legal framework, improved capacity building for law enforcement personnel, and strong public oversight are necessary to ensure that freedom of expression remains protected while promoting social responsibility within digital spaces.

1.3 Government and Community Efforts in Promoting Responsible Freedom of Speech in Cyberspace

In the digital era, characterized by the rapid flow of information and the expansion of expressive freedom, responsibility in exercising the right to free speech has become increasingly crucial. In Indonesia, the government and the public have made continuous efforts to promote responsible freedom of speech in cyberspace through regulatory, educational, and collaborative approaches among various stakeholders.

From the government's perspective, the main effort has been the establishment and refinement of the legal framework that both guarantees and guides the ethical exercise of free expression. The government regulates online freedom of speech through *Law No. 11 of 2008 on Electronic Information and Transactions (ITE Law)*, as amended by *Law No. 19 of 2016*, as well as the *Joint Decree of the Minister of Communication and Informatics, the Chief of the National Police, and the Attorney General (2021)*, which provides enforcement guidelines to prevent misuse of the law against legitimate expression. According to *Listiyani and Christiyana (2023)*, the amendment of the ITE Law represents an important step toward balancing the protection of freedom of expression with the safeguarding of honor, public order, and national security.

Beyond legislation, the government has also implemented digital literacy initiatives to foster public awareness of online communication ethics. The *National Digital Literacy Movement*, launched by the Ministry of Communication and Informatics (Kominfo) in 2021, aims to build a healthy digital culture based on four key pillars: *digital ethics, digital safety, digital skills,* and *digital culture.* This program serves as a strategic effort to educate citizens on using their freedom of expression responsibly, avoiding the spread of

hoaxes, hate speech, and defamatory content. As *Sabubun and Hammar (2023)* emphasize, digital literacy is a vital instrument for protecting freedom of expression in social media while maintaining ethical and legal boundaries.

From the community's perspective, responsibility in exercising free speech is reflected through active participation in creating a democratic and respectful digital environment. Citizens play a crucial role in verifying information before dissemination and upholding ethical communication based on facts and respect for differing opinions. *Wisanjaya and Widodo (2023)* note that fostering a culture of critical dialogue and tolerance is a prerequisite for achieving productive and meaningful freedom of expression. Civil society organizations, academics, and digital communities also contribute through advocacy, research, and public campaigns that promote responsible and rights-based online expression.

These efforts align with the principles enshrined in *Article 19 of the Universal Declaration of Human Rights (United Nations, 1948)*, which guarantees every individual the right to seek, receive, and impart information and ideas through any media without interference. However, such freedom must be exercised with due regard for the rights and reputations of others, public morality, and national security. Therefore, collaboration between the government, digital platforms, media organizations, and civil society is essential to maintaining a balance between freedom and responsibility in cyberspace.

Responsible freedom of speech in the digital realm is not solely an individual obligation but the result of synergy between the government, the community, and social institutions. Legal reform, enhanced digital literacy, and the cultivation of respectful communication culture are the fundamental pillars for sustaining a democratic, open, and ethical digital public sphere.

4. CONCLUSION

Freedom of expression remains a vital pillar of democracy and human rights in Indonesia, both constitutionally and within the framework of international law. In the digital era, the exercise of this right has expanded through online platforms, allowing for broader participation in public discourse. However, the misuse of digital spaces such as the spread of misinformation, hate speech, and defamation poses significant challenges to maintaining a balance between freedom and responsibility. Although Indonesia's legal system provides a solid foundation for protecting freedom of expression through the **1945 Constitution** and **Law No. 39 of 1999 on Human Rights,** the implementation of the **Electronic Information and Transactions Law (UU ITE)** often creates ambiguity and raises concerns about overcriminalization. To ensure that this fundamental right is upheld, it is necessary to pursue **regulatory reform**, enhance **digital literacy**, and promote **collaborative efforts** among the government, law enforcement, and the public. In conclusion, achieving responsible freedom of expression in the digital era requires not only strong legal protection but also a cultural and educational commitment to use digital platforms ethically and constructively. Such synergy will help create a digital ecosystem that respects both individual rights and collective harmony.

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PUBLIC LEGAL AWARENESS AND PARTICIPATION IN SUSTAINABLE TECHNOLOGY DEVELOPMENT

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Abstract

Public legal awareness is a crucial aspect in realizing sustainable technology development. Without legal understanding and active public participation, efforts to develop environmentally friendly technology will not run optimally. This study aims to examine the relationship between legal awareness and public participation in sustainable technology development in Indonesia. The method used is a juridical-normative approach with a conceptual approach. The results of the study indicate that a high level of public legal awareness can increase social responsibility for the ethical and sustainable use of technology.

Keywords: *Legal awareness, public participation, sustainable technology, environmental law*

1. INTRODUCTION

Public legal awareness is a crucial element in creating a balance between technological progress and social responsibility. A legally aware society will play an active role in ensuring that technology is used in accordance with legal provisions and sustainability principles. [Satjipto Rahardjo, Ilmu Hukum, (Bandung: Citra Aditya Bakti, 2000), p. 45.] Therefore, public participation in the development of sustainable technology requires not only technical skills but also an understanding of the legal norms that govern the ethics and social responsibility of technology use. [Soerjono Soekanto, Pengetahuan Hukum dan Kepatuhan Hukum, (Jakarta: Rajawali Press, 1982), p. 32.]

Technological developments in the 21st century have brought about major changes to human lifestyles. Advances in information, communication, and industry have provided significant benefits for improving societal welfare. However, this progress has also had negative environmental and social impacts, such as pollution, overexploitation of natural resources, and increasing social inequality. [Satjipto Rahardjo, Ilmu Hukum, (Bandung: Citra Aditya Bakti, 2000), p. 23.] In this context, technological development must not only be oriented towards efficiency and economic profit, but also consider the principle of sustainability to ensure environmental sustainability and the well-being of

future generations. [United Nations, Agenda 21: Programme of Action for Sustainable Development, (New York: UN Publications, 1992).]

On the other hand, the success of sustainable technological development is inseparable from the role of society as a legal subject and development actor. Public legal awareness is a crucial aspect because it determines the extent to which individuals understand, appreciate, and comply with legal regulations governing the use of technology and environmental protection. [Soerjono Soekanto, Legal Awareness and Public Legal Compliance, (Jakarta: Rajawali Press, 2008), p. 12.]

Communities with a high level of legal awareness will actively participate in supporting sustainable technological policies and innovation.

Low legal awareness can lead to misuse of technology that can lead to environmental damage, such as the use of hazardous materials, unmanaged industrial waste, and the exploitation of natural resources without regard for environmental carrying capacity. [Ibid., p. 15.] Therefore, increasing public legal awareness is a strategic step in fostering collective responsibility for the development of environmentally sound technology.

Furthermore, public participation in the development of sustainable technology is also a key prerequisite for the successful implementation of national development policies. Law Number 32 of 2009 concerning Environmental Protection and Management has provided space for public involvement in monitoring and decision-making related to natural resource management. [Law Number 32 of 2009 concerning Environmental Protection and Management, Article 67.] Through this participation, the public is not only the object of policy but also a subject playing an active role in maintaining the balance between development and environmental preservation.

Thus, the relationship between legal awareness and public participation is crucial for the development of sustainable technology. This study seeks to explain how the level of public legal awareness can influence participation in the implementation of environmentally friendly technologies and how the government can strengthen the synergy between law, society, and technological innovation to realize sustainable development in Indonesia. [Bambang Sunggono, Legal Research Methodology, (Jakarta: Raja Grafindo Persada, 2010), p. 78.]

The rapid development of science and technology in the 21st century has brought significant changes to the lifestyles of modern society. On the one hand, technological advances provide convenience in various fields such as communication, transportation, education, economics, and governance. However, on the other hand, technological development that is not accompanied by principles of sustainability and legal awareness can have negative impacts such as environmental damage, social inequality, and misuse of technology that harms the wider community.

In the context of national development, Indonesia places sustainable development as a strategic policy direction, outlined in various regulations and long-term development plans. One crucial aspect of sustainable development is the implementation of sustainable technology, namely technology designed to meet present needs without compromising the ability of future generations to meet their own needs. The implementation of sustainable technology requires the support of clear legal regulations, consistent law enforcement, and a high level of public legal awareness.

Public legal awareness plays a crucial role in supporting the success of sustainable technology-based development policies. According to Soerjono Soekanto, legal awareness can be defined as the awareness or values inherent in humans regarding

existing or anticipated laws. [Soerjono Soekanto, Factors Influencing Law Enforcement, (Jakarta: Raja Grafindo Persada, 2012), p. 42] A legally aware society will understand its rights and obligations, comply with applicable regulations, and actively monitor the implementation of law in its environment. Without legal awareness, laws and regulations will remain merely written norms without any meaning in everyday life.

Furthermore, legal awareness must be accompanied by active public participation in every stage of development, particularly in the context of sustainable technology development. Public participation is not only This includes support for government policies, as well as involvement in local innovation, environmental conservation activities, and the use of environmentally friendly technology. Through this participation, the community becomes an empowered subject of development, not simply a recipient of policy.

Practically, Palembang, as one of Indonesia's major cities, faces challenges in implementing sustainable development principles, particularly amidst increasing industrialization, population mobility, and energy demand. Government programs such as digital-based waste management, the use of renewable energy, and green transportation require the support of a community with a high level of legal awareness and active participation to ensure their sustainability. Without the involvement of a community aware of its legal and social responsibilities, these policies will struggle to achieve optimal results.

Furthermore, globalization and digitalization have also brought changes to the public's legal awareness. The use of information technology in everyday life demands a new understanding of digital law, environmental ethics, and data protection. Therefore, increasing public legal awareness needs to be systematically implemented through legal education, policy dissemination, and collaboration between the government, academia, and the private sector.

The rapid development of science and technology in the 21st century has brought significant changes to the lifestyles of modern society. On the one hand, technological advances provide convenience in various fields such as communication, transportation, education, economics, and government. However, on the other hand, technological development that is not accompanied by principles of sustainability and legal awareness can have negative impacts such as environmental damage, social inequality, and misuse of technology that harms the wider community.

In the context of national development, Indonesia has positioned sustainable development as a strategic policy direction, outlined in various regulations and long-term development plans long-term. One important aspect of sustainable development is the implementation of sustainable technology, namely technology designed to meet present needs without compromising the ability of future generations to meet their own needs. The implementation of sustainable technology requires the support of clear legal regulations, consistent law enforcement, and a high level of public legal awareness. Public legal awareness plays a crucial role in supporting the success of sustainable technology-based development policies. According to Soerjono Soekanto, legal awareness can be defined as the awareness or values inherent in humans regarding existing laws or laws that are expected to exist.1 A legally aware society will understand its rights and obligations, comply with applicable regulations, and actively monitor the implementation of laws in its environment. Without legal awareness, laws and regulations will remain merely written norms without any meaning in everyday life.

Furthermore, legal awareness must be accompanied by active public participation in every stage of development, particularly in the context of sustainable technology development. Public participation encompasses not only support for government policies but also involvement in local innovation, environmental conservation activities, and the use of environmentally friendly technologies. Through this participation, the public becomes empowered subjects of development, not simply recipients of policy.

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Furthermore, globalization and digitalization have also brought changes to public legal awareness. The use of information technology in everyday life demands a new understanding of digital law, environmental ethics, and data protection. Therefore, increasing public legal awareness needs to be systematically implemented through legal education, policy dissemination, and collaboration between the government, academics, and the private sector.

Therefore, research on public legal awareness and participation in sustainable technology development is crucial. This research aims not only to determine the level of public legal awareness but also to encourage synergy between law, society, and technology to create just, ethical, and environmentally sound development. Strong legal awareness will serve as a moral and social foundation for a society that actively participates in supporting sustainable technological innovation in Indonesia, particularly in the city of Palembang.

The rapid development of technology in the current era of globalization has had a significant impact on various aspects of people's lives, including social, economic, and legal aspects. Sustainable technology has become a primary focus of modern development because it focuses on efficient, environmentally friendly, and socially just resource utilization. However, the success of sustainable technology development depends not only on the advancement of innovation and government policies, but also on the level of public legal awareness, understanding, complying with, and actively participating in their implementation.

Legal awareness is a crucial indicator in creating an orderly and just society. A society with a strong legal awareness will be able to respect, comply with, and participate in overseeing the implementation of applicable laws and regulations. In the context of sustainable technology development, public legal awareness is a determining factor in the successful implementation of various policies, such as waste management, renewable energy use, and carbon emission reduction. Without public understanding and participation, government regulations will not be implemented effectively.

On the other hand, community participation is a form of social responsibility towards sustainable development. This participation includes active involvement in the planning, implementation, and monitoring of environmentally friendly technology-based policies. Through participation based on legal awareness, communities can become partners with the government and businesses in realizing technological transformation that is not only modern but also sustainable.

Large cities in Indonesia, including Palembang, face significant challenges in realizing sustainable development. High urbanization, increasing energy needs, and changing consumption patterns require synergy between government policies, community legal awareness, and technological innovation. Therefore, research on the level of community legal awareness and participation in sustainable technology development is crucial to determine the extent to which communities understand their legal role and contribute significantly to supporting the sustainable development agenda at the local level.

2. RESEARCH PROBLEMS

The problems to be examined in this paper are:

1. What is the level of public legal awareness in supporting the development of sustainable technology in Palembang City?
2. What efforts can the government make to increase legal awareness and encourage active public participation in the development of sustainable technology in Palembang City?

3. METHODOLOGY

This paper uses a normative juridical legal research method, namely research focused on the study of positive legal norms, legal principles, and legal concepts related to the theme of legal awareness and sustainable technology. [Bambang Sunggono, Legal Research Methodology, (Jakarta: Raja Grafindo Persada, 2010), p. 43]

3.1 Research Approach

The approaches used are a conceptual approach and a statutory approach.

The conceptual approach is used to understand legal theories and principles regarding legal awareness and community participation in sustainable development. [Peter Mahmud Marzuki, Legal Research, (Jakarta: Kencana Prenada Media, 2011), p. 95.] The statutory approach is used to examine relevant legal regulations, such as Law Number 32 of 2009. Concerning Environmental Protection and Management and its derivative regulations. [Law Number 32 of 2009 concerning Environmental Protection and Management.]

3.2 Types and Sources of Legal Materials

The legal materials used consist of: Primary legal materials, namely laws and regulations related to the environment, sustainable development, and public participation; Secondary legal materials, such as books, journals, and research results discussing legal awareness and the application of sustainable technology; Tertiary legal materials, in the form of legal dictionaries, encyclopedias, and other supporting sources to clarify legal terms. [Soerjono Soekanto, Introduction to Legal Research, (Jakarta: UI Press, 1986), p. 52.]

3.3 Legal Material Collection Techniques

Legal materials were collected through library research by searching relevant laws and regulations, books, scientific journals, and academic literature. [Ibid., p. 56.]

3.4 Analysis Technique

The analysis was conducted using qualitative descriptive analysis, which systematically describes and interprets legal data based on applicable legal theories and norms. [Bambang Sunggono, Op.Cit., p. 48.]

This method aims to describe the relationship between public legal awareness, public participation, and the implementation of sustainable technology as a whole.

4. RESULTS AND DISCUSSION

4.1 Level of Public Legal Awareness in Supporting Sustainable Technology Development in Palembang

Palembang, as one of the major cities in South Sumatra, is experiencing rapid development in technology and industrialization. This growth includes the energy, transportation, and home industry sectors, which are increasingly dependent on modern technology. However, the level of public legal awareness in using and managing technology to maintain a sustainability orientation still varies and is not evenly distributed across all levels of society. [Palembang City Government, Palembang City Profile in Figures 2024, (Central Bureau of Statistics, 2024), p. 45.]

Observations and studies indicate that the people of Palembang generally have a basic understanding of the importance of preserving the environment, but do not fully understand the legal aspects governing the use of sustainable technology. Public legal awareness is often limited to a normative understanding—that breaking the law can result in sanctions—without being accompanied by a substantive understanding of legal responsibility towards the environment. [Soerjono Soekanto, Legal Awareness and Public Legal Compliance, (Jakarta: Rajawali Press, 2008), p. 28.]

Several factors influencing the low level of legal awareness among the people of Palembang include:

1. Minimal direct socialization of environmental laws and policies by the local government to the community;
2. Low legal and technological literacy among the lower-middle class;
3. A consumerist and pragmatic culture that tends to focus more on economic efficiency than environmental sustainability;
4. Lack of legal oversight of small businesses using environmentally unfriendly technology.

Nevertheless, there have been positive developments, particularly within higher education and environmental communities in Palembang. Several universities, such as Sriwijaya University and the University of Palembang, and environmental non-governmental organizations (NGOs), are actively promoting the use of environmentally friendly technologies, such as community-based waste management, solar energy for households, and innovative plastic recycling. [Palembang City Environmental Agency, 2023 Environmental Management Performance Report, p. 52.]

In the legal context, the legal awareness of the Palembang community can be categorized into four levels according to Soerjono Soekanto's theory, [Soerjono Soekanto, Legal Awareness and Public Legal Compliance, pp. 18–19.], namely:

1. Legal knowledge — some people are already aware of environmental regulations, such as Law Number 32 of 2009;
2. Legal understanding — a small percentage understand the meaning and purpose of environmental law, for example, the importance of AMDAL-based business permits;
3. Legal attitude — people are beginning to show a positive attitude by supporting policies to reduce plastic waste and use environmentally friendly transportation;
4. Legal behavior — some people have implemented concrete actions such as sorting waste and conserving energy, although this has not yet become a common practice. [Ibid., p. 21.]

In addition, the Palembang City Government has issued several policies that support increasing legal awareness in the field of sustainable technology, such as

Palembang Mayoral Regulation Number 26 of 2019 concerning the Management of Household Waste and Household-Like Waste. [Palembang Mayoral Regulation Number 26 of 2019 concerning the Management of Household Waste and Household-Like Waste.] This policy emphasizes the community's responsibility to sort and manage waste before disposal, and regulates the obligations of producers to reduce plastic waste. However, the implementation of this regulation still faces obstacles due to low legal awareness and public participation in its implementation. [Palembang City Environmental Agency, Evaluation of the Implementation of Mayoral Regulation No. 26 of 2019, (Palembang, 2023), p. 14.]

Thus, it can be concluded that the level of legal awareness among the people of Palembang City in supporting the development of sustainable technology is in a transitional stage—still evolving from normative awareness to substantive awareness. Efforts to increase legal awareness need to be continuously carried out through environmental law education, public participation, and the implementation of strict legal sanctions for violations of sustainability principles. [Bambang Sunggono, Legal Research Methodology, (Jakarta: Raja Grafindo Persada, 2010), p. 83.]

4.2 Efforts to Increase Legal Awareness in Palembang City

To strengthen the role of the community in the development of sustainable technology, several strategic steps can be taken, including:

1. Continuous environmental law education through schools, universities, and community organizations;
2. Disseminating regional regulations and national policies regarding green technology and waste management;
3. Engaging the public in green technology programs such as digital waste banks, household-scale renewable energy, and urban agricultural innovations;
4. Increasing collaboration between the government, academics, and the public to build a legal ecosystem that supports sustainable technological innovation. [Peter Mahmud Marzuki, Legal Research, (Jakarta: Kencana Prenada Media, 2011), p. 102.]
5. These efforts will not only increase legal awareness but also strengthen public participation in maintaining a balance between technological progress and environmental sustainability in the city of Palembang.

5. CONCLUSION

Based on the results of the discussion regarding public legal awareness in supporting the development of sustainable technology in Palembang City, public legal awareness in Palembang City in supporting the development of sustainable technology shows significant progress, although various obstacles remain in its implementation. Based on observations and various research sources, the people of Palembang are beginning to demonstrate a better understanding of the importance of regulations and policies that support sustainable development, such as environmental management, the use of renewable energy, and the application of environmentally friendly technology in daily activities.

Public legal awareness can be seen in increasing compliance with government policies, such as digital-based waste management (smart waste management), the Palembang Zero Waste program, and efforts to use electric-powered public transportation introduced by the Palembang City Government. Furthermore, several community groups,

particularly Students, university students, and environmental communities have actively participated in social activities such as plastic waste recycling, tree planting, and digital campaigns on sustainable lifestyles.

However, legal awareness remains relatively low among some communities, particularly among the lower-middle class, who do not fully understand the importance of complying with environmental and technological regulations. Contributing factors include a lack of legal awareness, low levels of environmental legal education, and weak law enforcement against environmental violations such as waste disposal, waste incineration, and excessive use of fossil fuels.

From a participation perspective, the involvement of the Palembang City community in the development of sustainable technology has begun to be evident through various community-based programs. Some concrete examples include:

1. The Digital Waste Bank Program, which encourages the public to exchange inorganic waste for something of economic value through an online application.
2. The Green Palembang Movement, which involves students and residents in tree planting in public areas and along riverbanks.
3. Government collaboration with universities, such as Sriwijaya University and the University of Palembang, in research and outreach on renewable energy technology and household waste management.

This public participation demonstrates that legal awareness is not only reflected in compliance with regulations, but also in concrete actions and concerns in supporting the implementation of sustainable public policies.

1. The level of legal awareness among the people of Palembang City regarding sustainable technology remains moderate. Some people understand the importance of using environmentally friendly technologies, such as digital waste management and renewable energy, but many have not implemented them consistently. This awareness is higher among highly educated groups and young people who are active on social media.
2. Legal education and outreach significantly influence increased legal awareness. The lack of environmental and technological legal education at the community level contributes to a low public understanding of their legal obligations to preserve the environment through the use of sustainable technology.
3. The role of the Palembang City government in encouraging public participation has begun to be evident through various programs, such as the implementation of smart cities, digital waste management, and green technology campaigns. However, the implementation of these policies has not been fully effective due to limited law enforcement and low community participation at the grassroots level.
4. From a legal perspective, sufficient regulations are available, such as Law Number 32 of 2009 concerning Environmental Protection and Management and the Palembang City Regional Regulation on Environmental Management. However, the enforcement and internalization of these legal values in the community's daily lives still need to be improved to truly realize legal awareness.

Efforts to Increase Legal Awareness and Public Participation to strengthen public legal awareness and increase participation in sustainable technology development, several strategic collaborative steps are needed between the government, community, academics, and the private sector, including:

1. Improving Environmental Law Education and Socialization

The Palembang City Government needs to expand environmental-based legal education programs in schools, universities, and community settings. Through legal

education, the public will better understand their rights and obligations, as well as the role of law in maintaining environmental and technological sustainability.

2. Optimizing the Role of Digital Media and Information Technology: Social media and digital platforms can be utilized to disseminate information, conduct legal awareness campaigns, and innovate sustainable technology. Digital-based education has proven to be more effective in reaching the wider community, especially the younger generation.

3. Multi-Party Collaboration (Pentahelix Collaboration). The collaborative approach between government, academics, business actors, communities, and the media (the pentahelix concept) needs to be strengthened to ensure the integrated implementation of sustainable technology. With this collaboration, the public becomes not only the recipient of policies but also an active participant in sustainable development.

4. Improving Law Enforcement and Environmental Oversight: The government needs to strengthen law enforcement instruments against environmental violations, while also providing incentives for communities and businesses committed to sustainable technology practices.

5. Developing a Circular Economy and Local Innovation: Encourage communities to develop circular economy-based innovations such as utilizing waste to create economically valuable products, using solar energy in households, and technology-based organic farming.

6. Building a Sustainable Legal Culture: A long-term effort that needs to be emphasized is building a legal culture oriented toward sustainable values. This can be achieved through exemplary behavior from officials, strengthening public ethics, and consistent development policies.

Increasing public legal awareness is not only the state's obligation through legal education and outreach, but also a shared responsibility to create a social environment that supports the implementation of fair, ethical, and environmentally friendly technology for future generations.

Thus, research on public legal awareness and participation in sustainable technology development is crucial. Through the implementation of these various efforts, it is hoped that the level of legal awareness in Palembang City will significantly increase, enabling the public to become not merely passive participants but also agents of change in realizing sustainable technology that is just, environmentally friendly, and aligned with national legal values.

This research aims not only to determine the level of public legal awareness but also to encourage synergy between law, society, and technology in creating just, ethical, and environmentally sound development. Strong legal awareness will serve as a moral and social foundation for the creation of a society that actively participates in supporting sustainable technological innovation in Indonesia, particularly in Palembang City.

6. RECOMMENDATIONS

Based on the conclusions above, the following recommendations can be made:

1. The Palembang City Government needs to increase the intensity of socialization of environmental law and sustainable technology through collaboration with universities, non-governmental organizations, and green technology communities to strengthen public legal awareness.

2. There is a need to strengthen regional regulations (Perda) that specifically regulate community participation in the implementation of environmentally friendly

technology and the use of clean energy. These regulations must also be accompanied by clear sanction mechanisms and incentives for businesses and residents.

3. Educational institutions and the mass media are expected to play an active role in providing ongoing education on environmental law and sustainable technology. Environmental law education should be included in local curricula, especially at the secondary school and university levels.

4. The government, together with the private sector, can encourage the creation of a green innovation hub in Palembang, a center for environmentally friendly technology innovation that involves the community, academics, and businesses to create sustainable solutions based on local technology.

5. Environmental and technological law enforcement must be strengthened by increasing the capacity of officials, ensuring policy transparency, and providing awards to communities or businesses that consistently implement sustainable development principles.

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THE ROLE OF ARTIFICIAL INTELLIGENCE, INTELLECTUAL PROPERTY RIGHTS AND TECHNOLOGY IN ECONOMIC DEVELOPMENT

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Abstract

This article is entitled the role of artificial intelligence, intellectual property rights, and technology in economic development. The problems discussed in this article are how the legal regulations regarding artificial intelligence, intellectual property rights and technology in national legislation and how the role of artificial intelligence, intellectual property rights, and technology in economic development. The research method used in this study is the normative legal research method. The purpose of this study is to determine the role of artificial intelligence, intellectual property rights, and technology in economic development while the benefits obtained from this study are expected to enable readers to know and understand the role of artificial intelligence, intellectual property rights, and technology in economic development. From this study it can be concluded that first, legal regulations regarding artificial intelligence do not yet exist in Indonesia while legal regulations regarding intellectual property rights and technology are already regulated in separate laws. Second, in general, both Artificial Intelligence, Intellectual Property Rights, and technology simultaneously play a key role in the growth and development of the country's economy.

Keywords *: Artificial Intellegence, Intellectual Property Rights, Technology, Economic Development.*

1. INTRODUCTION

Indonesia as a developing country is a member of the Association of Southeast Asian Nations (hereinafter referred to as the Association of Southeast Asian Nations) in this article abbreviated as ASEAN) namely A an organization that accommodates member countries in the Southeast Asia Region . Which is Indonesia as wrong wrong one member becomes countries in the development stage the economy Not yet so established . Even the experts mention that Indonesia is an ASEAN country with a growth rate of Its economy is very behind compared to other ASEAN members . 1997 , Indonesia actually reap Lots praise from various parties both domestic and international as high performing Asian economic countries that have high performance a very proud economy . However , the blow crisis monetary crisis that hit this country in mid - 1997 has wreck havoc economy national so that tired For Rise Again (Abdul Manan, 2016).

Crisis monetary events that occur type That Then develop become complex and massive crisis to cause pessimism among economists intertwined with time to gold economy national in the future . At first crisis monetary This is a contagion effect of from Thai baht currency against the US dollar. However , because foundation economy national Not yet so established so matter That also has an impact on Indonesia, where the economic recovery process is going on lasts a long time.

Development and advancement system law riches intellectual now is need real and important for Indonesia. Domestic conditions require Indonesia to proceed to direction That along with economic development as well as adaptation to impact globalization . With development law riches intellectuals in Indonesia, then must notice ability , power support , and tamping capacity , as well as interest national (Andi BasoIlmar , 2020).

Property rights intellectual That Alone is a reward given by the state for results work intellectual a valuable human being economical . The resulting on base strength Power thinking and abilities that include creativity , feeling, and will that each person has . However so , no everyone can produce a valuable masterpiece economical high (OK Saidin, 2013).

On progress agreed existence various types of property rights The previous intellectual not known as Property Rights Intellectual , however Because triggered by the existence of the General Agreement on Tariffs and Trade, abbreviated as GATT part from the formation of the world rrrade organization then also known as branches of Property Rights Intellectual ysang get protection namely :

1. Copyright;
2. Brand;
3. Indication Geographical ;
4. Patent;
5. Protection Plant Varieties ;
6. Trade Secrets ;
7. Industrial Design; and
8. Circuit Layout Design Integrated .

In the era of globalization and development economy as well as development technology that occurs mature This is the development of intellectual property rights Intellectual play a role strategic in the world of business and trade (Joni Sansri Ritonga et.al, 2024). One of the development quite recent confiscate public attention is emergence A phenomenon known in society with Intelligence The creation that is thought to be also included as branch new from right riches intellectual .

As for the method research used in this article is method normative research , namely something method research conducted with study various literature and libraries related laws with issue the law discussed (Marzuki, 2015).

The purpose of study This is For know role intelligence artificial , rights riches intellectual and technological in economic development whereas benefits obtained from study This is readers are expected can know as well as understand role intelligence artificial , rights riches intellectual and technological in Economic Development .

Based on exposure above , and looking at development phenomena that occur in society so problems that will discussed in this article is

1. How arrangement law about intelligence artificial , rights riches intellectual and technological in regulation legislation national

2. How role intelligence artificial , rights riches intellectual and technological in growth the country's economy .

2. RESULT AND DISCUSSION

2.1 Arrangement intelligence artificial in regulation legislation national

Intelligence artificial or known with artificial intelligence originating from a combination of two words , namely artificial, which means artificial and meaningful intelligence intelligence (Fatimah Nad et.al, 2023). Artificial Intelligence is A designed technology For make system purpose- built computer For make things easier work man .

With input and knowledge Artificial Intelligence humans possible Can accept knowledge via simulation of reasoning processes and power think humans to complete various existing problems in society . Although intelligence artificial This own limitations like not Can used For look for experience even do study as it should be man However intelligence artificial This Can used For get whatever you want .

Then you can concluded that intelligence artificial created such appearance to be able to do things as it should be man even Can functioning as tool servant for man even something very extreme that intelligence artificial This can replace man in routine life daily .

Indonesia recognizes two kinds subject law namely humans and legal entities . Both subject This own different characteristics . Categorization intelligence artificial as subject law Still reap debate among the community and practitioners law . Considering intelligence artificial is A system design man so existence intelligence artificial This classified as subject corporate law . This is caused by Because intelligence artificial not own naturalness as aspect main existence human . Remembering existence conflict between the community and practitioners law about matter This as well as remember existing needs and developments in society so Already as it should be intelligence artificial This arranged alone as subject law .

2.2 Arrangement law right riches intellectual in regulation legislation national

As we know that Indonesia know a set rule about right riches intellectual that is right copyright , patent, trademark , secret trade , industrial design , and layout design circuit integrated .

First right creation in a way new related rules with right creation is Law No. 28 of 2014 which replaces Law no. 19 of 2002 as for background behind main occurrence change Constitution right creation is Because such a development rapidly to right creation in society .

In Indonesia, the journey Copyright regulations have experience evolution length that reflects dynamics social , economic and legal national and international . Since colonial times with implementation Auteurswet 1912 as inheritance Dutch law , regulation regarding Copyright continue experience update until birth Constitution Number 28 of 2014 concerning Copyright. Law This present as response to various challenge new emerging consequence progress digital technology and as form harmonization to various convention international which has ratified by Indonesia, such as The Berne Convention and the TRIPs Agreement (*Trade-Related Aspects of Intellectual Property Rights*) (Ervan Susilowati, 2023).

Constitution Number 28 of 2014 adopted principles more Copyright protection progressive and contextual , with strengthen position law creator through confession

on moral rights and rights economy in a way more firm . Law this also introduces various update important , such as extension of protection period , regulation license , protection right related , and mechanism settlement disputes and systems registration right more creations systematically . In addition , this law give role important to institution collective management and state institutions in supervise and enforce right creation , and accommodate development digital technology as room new in existence and distribution work Copyright (Rizkia , 2022).

Copyright is right exclusive the creator who arises in a way automatic based on principle declarative after something creation realized in form real without reduce restrictions in accordance with Provision Legislation . The Copyright Holder is the Creator as Copyright owner , receiving party right the in a way legitimate from Creator , or other party receiving more carry on right from the receiving party right That in a way valid . Scope arrangement right creation covering right economic and moral rights .

Protected creations covering Creation in field knowledge knowledge , art , and literature, consisting of above : a. books , pamphlets , typography work write published , and all results work write others ; b. lectures , talks , speeches , and creations similar others ; c. tools the props made For interest education and science knowledge ; d. songs and/ or music with or without text ; e. drama, musical drama , dance, choreography , puppetry , and pantomime ; f. works art appearance in all form like painting , drawing , carving , calligraphy , art chisel , statue , or collage ; g. work art applied ; h. works architecture ; i . maps ; j. works batik art or other motif art ; k. works photography ; Portrait ; m. work cinematography ; n. translation , interpretation, adaptation , anthology , database, adaptation , arrangement , modification and other works of results transformation ; o. translation , adaptation , arrangement , transformation , or modification expression culture traditional ; p. compilation Creation or data, either in a format that can be read with Computer Program or other media ; q. compilation expression culture traditional during compilation the is original works ; r. video games ; and s. Computer Programs.

No Copyright on results work in the form of : a. results meeting open state institutions ; b. regulations legislation ; c. speech statehood or speech officials government ; d. decision court or judge's determination ; and e. Scripture or symbol religious protection law to right creation with existence Constitution new This has give framework clear and comprehensive laws Because Constitution This also regulates regarding Settlement Dispute namely If happen violation to right creation This can resolved via court Commerce and rights holders know experts his heirs will get compensation . However in its manifestation Still face complex challenges . In practice, one of the constraint main is low public understanding of importance protection right creation . Challenge other is weakness enforcement law to violation right creation although regulations right creation This has arrange sanctions criminal and civil However so implementation Still not optimal.

Handling process case often slow and convoluted consequence bureaucracy that is not efficient as well as limited coordination between authorized institutions . This is aggravated with limited source Power capable human and infrastructure handle violation right creation professionally , especially those related to with digital realm (Simatupang , 2011).

Development technology and its popularity Internet use has also become factor significant complicating protection right creation . Digital platforms such as YouTube,

Instagram, and social media sites others , become a new medium distribution work creation , but also at the same time become gap occurrence violation right creation . In one side , society now can with easy access and distribute content entertainment . On the other hand , the works creation often used without permission creator with reason convenience digital access . Although these platforms has provide mechanism reporting violations , responses and handling often No fast or effective , so that cause loss economic and moral for owner right creation .

Another challenge that is quite significant is protection to work creation traditional and cultural local . System law right creator - oriented creation individual Not yet fully capable accommodate works collective owned by public customs . As a result , many inheritance culture, such as music regions and dances traditional , used by other parties without compensation or confession to community origin . This shows existence need will development instrument more laws sensitive to right collective public customs in framework protection riches intellectual (Fadilah, 2024).

In facing the various problem mentioned , optimization protection right creation can done through a number of approach . First is improvement education and literacy law to public wide , especially to the perpetrators industry creative and internet users . Socialization about importance right creation and consequences law from violation must Keep going intensified by the government and institutions related . Second , the system registration creation through Directorate General Riches Intellectuals (DJKI) must strengthened and simplified .

In a way overall , protection right creation in Indonesia indeed has own foundation strong law , but challenges in the field Still big . With Thus , hope to creation ecosystem protection work fair , balanced and productive intellectual can realized in the future .

Second , Patent. Protection patent law in general national arranged in Law No. 13 of 2016 replaces Constitution previously . Changes to this patent law aim For align system national patent law with development technology and practical . Patents are right exclusive grant given by the state to top inventors results his inventions in the field technology For term time certain carry out Alone invention the or give agreement to other parties to carry it out . Invention is the inventor's idea that is poured out to in something activity solution specific problems in the field technology in the form of product or process, or refinement and development product or process. Inventor is a or some people who are together implement the ideas that are put forward to in activities that produce invention (Fadilah, 2024).

Patent rights are form protection the law given to inventor or holder patent rights for control use his invention during term time certain period , usually 20 years . Patents only given For inventions that meet three criteria main : novelty , steps inventive , and applications industry . Invention must nature new , meaning No There is knowledge or the same technology previously ; must contain step inventive , namely have level enough creativity For No considered as commonplace ; and must can implemented in industry or own mark practical that can used in production or industrial processes (Simanjuntak et.al, 2025). The scope of Patent protection includes ordinary patents and simple patents . A patent is classified as a regular patent if fulfil condition First is findings in the field technology , second contains an inventive step , and third can implemented in industrial activities .

Protection patent rights grant diverse benefit good at the level individual and industry . One of the benefit main from patent rights are give incentive for inventor

For Keep going innovate . With existence patent , inventor own control exclusive to use his invention , which allows they For monetize invention they Good through license , cooperation technology , or commercialization invention those . Benefits economy this is very important , okay for individual and for companies that want to develop product new based technology .

For industry , protection patents also function For increase Power competitive . With existence patents , companies Can prevent other parties use technology they without permission , which encourages company For invest in research and development . In addition , patents can also become source income through licensing and technology transfer , which allows company or individual For get royalty from use inventions by other parties . On a larger scale broad , patent rights become component important in economy based knowledge , which contributes to growth economy , creation field work , and improvement Power global competitiveness . Countries that have strong patent system tend more proceed in matter innovation and technology , so that patents do not only functioning For protect inventor , but also become instrument development economy .

Although the patent system in Indonesia is already experience development , implementation Still face diverse significant challenges . One of them challenge main is lack of awareness public to importance patent rights . Many actors businesses , researchers , and innovators who have not understand right How patent rights can protect results work them and give profit economy . In addition , the complex and lengthy patent registration process also becomes obstacles . Besides that , enforcement law to patent infringement national Still weak .

In order to handle obstacles the on government can take steps namely First simplification system patent registration ; second , granting incentive to local inventors; and third , increasing enforcement law to patent infringement . Third , the trademark. general protection brand arranged in Law No. 20 of 2016. Law This No only arrange problem protection brand solely but also regulate about protection indication geographical .

Brand (language English : *brand*) or brand is a mark applied by entrepreneurs (factories , producers , etc.) on the goods they produce as sign identifier . Brand is signs that can displayed in a way graphic in the form of image , logo, name, word, letter , number , arrangement color , in 2 -dimensional and/ or 3- dimensional forms , sound , holograms, or combination of 2 or more element the For differentiate goods and/ or services produced by individuals or legal entities in activity trading goods and/ or services . Brands are his heart sustainability A business , because through brand it something product Can known by the public wide . Even when public wide Already fanatic to something brand , society No Want to look at brand others . It means brand is tools that make something product produce multiple benefits . Reflecting from benefits gained from the importance of the "name" contained in a brand , of course No close possibility can happen dispute brand and/ or own designation similar brands .

Activity For introduce and popularize brand trade is something condition For success company market product said , because That do it through “ use brand " for product business For differentiate it with product other competitors . brand is one of the factor important for success market dominance .

There are two brands , namely brand trade and brands services . Trademarks is a brand used on goods traded by a person or some people in particular together or legal entity For differentiate with goods similar others . Service marks that is a brand used

for services traded by a person or some people in particular together or legal entity For differentiate services similar others . Special For brand collective Actually No can it is said as type the new brand because brand collective This its use used in a way collective , but understanding brand collective that is as brand used on goods and / or service with the same characteristics traded by several people or legal entities in a way together For differentiate with goods and/ or service similar others (Widiantoro , 2022).

Registration brand aim For get certainty law and protection law to right on trademark . Registration brand conducted at the Directorate General of Property Rights Intellectuals . Directorate General HKI is agency registration assigned brand For register the trademark applied for registration by the owner trademark . Registration brand in matter This is For gives the status that applicant considered as user First until there are other people who prove it on the contrary . The right to brand No There is without registration . Here's what's more bring certainty . Because if somebody can prove He has register something brand and he given something Trademark Certificate which is proof than right his on something brand , then other people don't can use it and others don't entitled For use same brand For similar items too (Semaun , 2016).

Legal Protection Provided to brand owner whose brand imitated by others, can submit lawsuit on Trademark infringement . Article 83 of the Republic of Indonesia Law Number 20 of 2016 states :

1. Registered Trademark Owner and/ or recipient Registered Trademark License can submit lawsuit to other parties who without right use the brand you have similarities in principle or the whole thing For goods and/ or similar services in the form of :

a. lawsuit change loss ; and/ or

b. termination all related actions with use

The brand .

2. Lawsuit as referred to in paragraph (1) may also be submitted by the owner of a well-known trademark based on decision court .

3. Lawsuit as referred to in paragraph (1) is submitted to Court Commerce .

To similarity brands that are still used at the time submitted lawsuit , Article 84 of the Republic of Indonesia Law Number 20 of 2016 provides protection the law which states " As long as Still in examination and for prevent greater losses large , brand owners and/ or recipient License as plaintiff can submit application to the judge to stop activity production , distribution , and/ or trading goods and/ or services that use the Trademark in a way without rights .”Article 87 of the Republic of Indonesia Law Number 20 of 2016, Regarding decision Court Commerce about brand only can submitted cassation .

Settlement dispute others that can done to dispute brand that is , the solution dispute through criminal offense . Article 103 of the Republic of Indonesia Law Number 20 of 2016 states " Criminal acts criminal as intended in Articles 100 to with Article 102 being offense complaint .” Crime complaint *(klacht delict)* means only with existence complaint from si owner counterfeit brand , then can prosecuted and charged criminal or held investigation . Without any complaint from the party who feels himself harmed from action forgery that , then No There is investigation from party Police (Runtung et.al, 2014).

Fourth , Trade Secrets , Trade Secrets is information that is not known to the public in the field technology and/ or business , have mark economy Because useful

in activity business , and maintained confidentiality by the owner of the Trade Secret . Scope Trade Secret Protection covering method production , method processing , method sales , or other information in the field technology and/ or businesses that have mark economy and not known to the public general .

Apart from being a state of law , Indonesia is a welfare state or *the welfare state* also wants to realize goals principal , with existence involvement and intervention of the state (government) in form regulations so that goals the can come true in various aspect life society . This is in accordance with provisions of Article 28C of the 1945 Constitution which states that everyone has the right For advance himself in fight for his rights in a way collective For build society , nation and country .

Every business or business will always own information of a nature secret and in as category confidential that is confidential trade . Business actors will realize importance confidential trade at the time its competitors or its competitors try For get information in the form of Who its customers , plans marketing , or another very important thing for his efforts . Indonesia knows term confidential trade with the term trade secret or undisclosed information , or information that is not known . Trade secrets is information that has mark economy alone Good current and potential Because generally No known to others, valuable for others who don't can get information in a way valid and protected as confidential through effort reasonable actions taken by the owner confidential trade . If something when one of or more from third the above criteria No Again fulfilled , then information the No Again including to in confidential trade . Various type information that provides superiority competitive can become confidential trade , including formula or recipe , design products , customer list , schedule price , technique manufacturing , and marketing strategies . (Katya Benalda et.al, 2024).

In the Trade Secrets Act , the owner confidential trade also has right Good For use Alone confidential the trade he owns and For give license and forbid other parties to use or disclose confidential trade the to party third For interests of a nature commercial as arranged in provisions of Article 4 of the Trade Secrets Law . Protection confidential trade ongoing during confidential trade the kept secret . After confidential trade known public in a way valid (not Because theft or abuse rights) then protection confidential trade end .

Protection of Property Rights Intellectual in framework Property Rights Law Intellectuals in Indonesia, after ratification of the WTO into Constitution Number 7 of 1994, as action carry on agreement implementation of TRPs then has promulgated Laws in the field of Property Rights Intellectual based on 7 (seven) fields in TRIPs distribution , namely :

1. Copyright, Law Number 28 of 2014;
2. Trademarks, Law Number 20 of 2016;
3. Patents, Law Number 13 of 2016;
4. Industrial Design, Law Number 31 of 2000;

Circuit Layout Design Integrated , Law Number 32 of 2000;

Trade Secrets , Law Number 30 of 2000;

7. Plant Varieties , Law Number 29 of 2000

Protection law design Industry In a way substantive , in The Industrial Design Law consists of of 57 articles the arrange a number of matter important related with definition about designer , requirements protection design industry , exceptions protection design industry , subject , scope rights , requests registration cancellation

and settlement Industrial Design disputes and system registration design industry , settlement disputes and and determination dispute (Mokoginta , 2017).

Arrangement registration This in a way details there is in Law no. 32 of 2000, which makes it mandatory applicant For deliver document design in form picture or diagram, description function design , as well as statement authenticity . After through administrative processes and not there is object from party third during the announcement period , then applicant will get certificate layout design that becomes proof right exclusive (Nazhif Ali, 2024).

Term time protection provided by law is for 10 (ten) years , starting from since date reception registration or since date first time design the used in a way commercial anywhere , with condition registration done in maximum period of two years after use commercial First .

2.3 Settings technology in regulation legislation national

Constitution Number 11 of 2008 concerning Information and Electronic Transactions (ITE Law) is Constitution the first one that is special arrange action criminal cyber in Indonesia. Based on letter President of the Republic of Indonesia. No. R . /70/Pres/9/2005 dated September 5 2005, the text of the ITE Law in full official delivered to the Indonesian House of Representatives then ratified on April 21 , 2008.

Although has the ITE Law was formed in Indonesia but in fact or the reality of the cyber world still difficult For tamed because cyberspace is a virtual world that is difficult found in a way real but can visited by millions users all over the world every when . Characteristics This is what influences the ITE Law have constraint in its implementation , because in reality action criminal cyber often nature across countries so that cause question about applicable jurisdiction on actions or consequence action criminal as well as on the perpetrator . This is Indonesia realized that limitations legislation conventional owned difficult For answer problem this , so that look at need For adapt the law For still guard sovereignty and integrity of the state (Setiawan, 2013).

2.4 Role Intelligence Artificial in Economic growth

In the digital era, Artificial Intelligence has become one of the technology trends ysang change landscape economy globally . Technology This utilize ability in - depth data analysis processing information in scale big and learning machines to create problem solving that can increase efficiency operational as well as push innovation in all sector .

Developments that have occurred now use of Artificial Intelligence not only to improve internal business processes but also as a determining factor in building superiority competitive (Hendri Afriadi et.al, 2024). The impact from the development of Artificial Intelligence mature This is birth A draft digital economy namely something businesses that utilize intelligence artificial and internet to help growth economy massively and comprehensively . Changes paradigm business from manual processes to digital processes give birth to so many online platforms are used as facilitator for activity economy , services production and distribution (Budi Harto et.al, 2023).

As for the development the digital economy has bring Lots benefit among them is First Improvement efficiency operational . Second , Improvement global access . Third , innovation products and services. Fourth , Creation field Work new . Fifth , improvement collaboration and networking .

However thus , with existence development economy digital -based that brings so Lots benefits , there are also challenges that must be faced in this digital among others First lack of infrastructure technology . Second , the existence of digital inequality as well as lack of digital skills . Third , changes pattern consumers and changing business models . Fourth global competition . Fifth trust consumers . Lastly , dependence on technology (Tanjung, 2024).

2.5 The Role of Property Rights Intellectuals in Economic Growth

Business world in growth and development not Possible off from what is called Property Rights Intellectuals . Business world need protection on the product as well as What only intertwined with the product for example brand and design from A products and so on . What is needed protection so that it doesn't exploited by others for profit personal and can harm rightful owner .

Progress economy a country can also looked at from many protection of intellectual property rights The intellectual he has . However sadly implementation protection of intellectual property rights Intellectual in a way national Lots meet obstacles triggered by differences culture of society that is communal with character from Property Rights regime Individual intellectuals (Sopia Siregar et.al, 2019).

Intertwined with the role of property rights Intellectual in growth economy at least there are two sectors affected namely First sector business micro , small and medium as well as second sector tourism .

First , effort micro , small and medium play a role central in structure economy national . This sector become a primary pillar for economy and as entity spread out businesses wide . Micro , small and medium enterprises covers various sector business start from the creative industry until sector agribusiness .

However thus although own a huge contribution for economy , sector This Still face various challenge like limitations access to financing , low access technology , and the lack of understanding related with protection of intellectual property rights Intellectual (Simanjuntak et.al, 2025).

Creative economy That Alone is series activity the economy that started from utilization creativity , skills and talents individuals to create welfare as well as field Work with produce and explore Power creativity and power creation individual (Sulasi Rongiyati, 2018). In addition economy creative in essence is form from the Effort to seek sustainable development via creativity with which the economy sustainable is A climate an empowered economy economic competitiveness creative also opens opportunity for the community to develop his business with utilizing non - renewable resource reserves even not limited namely ideas and talents (Rosmadi , 2014).

Protection of Property Rights Intellectual play a role important for business micro , small and medium as well as based business economy creative . In terms of economy creative sector it really depends with creativity so that protection to right riches intellectual is very relevant . However , in practice protection to right riches intellectual This Lots face obstacle among them is lack of understanding of the business community in sector this is what concerns with right riches intellectual . Besides that , the administrative process is complicated become constraint the biggest for progress sector This .

So for overcome constraint the government take policy in the form of Simplify the management and registration process right riches intellectual as well as do

socialization and education related the importance protection hsak riches intellectual for business micro , small and medium .

Second , the role right riches intellectual for related economic development with sector tourism . tourism industry is sector economy that produces products and services that involve various activity economy that provides contribution to this industry Good directly and not directly (Sanjiwani , 2016).

For support businesses This sadly some big society realize how importance registration right riches intellectual For the products they make . On the other hand outside in a way careful understand problem this and try claim right use product local creative (Seharja et.al, 2023). Level of awareness local entrepreneurs in secure right riches intellectual they depending on the market share they have destination without confusing the values contained inside it .

One of uniqueness work Indonesian Community Creation is batik, right riches intellectual on batik works made by local craftsmen and have mark sell height is also important things For get protection (Anggraeni et.al, 2021).

In today's digital era This technology become an important factor in development economics and business development rapid technology has change method work and patterns think business , as well as give opportunities and challenges new for the perpetrators business .

At least there are two things main in discussion about role technology for development economy namely first , transformation economy , technology has give contribution big in transformation global economy . One of the an undeniable reality Can avoided is technology has adopting a new business model that has change method man access goods and services . Technology has also help in improvement productivity work . Besides that , technology has also give convenience in matter acquisition information and learning process teach .

Second , transformation business , role technology in the process of transformation very big business . Digital platforms have allows activity business For reach out greater market share wide and connecting customer with product the goods and services they provide need . This also allows the Company to develop a more effective marketing strategy effective and enables the Company to access global customers with the way that is not unimaginable previously . Besides that , technology has allows business For collect data and analyze it with more effective (Andriansyah , 2023).

However sadly behind convenience offered by technology for the business world , tucked away a number of obstacles and constraints namely First , the need skills new . Second problem data security . Third more competition tight . Fourth strict regulations . And Fifth challenge ethics and morals.

3. CONCLUSION

Problem intelligence the current booming creation This Not yet there is arrangement the law in something Constitution whereas concerning problem right riches intellectual and technological aspects of each field the Already there is the settings in something Constitution alone . Artificial intelligence which is currently This currently develop it really plays a role important and provide contribution positive for development economy . Because with the existence of Artificial Intelligence This can encourage the actors involved in this world business For build superiority competitive for companies and business industries they .

Property rights intellectual hold role key for growth and development the country's economy , especially in the sector business micro , small and medium enterprises (MSMEs) and sector tourism . This is caused by in operate activity business second sector This touch with riches culture and creativity humans . In the current digital era This utilization technology hold role central in development economy . This is due to with utilization technology so activity business Already can reach global class market share .

Finally can concluded that in a way general both Artificial Intelligence , Intellectual Property Rights Intellectual , as well as technology in a way simultaneously hold role key for growth and development the country's economy .

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TECHNOLOGICAL DEVELOPMENS IN ELECTRONIC EVIDENCE IN CORRUPTION CASES

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Abstract

The development of information technology has had a significant impact on the evidentiary system in criminal law enforcement, particularly in corruption cases that are becoming increasingly complex and sophisticated. The use of electronic evidence has emerged as a crucial innovation in uncovering corruption offenses, which are often carried out through digital transactions, online communications, and electronic financial systems. This study aims to analyze the technological developments in the use of electronic evidence and its effectiveness in the evidentiary process of corruption cases. The research employs a normative juridical approach by examining statutory regulations such as Law No. 30 of 2002 concerning the Corruption Eradication Commission and Law No. 31 of 1999 in conjunction with Law No. 20 of 2001 concerning the Eradication of Corruption Crimes. The findings indicate that technological advancement has expanded the types and forms of evidence, including digital recordings, emails, electronic banking transaction data, and metadata, which are now legally recognized as valid evidence. However, the main challenges lie in ensuring the authenticity, validity, and integrity of electronic data, which require digital forensic expertise and more adaptive legal frameworks. Therefore, synergy among technological advancement, law enforcement capabilities, and regulatory reform is essential to optimize the use of electronic evidence in combating corruption in the digital era.

Keywords: *information technology, electronic evidence, corruption crime, proof, criminal* law.

1. INTRODUCTION

Criminal procedural law is a set of rules and procedures that governs the implementation of criminal law, specifically the manner in which formal criminal law is administered. According to Moeljatno, criminal procedural law constitutes a part of the overall legal system in a country that provides the fundamental principles and regulations determining the methods and procedures through which criminal sanctions for a criminal

act may be imposed when there is suspicion that an individual has committed such an offense (Moeljatno, 1995).

The purpose of criminal procedural law is to serve as a framework for upholding the truth. Law enforcement officials ranging from the police and prosecutors to judges must rely on established procedures throughout the investigative process, inquiry, prosecution, and adjudication of a defendant. These processes must be grounded in factual truth proven during the proceedings. Criminal procedural law, through the Indonesian Criminal Procedure Code (KUHAP), regulates the types of admissible evidence and the requirements for their validity, which are subsequently used by prosecutors to substantiate their charges in court.

Evidence refers to anything connected to an act that, through such evidentiary items, may be used to build proof that persuades the judge of the truth of a criminal offense allegedly committed by the defendant (Hari Sasongko & Lili Rosita, 2003). Under criminal procedural law, Article 184 paragraph (1) of KUHAP establishes five types of lawful evidence: witness testimony, expert testimony, documents, indications (petunjuk), and the defendant's statement. Criminal procedural law, as set out in KUHAP, regulates the types and validity requirements of admissible evidence, which are then employed by the public prosecutor to prove the charges during trial.

In addition to KUHAP, the provisions regarding evidence have expanded to include electronic evidence, which may be used in criminal proceedings based on special legislation. As society has evolved due to globalization, modernization, and advancements in information technology reflecting broader social changes—the enactment of Law No. 11 of 2008 on Electronic Information and Transactions (ITE), later strengthened by Law No. 19 of 2016, established that electronic information, electronic documents, and/or their printouts are recognized as an extension of lawful evidence in criminal procedure. The ITE Law is the first legislation in the field of Information Technology and Electronic Transactions, forming the foundational regulatory framework for the use of information technology and electronic transactions.

Electronic evidence is deemed admissible only in criminal acts regulated under the ITE Law and in specific offenses that explicitly recognize electronic evidence as lawful proof. As stipulated in Article 5 paragraph (1) of the ITE Law, electronic evidence consists of electronic information, electronic documents, and/or their printouts, which are valid legal evidence and constitute an extension of the types of lawful evidence recognized under KUHAP. Electronic evidence is therefore admissible only in offenses prescribed under the ITE Law and other particular offenses that expressly regulate the use of electronic evidence.

Corruption is a criminal offense whose regulation is governed through specific legislation. In a legal context, corruption refers to conduct in which an individual gains personal benefit at the expense of others, particularly when such acts are committed by public officials in violation of the law. However, from a broader perspective, corruption may also occur outside of governmental institutions, such as in the business sector, when laws are violated or unethical practices are carried out (Amalia Syauket & Dwi Seno Wijanarko, 2024). With regard to electronic evidence, the Law on the Eradication of Corruption Crimes provides specific provisions concerning the use of electronic evidence in corruption cases.

Advancements in technology and information systems have enabled perpetrators of corruption to transform their methods by exploiting information technology. Corruption offenses are increasingly conducted through online means, digital

transactions, electronic communications, and electronic financial systems, positioning them within the broader category of cybercrime.

Various forms of corruption that have emerged in the digital era include:

1. Manipulation of Electronic Data
   Corruption involving manipulation of electronic data often occurs within governmental or financial systems. Examples include altering budget data or illegally modifying tax payment systems.
2. Digital Procurement Fraud
   Technology-based procurement systems are frequently targeted through collusion or bribery during online tender processes.
3. Misappropriation of Electronic Funds
   The use of electronic payment platforms or digital wallets enables perpetrators to obscure the trail of misappropriated funds.
4. Sale of Confidential Data
   Confidential governmental or corporate data can be traded on the digital black market (dark web), constituting a modern form of corruption.

Law No. 31 of 1999 on the Eradication of Corruption Crimes, as amended by Law No. 20 of 2001, outlines the types of lawful evidence admissible in corruption cases, including those derived from outside the provisions of Article 188 paragraph (2). Electronic evidence has become an essential innovation in efforts to uncover corruption offenses, which are often committed through digital transactions, online communications, and electronic financial systems.

Electronic evidence holds significant importance in criminal procedure. Its relevance lies in its ability to enhance the accuracy and reliability of proof, such as electronic data, audio recordings, or video recordings, thereby offering credible and trustworthy evidence in court proceedings.

Based on the background described above, the following research problems can be identified, How has technological development influenced the use of electronic evidence in corruption crimes, and what extent is the use of electronic evidence effective as a means of proof in criminal law.

The purpose of this research is to examine the development of technology in the use of electronic evidence and to assess the effectiveness of electronic evidence as a means of proof in criminal law. The practical benefit of this study is that its findings are expected to contribute valuable insights regarding the issues surrounding technological advancements in the use of electronic evidence in corruption crimes.

2. RESULTS AND DISCUSSION

2.1 Technological Developments in the Use of Electronic Evidence in Corruption Crimes

Etymologically, the term *corruption* originates from the Latin word *corruption*, meaning decay or deterioration, and is also used to describe wrongful conditions or immoral acts (Elwi Danil, 2012). The words *corruptus* and *corruptio* literally signify rottenness, immorality, depravity, dishonesty, bribability, and deviation from integrity. Corruption is classified as an extraordinary crime (*extraordinary crime*) because it gravely undermines the foundations of societal and governmental systems and results in substantial losses to the state's economy.

Baharuddin Lopa asserts that corruption constitutes a criminal act involving bribery, manipulation, and other unlawful acts that harm state finances and the national economy, as well as the welfare and public interest.

According to Article 2 paragraph (1) of Law No. 31 of 1999 on the Eradication of Corruption Crimes, corruption is defined as an unlawful act that results in losses to state finances or the national economy. Furthermore, Article 26A of Law No. 20 of 2001 (amending Law No. 31 of 1999) explicitly recognizes electronic information and electronic documents as admissible evidence. The legal framework governing electronic evidence in Indonesia is grounded in several statutory instruments, including:

1. The Electronic Information and Transactions Law (Law No. 11 of 2008), which establishes the legal foundation for electronic evidence and acknowledges it as an extension of lawful evidence.
2. Constitutional Court Decision No. 20/PUU/XIV/2016, which affirms that recordings and other forms of electronic evidence possess evidentiary value in criminal proceedings, subject to the evidentiary standards of *bewijsvoering* (criminal evidentiary analysis).
3. Minister of Communication and Informatics Regulation No. 20 of 2016, which regulates procedures for processing and utilizing electronic evidence in cases pertaining to communication and informatics (Daniel David et.al., 2024).

Article 44 of the Electronic Information and Transactions Law (ITE Law) stipulates that evidence admissible in investigation, prosecution, and trial includes: evidence recognized under the applicable laws; and other evidence in the form of electronic information and/or electronic documents as defined in Article 1 points 1 and 4, and Article 5 paragraphs (1), (2), and (3).

Thus, in addition to evidence recognized under KUHAP, electronic information and/or electronic documents—including electronic mail—are admissible as lawful evidence. Law No. 20 of 2001 explicitly affirms that electronic evidence constitutes an expansion of the evidentiary category of *petunjuk* (indications).

Article 26A of Law No. 20 of 2001 provides that lawful evidence in the form of *petunjuk*, as referred to in Article 188 paragraph (2) of KUHAP, may also be obtained from:

a. Other evidence consisting of information spoken, sent, received, or stored electronically by optical instruments or similar technologies; and
b. Documents, including any recording or information that can be viewed, read, or heard, produced with or without a device, whether on paper, other physical media, or electronically recorded in the form of text, sound, images, maps, designs, photographs, symbols, numbers, or perforations that convey meaning.

The explanation of Article 26A clarifies that "stored electronically" includes data stored in microfilm, Compact Disk Read Only Memory (CD-ROM), or Write Once Read Many (WORM). The phrase "optical instruments or similar technologies" encompasses, but is not limited to, electronic data interchange (EDI), electronic mail, telegrams, telex, and facsimiles.

Further elaboration under Law No. 19 of 2016 (amending Law No. 11 of 2008) defines various forms of electronic information and electronic documents, including digitally stored, transmitted, or processed data, as well as the technological means used for such processes.

Based on Article 26A, electronic evidence forms an integral part of *petunjuk*. Electronic information and/or documents are recognized as lawful evidence in criminal procedure. Electronic evidence may therefore function as a substitute for

documentary evidence, operate as an independent evidentiary category, and serve as an extension of *petunjuk*.

The Corruption Eradication Commission (KPK), as a state institution within the executive branch, has the mandate to prevent and eradicate corruption (Hasnawati, 2023). Pursuant to Article 12 paragraph (1) of Law No. 30 of 2002, KPK is authorized to conduct wiretapping and record communications involving individuals suspected of committing corruption.

Constitutional Court Decision No. 20/PUU-XIV/2016 categorizes wiretapping and recordings as electronic evidence obtained for the purposes of law enforcement upon the request of the police, prosecutors, or other legally authorized institutions under Article 31 paragraph (3) of the ITE Law.

KPK's authority to conduct wiretapping is grounded in Article 26A of Law No. 20 of 2001 and Article 12A of Law No. 30 of 2002. Wiretap results may be used as *petunjuk* in corruption cases. Although wiretap recordings alone do not constitute sufficient standalone evidence under criminal law, the information derived from them may serve as *petunjuk* in accordance with KUHAP. Thus, KPK remains bound by procedural requirements in carrying out investigations, inquiries, and prosecutions.

Wiretapping and related forms of electronic evidence have proven highly effective in uncovering corruption offenses and frequently lead to *Operasi Tangkap Tangan* (OTT), or arrest operations conducted in flagrante delicto. OTTs constitute one of KPK's most well-known enforcement methods and involve apprehending individuals caught in the act of committing corruption (Syaputra &Yudhistira, 2023).

In relation to OTTs, Article 12 of Law No. 30 of 2002 grants KPK the authority to conduct wiretapping and record all forms of electronic communications as part of its investigative powers. Wiretapping conducted by KPK is based on Article 12 paragraph (1), which reflects Article 6(c), granting KPK the authority to carry out investigations, inquiries, and prosecutions of corruption offenses, including the authority to record communications of targeted individuals.

Interception is regulated under the Law on the Corruption Eradication Commission (KPK Law), which defines interception as the activity of listening to, recording, diverting, altering, obstructing, and/or documenting electronic information and/or electronic documents that are not publicly accessible, whether transmitted through wired or wireless communication networks such as electromagnetic emissions or radio frequencies.

There are six forms of interception, described as follows (Steve Jelly Walintukan et.al, 2022):

1. Wired Telephone Interception

   This practice is carried out by installing devices on cable-based telephone networks and involves technologies that support the interception of information transmitted through fixed or wired telephone networks (Public Switched Telephone Network/PSTN).
2. Cellular Telephone Monitoring

   This form of interception targets information transmitted through mobile or cellular communication networks.
3. Internet Monitoring

   This form of communication interception involves capturing data in cyberspace during its transmission to its final destination (for example, data sent

to a specific email address). This practice is omnipresent, as it can occur and be conducted anywhere within the digital environment.

4. Video Technology Monitoring

   The most common form of video interception today is Closed-Circuit Television (CCTV), which is installed in specific locations to record any activity within its range. CCTV technology is capable of analyzing minute details of recorded subjects, such as biometric features of the face and even the cornea of the eye.

5. Global Positioning System (GPS) Location Monitoring

   Location tracking involves the use of specialized software to visually record and report information captured within the network regarding the movement or position of a subject.

6. Communication Intrusion

   This practice involves embedding software, such as certain types of malware, into a communication device to extract all information stored within it.

According to Article 5 paragraph (1) of Law No. 11 of 2008 on Electronic Information and Transactions (ITE Law), there are two categories that may be distinguished: first, electronic information and/or electronic documents, and second, printouts of electronic information and/or electronic documents. Electronic information and electronic documents constitute Electronic Evidence (Digital Evidence), whereas printouts of such information and documents constitute documentary evidence.

Article 5 paragraph (2) of Law No. 11 of 2008 on Electronic Information and Transactions stipulates that electronic information and/or electronic documents and/or their printouts constitute an extension of legally valid evidence in accordance with procedural law applicable in Indonesia. Consequently, emails, recorded chat files, and various other electronic documents may be used as admissible evidence.

Law No. 30 of 2002 explicitly grants the Corruption Eradication Commission (KPK) the authority to conduct interception and record communications for the purpose of conducting inquiry and investigation into corruption crimes. The KPK is authorized to use the results of interception as legally valid evidence in the investigation and prosecution of corruption cases in Indonesia. Technological advancements have broadened the types and forms of evidence. The KPK has collected and analyzed digital data such as digital recordings, emails, electronic banking transaction data, metadata, and electronic documents to prove corruption cases.

The KPK has used various forms of electronic evidence in the investigation and prosecution of corruption cases. The KPK has utilized audio and video recordings as evidence, such as recorded conversations between suspects and other parties. Electronic evidence in the form of CCTV recordings represents one of the most recent and significant types of evidence contributing to the clarity and efficiency of proving criminal acts, providing substantial assistance in illustrating a suspect's actions, thereby reducing unnecessary complexity during court proceedings (Rirynsusanti et.al, 2025). One of the functions of CCTV is to serve as a primary indicator when an incident occurs in the absence of eyewitnesses.

Therefore, CCTV is frequently presented as electronic evidence in criminal trials. CCTV, or closed-circuit television, consists of cameras connected to monitoring screens and is commonly used as a security device to monitor a specific location .

CCTV recordings can be submitted as electronic evidence because videos or images recorded by CCTV fall under the category of electronic information and/or electronic documents. Following the issuance of Constitutional Court Decision No. 20/PUU-XIV/2016 (hereinafter referred to as the 2016 Constitutional Court Decision), the role of CCTV evidence was subsequently limited to valid electronic circumstantial evidence.

The Corruption Eradication Commission employs Digital Forensics to analyze digital evidence and prove corruption cases. Digital forensics involves the forensic examination of investigative data found on digital devices such as computers and mobile phones. From a legal perspective, digital forensics plays a pivotal role in producing valid digital evidence that is admissible in court. Digital forensics is highly instrumental in verifying the authenticity of evidence in criminal cases (including corruption cases). For example, if the KPK obtains evidence in the form of intercepted communications, an expert in Audio Forensics will verify the authenticity of the recording. Similarly, WhatsApp conversations will be examined by a Mobile Forensics expert.

Digital forensics is a branch of forensic science focusing on the collection, analysis, and preservation of digital data for investigative purposes. One of its essential functions is to provide evidence that is legally admissible in court. Elements of digital forensic investigations include identifying, collecting, and analyzing data from various digital sources or devices, both through physical and non-physical communication channels, as well as from data storage media deemed relevant for presentation in court as supporting evidence in criminal proceedings (Amsori, 2024).

In corruption cases in the digital era, evidence often appears in electronic form, such as video recordings and digital communications. Computer metadata, data about data describes and provides additional key facts about documents, videos, photographs, or emails that are not visible to the naked eye. Metadata, which records information such as the date, time, and location of file creation, can be critical for reconstructing events. By analyzing metadata, the KPK can uncover the digital footprint of perpetrators, including information concealed from ordinary observation.

Commonly used forms of computer metadata include:

1. Files
   Creation date, deletion date, author, and editing history.
2. Software Applications
   Installation and uninstallation dates, frequency of use, and timestamps of use.
3. Browsing Metadata
   Web search history, webpage titles and URLs, browser used, and visit timestamps.

Digital evidence encompasses various types of information stored on digital devices. Forensic experts are capable of recovering computer metadata evidence, including data that has been deleted or concealed, regardless of the condition of the computer or mobile phone. For example, forensic investigators search for indications of tampering, such as attempts to alter or destroy evidence. The Corruption Eradication Commission (KPK) employs digital forensics, including metadata analysis, to examine digital evidence in corruption cases. Digital forensics is essential for verifying the authenticity and validity of electronic evidence, such as video

recordings or other electronic data by examining metadata and hash values to ensure that no manipulation has occurred.

The entire digital forensic process as outlined in ISO 27037 comprises four stages: identification of evidence at the crime scene, collection of data from discovered electronic devices, acquisition of electronic devices, and preservation of the evidence. The electronic evidence is subsequently strengthened through expert testimony from technical and professional specialists.

The Corruption Eradication Commission (KPK) has analyzed financial transaction data to trace the flow of funds and substantiate corruption cases. KPK uses financial transaction analysis to trace suspicious financial flows, often in cooperation with the Indonesian Financial Transaction Reports and Analysis Center (PPATK). PPATK is an institution specifically tasked with analyzing suspicious financial transaction reports to prevent and combat money laundering. KPK utilizes PPATK's data and analyses to support corruption investigations. The objective is to trace fund flows, identify the sources and destinations of illicit money, and gather strong evidence for corruption cases. This analysis serves as a key tool in uncovering corruption and money laundering crimes.

The Corruption Eradication Commission (KPK) has also employed Artificial Intelligence (AI) to uncover corruption-related crimes. Advances in technology have enabled perpetrators to use cyberspace platforms, data systems, and algorithms to commit corrupt acts. KPK has transformed its approach to meet these new challenges by adopting AI as a strategic instrument in the prevention and enforcement of corruption. AI is set to become a primary catalyst for the KPK's three core mandates: prevention, enforcement, and education. From detecting corruption patterns to enhancing public transparency, AI strengthens Indonesia's anti-corruption framework.

According to official information from the KPK, the Deputy for Information and Data, Eko Marjono, stated that AI will be applied for corruption risk detection, analysis of suspicious transactions, and data-driven enforcement support. Various AI tools, such as Microsoft Copilot, Gamma, and Sectors.app are used to improve work efficiency and enhance data analysis capabilities within the KPK. Artificial Intelligence is a computer-based system capable of performing tasks that normally require human intelligence. AI makes decisions by analyzing and utilizing data within the system, involving processes such as learning, reasoning, and self-correction (Lubis, 2021).

Electronic evidence can provide critical and in-depth information to reveal the truth and ensure justice in judicial processes. Electronic evidence can serve as accurate and trustworthy evidence in court, often possessing high integrity and being difficult to manipulate or alter. Additionally, electronic evidence broadens the scope of available evidence, such as electronic data, audio or video recordings and enhances the use of evidence in criminal cases. For example, electronic evidence may include records of electronic communications, CCTV recordings, financial transaction data, or relevant digital traces.

2.2 The Effectiveness of Electronic Evidence in Proving Corruption Crimes

Electronic evidence has emerged as a legal response to developments in both technology and information systems. The law has adapted its regulatory framework to accommodate the use of electronic evidence within judicial proceedings. Legal provisions governing electronic evidence aim to enhance the fairness and efficiency

of the justice system. One of the primary challenges in utilizing electronic evidence is ensuring its authenticity, validity, and integrity. Therefore, regulations concerning electronic evidence are intended to establish the standards and procedures required for such evidence to be admissible and properly considered by the court. These include requirements relating to authenticity, integrity, and lawful methods of collection and presentation.

Procedural law, as formal law, has not yet fully accommodated electronic documents as evidence. Although electronic evidence is not explicitly regulated in the Indonesian Criminal Procedure Code (KUHAP), several newer statutes explicitly recognize and legitimize the use of electronic evidence, such as Law No. 30 of 2002 on the Corruption Eradication Commission and Law No. 11 of 2008 on Electronic Information and Transactions, which may serve as the legal basis for declaring electronic evidence admissible in court.

When dealing with criminal acts regulated under these special statutes, electronic evidence may be used as legally valid evidence during trial. Even though KUHAP does not expressly provide for electronic evidence, the principle of *lex specialis derogat legi generali* applies, meaning that special laws override general laws such as KUHAP. Consequently, the provisions in such special statutes may lawfully serve as the basis for recognizing electronic evidence as admissible.

Furthermore, ensuring integrity in the use of electronic evidence requires expertise capable of verifying the authenticity of electronic data. Thus, the expansion of evidentiary types, namely through the use of electronic evidence has become a necessary solution in strengthening law enforcement. In this context, digital forensics as a scientific method plays a crucial role in the evidentiary process of criminal cases involving electronic evidence.

The Constitutional Court of Indonesia, through Decision No. 20/PUU-XVI/2016, established legal standards for the use of electronic evidence. The Court held that electronic evidence (information and/or electronic documents), including the results of interception, may be regarded as valid evidence, provided that it is lawfully obtained and conducted for the purpose of law enforcement upon the request of the police, the prosecutor's office, and/or other legally mandated law enforcement agencies. If electronic evidence is obtained unlawfully, judges must disregard it and treat it as having no evidentiary value in court.

status of electronic evidence is of significant importance in judicial proceedings, as electronic information and/or electronic documents and/or their printouts constitute legally valid evidence extending the types of evidence recognized under Indonesian procedural law. This validity, however, is conditioned upon the use of an electronic system compliant with Law No. 19 of 2016 amending Law No. 11 of 2008 on Electronic Information and Transactions (Asimah, 2020).

Under Indonesian procedural rules, electronic evidence must be subject to testing to determine its admissibility, similar to other forms of evidence. This testing includes formal and material requirements, which vary depending on whether the electronic evidence is submitted in its original form or as a printout.

The material requirements for electronic evidence are provided in Article 5 paragraph (3) of the ITE Law, which states that electronic information and documents are legally valid if processed through an electronic system in accordance with the provisions of the ITE Law. The formal requirements are stipulated in Article 5 paragraph (4) and Article 43 of the ITE Law, as follows:

1. Electronic information or documents do not apply to:
    a. Letters which, under statutory requirements, must be produced in written form.
    b. Letters and their documents which under statutory requirements must be produced as notarial deeds or deeds issued by an authorized official.
2. Searches or seizures of an electronic system must be conducted with the authorization of the head of the local district court.
3. Searches or seizures of an electronic system must be carried out while safeguarding the continuity of public services.

    Article 6 of the ITE Law provides that electronic documents shall be deemed valid insofar as the information contained therein can be accessed, displayed, guaranteed in its integrity, and accounted for in explaining a particular legal state of affairs.

    Referring to Article 5 paragraphs (3) and (4) in conjunction with Article 6 of Law No. 11 of 2008, including their explanatory provisions, electronic evidence is considered legally valid for proving criminal acts so long as the information contained therein can be accessed, displayed, its integrity is ensured (i.e., free from any alteration), and it can be legally accounted for.

3. CONCLUSION

Article 26A of Law No. 20 of 2001 on the Eradication of Corruption Crimes designates electronic evidence as an extension of legally admissible evidence for proving corruption offenses. Pursuant to the mandate of the Corruption Eradication Commission Law, specifically Article 12 paragraph (1) of Law No. 30 of 2002, the KPK is granted the authority to conduct interception and record communications occurring between perpetrators of corruption and other individuals involved in corrupt acts.

The Corruption Eradication Commission (KPK) has utilized electronic evidence in the investigation and prosecution of corruption cases, including the collection and analysis of various forms of digital data such as digital recordings, emails, electronic banking transaction data, and metadata. KPK employs digital forensics to analyze digital evidence and substantiate corruption cases. Additionally, the KPK conducts financial transaction analysis to trace the flow of funds and prove corruption offenses. The KPK has also adopted artificial intelligence (AI) to support its investigative and analytical processes.

Electronic evidence may be used as legally valid evidence in court. Electronic evidence constitutes a legitimate evidentiary instrument that significantly facilitates the adjudication of criminal cases. Such evidence can be used as material for proof, thereby enabling judges to form a conviction regarding the truth of the criminal act (in this context, corruption) committed by the defendant. However, this validity is conditional upon the requirement that the electronic evidence, whether in the form of electronic information and/or electronic documents is processed through an electronic system that complies with the applicable statutory provisions, so that the evidence may be declared admissible in court.

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LEGAL ASPECTS OF CONSUMER PROTECTION IN THE USE OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN INDONESIAARTIFICIAL INTELLIGENCE/AI

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ABSTRACT

The development of artificial intelligence (AI) technology has brought significant changes to transaction patterns between businesses and consumers in Indonesia. The use of AI in various sectors, such as e-commerce, digital banking, and data-driven services, offers convenience and efficiency, but also raises the potential for violations of consumer rights.

Issues such as the misuse of personal data, automated decisions that harm consumers, and a lack of algorithmic transparency present new challenges for the consumer protection legal system. This article aims to analyze how aspects of consumer protection law in Indonesia respond to the use of AI technology and review the effectiveness of existing regulations, including Law Number 8 of 1999 concerning Consumer Protection and Law Number 27 of 2022 concerning Personal Data Protection.

Using a normative juridical approach, this research highlights the need for regulatory reform to anticipate the legal risks arising from the use of AI, while ensuring a balance between technological innovation and the protection of consumer rights.

Keywords: *Consumer Protection, Artificial Intelligence (AI)*

1. INTRODUCTION

The development of Artificial Intelligence (AI) technology has become one of the main drivers of digital transformation across various sectors of life, including trade, financial services, healthcare, transportation, education, and government. In Indonesia, the utilization of AI has increased rapidly along with the growing penetration of the internet, the expansion of the digital economy, and the increasing demand from businesses and government institutions for faster, more efficient, and more accurate services. AI technology is now widely applied in the form of recommendation systems on e-commerce platforms, customer service chatbots, digital health applications,

biometric verification systems, as well as large-scale data analytics in the banking and cybersecurity sectors.

Despite offering numerous benefits, the use of AI also gives rise to new challenges, particularly in terms of consumer protection. AI technology operates by processing vast amounts of data and relying on complex algorithms, which often makes it difficult for consumers to fully understand how decisions are generated by such systems. This condition creates potential risks, including personal data breaches, algorithmic bias, digital discrimination, prediction errors, and financial losses resulting from automated actions beyond the user's control. These issues indicate that while AI brings innovation, it also introduces uncertainty and the potential violation of consumer rights.

Technologies such as AI are developing rapidly and influencing various sectors, including the legal sector; however, legal regulations have not always been able to keep pace with such technological dynamics. In the context of advances in artificial intelligence technology, laws are often left behind due to the extraordinary speed of innovation. This trend is highlighted by progressive legal theory, which views such developments as challenges that must be addressed by contemporary legal systems.

Based on the foregoing, law should not be regarded as a rigid and formalistic system, but rather as a dynamic instrument to achieve welfare, peace, and justice in society. According to this perspective, legislation must be flexible and capable of adapting to changing times, technological developments, and the evolving needs of society. Law must continue to grow in line with social and technological changes. In this regard, the development of Artificial Intelligence (AI) technology in Indonesia has indeed increased significantly in recent years, with applications across sectors such as finance, healthcare, education, agriculture, and transportation. To address the challenges associated with technological and cybernetic evolution, a progressive approach proposes solutions by emphasizing that the law must be more flexible, humane, and adaptive, while remaining focused on achieving substantive justice for society.

Within the Indonesian legal framework, consumer protection is essentially regulated through several laws, including Law Number 8 of 1999 on Consumer Protection, Law Number 19 of 2016 concerning Amendments to Law Number 11 of 2008 on Electronic Information and Transactions (ITE Law), and Law Number 27 of 2022 on Personal Data Protection (PDP Law). However, these regulations remain general in nature and have not specifically addressed the unique characteristics of AI, which is autonomous, adaptive, and often difficult to attribute responsibility to. Consequently, there is an urgent need to strengthen the legal basis and regulatory framework to ensure that the use of AI remains safe, transparent, ethical, and does not harm consumers.

Discussion of the legal aspects of consumer protection in the use of Artificial Intelligence technology has therefore become increasingly important in order to ensure legal certainty, reduce the potential violation of consumer rights, and encourage the creation of a responsible innovation ecosystem. Furthermore, the strengthening of regulations and policies is necessary to maintain a balance between technological advancement and public protection, so that the development of AI in Indonesia can provide optimal benefits without compromising consumer safety and fundamental rights. Accordingly, this study aims to provide an overview of the legal challenges faced as well as the direction of future regulatory arrangements.

Legal protection concerning Artificial Intelligence (AI) in Indonesia is further examined through a deeper exploration of the concept of the "rule of law," emphasizing

the importance of legal protection as a fundamental element of a fair and equitable legal system. This involves recognizing and safeguarding the basic rights of individuals. Legal protection also reflects the essential function of law in ensuring justice, legal certainty, and societal benefit. Through legal protection, individuals or groups who feel threatened can seek justice and obtain adequate remedies or compensation. Thus, legal protection constitutes a fundamental principle within the legal system, aimed at ensuring that legal legitimacy is genuinely upheld. Based on this framework, this study discusses how legal protection for consumers using Artificial Intelligence (AI) technology is regulated under Indonesia's positive legal framework, particularly the Consumer Protection Law, as well as the obstacles encountered in its implementation.

This research employs a normative juridical (legal research) approach, focusing on the examination of legal norms contained in statutory regulations and general principles of law. This approach is chosen because the objective of the research is to analyze the legal response to the use of Artificial Intelligence (AI) technology and to assess the effectiveness of existing regulations. The normative juridical approach is complemented by a statutory approach, examining Law Number 8 of 1999 on Consumer Protection, Law Number 11 of 2008 in conjunction with Law Number 19 of 2016 on Electronic Information and Transactions (ITE), Law Number 27 of 2022 on Personal Data Protection (PDP), as well as relevant government regulations, ministerial regulations, and court decisions related to the issues discussed.

2. DISCUSSION

2.1 The Current Legal Framework of Consumer Protection in Indonesia in Regulating the Use of Artificial Intelligence (AI)

Artificial Intelligence (AI) plays an increasingly important role in various sectors such as e-commerce, financial services, healthcare, and application-based transportation. However, the use of AI also raises the potential for violations of consumer rights, including behavioral manipulation through algorithms, bias in automated decision-making, misuse of personal data, and a lack of transparency in AI-driven decision-making processes. Therefore, an examination of the adequacy of national regulations is essential to ensure that consumer interests remain protected.

In the context of consumer protection for AI-based products, several previous studies have highlighted the urgency of establishing specific regulations governing the use of AI technology in Indonesia. The growing use of AI services, such as AI chatbots and generative AI, may have adverse impacts on consumers if not accompanied by adequate accountability on the part of service providers. These studies emphasize that, to date, there is no specific legislation regulating the use of AI services, resulting in a legal vacuum that weakens legal protection for users. Furthermore, AI's ability to process large volumes of personal data raises serious concerns regarding data accuracy and security. This demonstrates that consumer protection in AI-based products extends beyond contractual aspects or business liability and includes personal data protection, algorithmic transparency, and legal certainty regarding information generated by AI systems.

The application of the Consumer Protection Law in the context of business transactions involving Artificial Intelligence is crucial to ensuring consumer safety, fairness, and legal protection. One key aspect within consumer protection law is the principle of liability. Careful analysis is required to determine which parties can be held accountable and the extent of responsibility imposed on those parties in the event of

consumer rights violations. To protect consumers from AI-based misconduct or crimes, clear and effective legal regulations are necessary.

In this regard, there is a significant risk of misleading information in digital advertising practices involving AI. AI technology enables the creation of promotional content tailored to consumers' behavioral profiles, but at the same time opens opportunities for manipulating consumer perceptions and decisions. Consumers' lack of understanding of how AI algorithms function makes them vulnerable to misleading or deceptive advertising content. Unfortunately, the current legal framework has not sufficiently regulated this issue, particularly concerning the liability of AI providers for the informational impacts generated by their systems.

Law Number 8 of 1999 on Consumer Protection represents the government's commitment to providing legal certainty for all parties, both consumers and service providers, in relation to existing violations. Consumer protection is necessary to enhance consumer awareness, knowledge, concern, capability, and independence in defending their rights, while also fostering ethical behavior among business actors.

According to Article 1 paragraph (2) of the Consumer Protection Law, a consumer is defined as any person who uses goods and/or services available in society for personal, family, other persons, or other living beings, and not for resale. Consumer protection refers to all efforts that guarantee legal certainty in providing protection to consumers.

Legal protection for consumers in Indonesia is closely linked to the recognition of consumer rights as part of the welfare state concept enshrined in the 1945 Constitution of the Republic of Indonesia. Through the Consumer Protection Law, nine (9) consumer rights are established, namely:

1. The right to comfort, security, and safety in consuming goods and/or services;
2. The right to choose goods and/or services and to obtain such goods and/or services in accordance with the exchange value, conditions, and guarantees promised;
3. The right to correct, clear, and honest information regarding the condition and guarantees of goods and/or services;
4. The right to have opinions and complaints heard regarding goods and/or services used;
5. The right to advocacy, protection, and proper consumer dispute resolution;
6. The right to consumer education and guidance;
7. The right to be treated or served properly, honestly, and without discrimination;
8. The right to compensation, indemnification, and/or replacement if the goods and/or services received are not in accordance with the agreement or are not as they should be;
9. Other rights regulated by laws and regulations.

The Consumer Protection Law is not intended to hinder commercial activities. On the contrary, it aims to create an environment that encourages competitive businesses by offering high-quality goods and/or services. At the same time, the law provides special consideration to small-scale business actors during its implementation by promoting fair enforcement and proportional sanctions for violations.

The application of the Consumer Protection Law in AI-based business transactions is therefore essential to ensure consumer safety, fairness, and protection. One critical aspect is the principle of liability, which requires careful identification of parties who can be held responsible and the scope of their legal obligations in cases of consumer rights violations.

To protect consumers from AI-based crimes or abuses, clear and effective legal regulations are required. Although some countries have incorporated AI-related issues into their consumer protection laws, there remains a need to further develop and strengthen existing regulations. Such regulations must acknowledge the necessity of protecting consumers from AI-based misconduct and impose strict sanctions on violators. Law Number 8 of 1999 on Consumer Protection reflects the government's effort to ensure legal certainty for both consumers and service providers in relation to violations.

Consumers refer to individuals who use goods or services for personal, family, or household needs, rather than for production or resale. Consumer transactions involve the transfer of goods or services from providers to consumers for use or enjoyment. Consumer rights and obligations are clearly regulated in Articles 4 and 5 of the Consumer Protection Law, which define the position and bargaining power of consumers within business transaction mechanisms.

On the other hand, Article 7 of the Consumer Protection Law stipulates the obligations of business actors, including providing accurate, clear, and honest information regarding the condition and guarantees of goods and/or services, as well as explanations concerning their use, repair, and maintenance; and providing compensation, indemnification, and/or replacement if the goods and/or services received do not conform to the agreement.

Along with technological developments, the Consumer Protection Law is considered insufficient to address issues arising from digital transactions, particularly those mediated by AI. Therefore, amendments are necessary to prevent further consumer losses. Under Article 1 point 8 of Law Number 19 of 2016 concerning Amendments to Law Number 11 of 2008 on Electronic Information and Transactions (ITE Law), AI falls within the definition of an electronic agent. Consequently, developers or providers of AI systems are responsible for fulfilling all legal requirements and obligations. An electronic agent is defined as a device within an electronic system designed to automatically perform actions on specific electronic information under the operation of a person.

The regulation of electronic agents in electronic transactions is addressed in Article 21 of the ITE Law. Operators of electronic agents are essentially electronic system operators under the ITE Law, as electronic agents constitute a form of electronic system administration. Therefore, electronic agent operators have the same rights and obligations as electronic system operators and are responsible for ensuring that systems are operated responsibly, securely, and effectively. As a result, electronic agent operators are legally responsible for any consequences arising from their actions.

Based on Government Regulation Number 71 of 2019 on the Implementation of Electronic Systems and Transactions, electronic agent (AI) operators are subject to specific obligations related to consumer protection, namely:

a. Providing or disclosing specific information;

b. Ensuring that AI systems possess certain features; and

c. Establishing and implementing standard operating procedures based on principles of user data security control and electronic transaction integrity.

These obligations are directly related to consumer protection in the use of AI. Information disclosure enhances transparency in AI-related business practices, enabling consumers to identify potential errors or mismanagement. Functional requirements provide consumers with greater choice and control in commercial activities. Additionally, AI service providers are obligated to protect user data as part of their responsibility as

electronic agents and are therefore subject to Law Number 27 of 2022 on Personal Data Protection (PDP Law).

Electronic agent operators may act as Data Controllers or Data Processors in the collection and processing of personal data. Data Controllers are responsible for determining processing purposes and ensuring compliance with data protection principles, while Data Processors must process data according to the instructions of the Controller. Liability rests with the Controller unless the Processor acts beyond authorized instructions or purposes.

Article 1 paragraph (4) of the PDP Law defines a Personal Data Controller as any individual, public body, or international organization acting independently or jointly in determining the purposes and control of personal data processing. In this context, AI chatbot service providers qualify as Personal Data Controllers and are responsible for determining processing objectives, methods, and data security. The risk of data breaches in AI chatbot systems is significant, as regulated under Article 46 of the PDP Law.

In general, consumer protection regulations applicable to electronic agent operators using AI also apply to other types of electronic agents. However, a more comprehensive legal framework governing AI usage is still required, as existing provisions primarily address transactional aspects of AI implementation.

The above analysis indicates that while AI has begun to be widely applied in Indonesia, its use in business activities presents challenges not fully addressed by the current Consumer Protection Law. AI-based offering systems combined with large-scale personal data collection create significant information asymmetries for consumers. First, consumers may not understand pricing and offering mechanisms. Second, they may be unaware that their personal preferences are being profiled through AI-based procedures. Moreover, Article 28 of the Consumer Protection Law adopts a reversed burden of proof, which weakens consumers' bargaining position, as business actors or developers possess superior knowledge of AI systems.

This situation highlights the need for responsive, accountable, and transparent oversight and reporting mechanisms, accompanied by notification obligations and traceability of cause-and-effect relationships in AI decision-making. Regulatory reform is therefore essential, not only to recognize AI as advanced technology, but also to clearly assign legal responsibility for the consequences of AI-generated decisions.

2.2 Obstacles in Legal Protection for Consumers Using Artificial Intelligence (AI)

If Artificial Intelligence (AI) is considered a product, manufacturers or developers may be held legally liable for damages suffered by consumers. In this case, AI products must meet adequate safety and quality standards. Article 19 of the Consumer Protection Law provides that companies are responsible for damages caused by the use of goods or services they produce or sell. In the AI context, if an AI product such as an autonomous vehicle or intelligent robotcauses harm to consumers, developers or manufacturers may be held liable under this provision. Losses resulting from software errors, system failures, or product defects may serve as grounds for consumer claims, requiring producers to provide repairs, replacements, or compensation.

In addition to product liability, legal responsibility may also arise from negligence. If harm caused by AI results from errors in design, testing, or implementation, developers or users may be held accountable. This includes insufficient security measures before market release or failure to update AI systems, leading to technical issues.

The principle of negligence under Article 1365 of the Indonesian Civil Code stipulates that any unlawful act causing harm to another obliges the responsible party to

compensate for the loss. In the AI field, if evidence shows that developers or users failed to ensure adequate system security or risk assessment, they may be held legally liable. For example, if an intelligent robot causes harm due to flawed decision-making algorithms and the developer failed to conduct proper testing, liability may arise from such negligence.

Overall, although Indonesia does not yet have specific legislation explicitly regulating AI liability, existing principles in consumer protection law, personal data protection law, and civil law can be applied to AI-related damages. Future regulations are likely to be developed to address more complex issues, such as liability in autonomous vehicle accidents or AI system failures in the public sector. In addition to developers and manufacturers, AI users may also bear responsibility if negligence occurs in operation or maintenance, depending on contractual arrangements and applicable regulations.

Currently, Indonesia lacks comprehensive legislation governing the development, deployment, and supervision of AI technology. Although several laws exist, such as consumer protection and personal data protection laws, significant legal gaps remain regarding AI complexity. Issues such as legal liability, AI ethics, and data protection in AI applications remain unclear, resulting in legal uncertainty for developers, users, and consumers.

Globally, AI development has prompted many countries to introduce regulations ensuring ethical and responsible use. For instance, the European Union has developed the EU Artificial Intelligence Act, which classifies AI risks and establishes security and transparency standards for developers.

Indonesia's national regulations must align with international trends and standards. Delays in regulatory development risk the importation of AI technologies that fail to meet expected safety or ethical standards, potentially undermining domestic technological competitiveness in the global market.

Finally, a major legal debate in AI law concerns whether AI should be regarded as a legal subject or merely as a technological tool. Currently, both nationally and internationally, AI is still considered a human-made tool without legal personality equivalent to that of individuals or legal entities.

3.CONCLUSION

Law Number 8 of 1999 on Consumer Protection in Indonesia has not yet adequately provided legal protection for consumers who use Artificial Intelligence (AI)-based technologies. The regulation does not specifically address the risks arising from the use of AI, such as automated decision-making that may disadvantage consumers and the lack of transparency in AI systems. In addition, the protection of consumers' personal data has not been fully guaranteed, as the provisions under the ITE Law remain limited and do not sufficiently accommodate the complexity of data processing within AI technologies. As a result, data security and privacy in the AI-driven digital ecosystem are not yet fully ensured.

The implementation of Artificial Intelligence (AI) technology presents significant challenges and obstacles due to legal gaps or unclear regulatory frameworks, difficulties in determining the parties responsible for consumer losses particularly with respect to data security and the limited understanding of consumers regarding how AI systems operate. Furthermore, the rapid pace of technological development is not aligned with regulatory updates. These challenges arise across various sectors, including private companies, government institutions, and educational organizations.

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REFORMULATION OF THE REGULATION ON CORRUPTION CRIMES IN INDONESIA (A PERSPECTIVE OF ISLAMIC CRIMINAL LAW: ḤADD AL-ḤIRĀBAH)

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Abstract

The regulation of corruption crimes in Indonesia continues to reveal fundamental weaknesses. Corruption convicts are still treated as "ordinary offenders," allowing them to receive sentence remissions despite relatively short average prison terms of approximately 3.4 years. In addition, the political rights of former corruption convicts may be restored, enabling them to run again for public office. The revision of the Law on the Corruption Eradication Commission (KPK) and the prolonged delay in deliberating the Draft Law on Asset Confiscation and the Impoverishment of Corruptors further illustrate the fragility of Indonesia's anti-corruption legal framework. Over the last two decades (2003–2023), the Corruption Perceptions Index has consistently placed Indonesia among the five most corrupt countries within the ASEAN group in 2023, with Indonesia's score

falling below the global standard. As an extraordinary crime, corruption should be addressed with extraordinary threats and sanctions. The dangers posed by corruption are comparable to other extraordinary crimes such as terrorism, narcotics abuse, and severe environmental destruction. Moreover, corruption, by virtue of its systemic and destructive impact, may be aligned with extraordinary crimes under the Rome Statute, including genocide, crimes against humanity, and crimes of aggression. In Indonesia, the death penalty for corruption is regulated under Article 2 paragraph (2) of Law Number 31 of 1999 on the Eradication of Corruption Crimes, which provides that capital punishment may be imposed under certain circumstances. However, to date, no court verdict has imposed the death penalty on a corruption offender. This situation stands in stark contrast to countries with communist or authoritarian legal orientations such as China, Vietnam, North Korea, as well as the Islamic Republic of Iran, which apply capital punishment to corruption offenders. In Islamic legal literature, corruption is referred to as al-fasād , meaning the act of causing destruction; gratification is known as al-ishbā', meaning to provide excessive benefit; and bribery is termed rishwah. All three concepts refer to acts constituting corruption crimes. Accordingly, corruption in Islamic criminal law is understood as an act of causing destruction, which may include the deliberate embezzlement of state funds, manipulation of the legal system, or conduct that threatens humanity itself. Causing destruction signifies an attack against the state through acts of corruption. At a certain scale, corruption constitutes an assault on the state system through the theft of public funds, which essentially belong to the people. When corruption is interpreted as state capture and as an unlawful act that violates humanitarian values (unlawful acts against humanity), it may be categorized as a ḥadd crime of ḥirābah, namely a crime that causes widespread harm and threatens public and state security, for which the most severe punishment-capital punishment-may be imposed. This article seeks to explain corruption as an extraordinary crime whose eradication must likewise be extraordinary, by grounding its argument in the values of truth and justice derived from Islamic law through the concept of ḥadd al-ḥirābah. A statutory approach and a conceptual approach are employed to reformulate the regulation of corruption crimes in Indonesia.

Keywords: *Reformulation, Corruption Crime, Ḥadd al-Ḥirābah*

1. INTRODUCTION

The Government of Indonesia has continuously sought to strengthen anti-corruption efforts through statutory regulations and other legal instruments. The establishment of the Corruption Eradication Commission (*Komisi Pemberantasan Korupsi*-KPK) as an independent institution in 2002 was a constitutional mandate intended to position Indonesia as a more advanced state, reflected in a declining level of corruption. However, more than two decades later, these efforts have yet to produce encouraging results, as indicated by Indonesia's Corruption Perceptions Index (CPI), which has remained stagnant and even demonstrated a downward trend. Corruption is widely recognized as an extraordinary crime (*extraordinary crime*). This recognition was reaffirmed during the commemoration of International Anti-Corruption Day (*Hari Antikorupsi Sedunia*-Hakordia) in Indonesia in 2025, which adopted the overarching theme "Unite in Action to Eradicate Corruption." The official logo published on the KPK's website symbolized collective resistance to corruption and emphasized concrete, collaborative action by society. Previously, during the 2024 commemoration, the National Strategy Team for Corruption Prevention (*Strategi Nasional Pencegahan Korupsi*-Stranas PK) officially launched 15 anti-

corruption prevention actions aimed at strengthening implementation effectiveness and enhancing tangible impact. These actions remain aligned with the three primary pillars of the National Strategy for Corruption Eradication, namely licensing and trade governance, state finance, and law enforcement coupled with bureaucratic reform.(Danurdara & Adhari, 2024)

The focus on law enforcement and bureaucratic reform consists of five key actions: strengthening political party integrity through the implementation of political party information systems; reinforcing the role and quality of internal government supervisory apparatus (*Aparat Pengawasan Intern Pemerintah*-APIP); enhancing governance in tax case handling; improving the management of criminal cases through information technology–based systems; and strengthening cooperation between state-owned enterprises (BUMN) and region-owned enterprises (BUMD). To measure both the depth of corruption and the effectiveness of anti-corruption measures, the KPK conducts the Integrity Assessment Survey (*Survei Penilaian Integritas*-SPI). Entering its fourth year, the SPI has been implemented across 92 central government institutions and 542 regional governments. Overall, national-scale SPI results over the past three years have shown a declining trend. On a scale of 0–100, the SPI score in 2023 was 70.97, compared to 71.94 in 2022 and 72.43 in 2021.(Ghozali et al., 2025)

According to the *Kamus Besar Bahasa Indonesia* (KBBI), corruption refers to the misappropriation or misuse of state funds (or corporate funds and the like) for personal gain or for the benefit of others. Article 2 paragraph (1) of Law Number 31 of 1999 on the Eradication of Corruption Crimes (*UU Tipikor*) defines corruption as an act of unlawfully enriching oneself, another person, or a corporation that causes losses to state finances or the national economy.(Margono et al., 2024) Article 3 further characterizes corruption as an act committed with the intent to benefit oneself, another person, or a corporation by abusing authority, opportunity, or means associated with one's office or position, thereby causing losses to state finances or the national economy.(Senajaya et al., 2026)

From a terminological perspective, the term "corruption" originates from the Latin word *corruptio*, meaning decay or deterioration, and is also used to denote a state or act of moral depravity. Over time, the term has been absorbed into the legal and linguistic vocabularies of many countries, commonly associated with dishonesty or fraud in financial matters.(Qori'ah & Sa'i, 2025) According to Henry Campbell Black, corruption is an act committed with the intent to confer an improper advantage inconsistent with official duties and the lawful rights of others. Black further defines corruption as the unlawful use of public office to obtain benefits contrary to official obligations. Similarly, *Webster's New American Dictionary* defines "corruption" as "decay," "contamination," and "impurity," while "corrupt" denotes a condition of becoming rotten, degraded, or morally depraved. Following the enactment of Law Number 1 of 2023 on the Criminal Code (*Kitab Undang-Undang Hukum Pidana*-KUHP), the handling of corruption offenses appears to have weakened. According to Srimin Pinem et al., the risk of punishment for corruption crimes under the Criminal Code is lower than under the Corruption Eradication Law (*UU PTPK*). The incorporation of corruption offenses into the 2023 Criminal Code has also raised concerns that corruption may no longer be treated as an extraordinary crime. Under Article 2 paragraph (1) of the Anti-Corruption Law, offenders are subject to imprisonment for a minimum of four years and a maximum of twenty years, along with fines of at least IDR 200 million. By contrast, Article 606 paragraph (2) of the 2023 Criminal Code stipulates that civil servants who receive gifts or promises related to their office are subject to a maximum imprisonment of four years.(Zainuddin, 2024)

Furthermore, Articles 603–606 of the 2023 Criminal Code regulate corruption with sanctions that are, in several respects, lighter than those provided under Law Number 20 of 2001 on the Eradication of Corruption Crimes. For instance, Article 603 prescribes life imprisonment or imprisonment ranging from a minimum of two years to a maximum of twenty years, accompanied by fines ranging from category II to category VI. Under Article 11 of the Anti-Corruption Law, civil servants committing similar offenses are subject to imprisonment of up to five years. Article 622 paragraph (4) of the Criminal Code stipulates that provisions of the Anti-Corruption Law referenced therein shall be replaced by the corresponding articles of the new

Criminal Code, including the replacement of Article 2 paragraph (1) with Article 603, Article 3 with Article 604, Article 5 with Article 605, Article 11 with Article 606 paragraph (2), and Article 13 with Article 606 paragraph (1). The codification of corruption offenses into the Criminal Code, aside from reducing penalties, effectively reclassifies corruption as a general crime rather than a special crime. This development is particularly concerning, as corruption risks losing its status as an extraordinary crime.(Novianti, 2023)

As an extraordinary crime, corruption should be met with extraordinary legal threats and sanctions. The dangers posed by corruption are comparable to other extraordinary crimes, such as terrorism, narcotics abuse, and severe environmental destruction. Indeed, corruption has been equated with other extraordinary crimes under the Rome Statute, including genocide, crimes against humanity, and crimes of aggression. In Indonesia, the death penalty for corruption is regulated under Article 2 paragraph (2) of Law Number 31 of 1999 on the Eradication of Corruption Crimes, which provides that capital punishment may be imposed under certain circumstances. Nevertheless, to date, no court decision has imposed the death penalty on a corruption offender. This stands in contrast to countries with communist or authoritarian legal systems such as China, Vietnam, North Korea, as well as the Islamic Republic of Iran, which apply capital punishment to corruption offenses. Given that Indonesia's population is predominantly Muslim (approximately 87%), it is appropriate for the legal system to explore and incorporate values of truth and justice derived from Islamic teachings, particularly theories of Islamic criminal law (*fiqh jināyah*). Within Islamic criminal law theory, the concept of *ḥadd al-ḥirābah* refers to a crime characterized by acts of destruction and threats to public and state security, for which the most severe punishment, capital punishment, may be imposed. This article employs a statutory approach and a conceptual approach to examine the relevance of applying the theory of *ḥirābah* as an *argumentum per analogiam* to corruption crimes. The central question addressed in this article is whether the concept of *ḥirābah* can serve as a legitimate analogical framework for reformulating the regulation of corruption crimes in Indonesia.(Dayati et al., 2024)

2. DISCUSSION

2.1. Regulation of Corruption Crimes in Indonesia

The regulation of corruption crimes in Indonesia has in fact long been embedded in the Criminal Code (KUHP), which contains provisions criminalizing individuals who commit offenses related to abuse of office, particularly corruption by public officials. However, the corruption-related provisions in the KUHP have been widely regarded as insufficient to prevent, let alone effectively combat, corruption crimes.

Consequently, for the first time, a special law was enacted to address corruption with the aim of remedying the deficiencies of the KUHP. This effort materialized through the enactment of Law Number 20 of 2001, which amended Law Number 31 of 1999 on the Eradication of Corruption Crimes. Corruption offenses are categorized as part of special criminal law (*hukum pidana khusus*), which contains provisions that deviate from the general rules set out in the Criminal Code (KUHP). Such deviations are recognized and regulated under Indonesian positive law, particularly Law Number 8 of 1981 concerning the Criminal Procedure Code (KUHAP). Article 284 paragraph (2) of the KUHAP stipulates that the provisions of this law apply to all cases within two years of its promulgation, except for procedural rules stipulated in specific laws that remain applicable until amended or repealed. The elucidation of Article 284 paragraph (2) letter (b) clarifies that "special criminal procedural provisions regulated in certain laws" refer to procedural rules contained in specific criminal statutes, such as Law Number 7 (Emergency Law) of 1955 on the Investigation, Prosecution, and Trial of Economic Crimes. In addition, the Anti-Corruption Law (Law Number 3 of 1971) mandated that all special procedural provisions contained therein be reviewed, revised, or repealed without delay. The Corruption Crime Court (*Pengadilan Tindak Pidana Korupsi*) was initially established under Article 53 of Law Number 30 of 2002 on the Corruption Eradication Commission (KPK). However, after the Constitutional

Court declared this provision unconstitutional, Law Number 46 of 2009 on the Corruption Crime Court was enacted, granting the court authority to adjudicate corruption cases. Due to its distinctive nature, procedural law in corruption cases exhibits a dual character. It adheres to procedural rules stipulated in Law Number 31 of 1999 while simultaneously deviating from the general principles of criminal procedure as set forth in Law Number 8 of 1981. These deviations are explicitly permitted under Law Number 31 of 1999 on the Eradication of Corruption Crimes.(Muslich, 2025)

Legislative policy in the field of special criminal law on corruption has undergone extraordinary and dynamic development. This evolution reflects deep concern over corruption, which has caused widespread suffering among the Indonesian people. To date, there are seven (7) statutory instruments governing the eradication of corruption, namely:

1. Law Number 31 of 1999 on the Eradication of Corruption Crimes as amended by Law Number 20 of 2001;
2. Law Number 30 of 2002 in conjunction with Law Number 10 of 2015 and Law Number 19 of 2019 on the Corruption Eradication Commission (KPK);
3. Law Number 46 of 2009 on the Corruption Crime Court;
4. Law Number 28 of 1999 on Clean and Corruption-Free State Administration;
5. Law Number 8 of 2010 on the Prevention and Eradication of Money Laundering;
6. Law Number 13 of 2006 on the Protection of Witnesses and Victims;
7. Law Number 7 of 2006 on the Ratification of the United Nations Convention Against Corruption (UNCAC) 2003.

From a legal positivist perspective, the existence of these statutory instruments is considered sufficient to prevent and limit corruption crimes, relying primarily on the doctrine of unlawfulness (*melawan hukum*) as the benchmark for evidentiary assessment by law enforcement authorities in determining corruption offenses.(Jawa et al., 2024)

Law Number 31 of 1999 initially identified thirty (30) forms of corruption, which were later simplified into six (6) categories under Law Number 20 of 2001. According to this law, corruption constitutes criminal conduct that causes losses to state finances, including bribery, embezzlement in office, extortion, fraudulent acts, conflicts of interest in procurement, and gratification. The substantive regulation of corruption offenses consists of:

First, bribery, regulated under Articles 5, 6, 11, 12 letters (a), (b), (c), and (d) of Law Number 20 of 2001, and Article 13 of Law Number 31 of 1999. Second, embezzlement in office, involving intentional misappropriation of funds or securities, falsification of administrative records, destruction of evidence to protect bribe-givers, and similar acts, regulated under Articles 8, 9, and 10 letters (a), (b), and (c) of Law Number 20 of 2001. Third, extortion, defined as acts where public service officers actively offer services or demand compensation from service users to accelerate processes in violation of applicable procedures, regulated under Article 12 letters (e), (f), and (g) of Law Number 20 of 2001. Fourth, fraudulent acts, intentionally committed for personal gain and potentially endangering others, regulated under Article 7 paragraph (1) of Law Number 20 of 2001. Fifth, conflicts of interest in procurement, regulated under Article 12 letter (i) of Law Number 20 of 2001.
Sixth, gratification, broadly defined as gifts in the form of money, goods, commissions, interest-free loans, travel tickets, accommodation facilities, and other benefits related to official positions, prohibited under Article 12 letter (b) of Law Number 20 of 2001.(Hidayat et al., 2025)

Sanctions include, inter alia, restitution equal to assets obtained from corruption (Article 18 paragraph (1) letter (b)), reverse burden of proof concerning illicit assets (Article 37A paragraph (1)), and asset seizure and forfeiture. Failure to pay restitution within one month after a final judgment permits the prosecutor to confiscate and auction assets. If insufficient assets exist, imprisonment of up to two years may be imposed.(Faturachman et al., 2024)

Nevertheless, the regulation of corruption offenses under the newly enacted Criminal Code (KUHP 2023) indicates a potential weakening of anti-corruption enforcement and

normative conflict (*antinomy of norms*) with Law Number 31 of 1999 as amended by Law Number 20 of 2001. According to Srimin Pinem et al.,corruption causes significant state economic damage; therefore, anti-corruption efforts must focus not only on imposing severe imprisonment but also on restoring state losses. Failure to recover assets reduces the deterrent effect of punishment. Asset recovery may occur through criminal restitution, civil proceedings, plea bargaining mechanisms, or court-ordered confiscation. Corruption offenses extend beyond state officials to civil servants and private actors involved in state financial losses. These offenses are grouped into state financial losses, bribery, embezzlement, extortion, fraud, conflicts of interest in procurement, and gratification. Ultimately, anti-corruption policy encompasses prevention, prosecution, and asset recovery, aiming at social welfare and public protection. From a criminal policy perspective, law enforcement strategies must balance legal certainty, justice, and efficiency. The enactment of KUHP 2023 raises serious concerns, as many provisions potentially hinder anti-corruption efforts. Transparency International reports confirm Indonesia's continued placement among the most corrupt countries in ASEAN, with a Corruption Perceptions Index score of 34 in 2023-below the global average of 43.(Harefa et al., 2024)

2.2. Corruption as an Unlawful Act

In the former Criminal Code, the principle of legality under Article 1 paragraph (1) stipulates that no act may be punished except pursuant to prior statutory provisions. This principle, derived from the French Penal Code, mandates strict interpretation of criminal law. Two conclusions follow: (1) criminal liability must be explicitly stipulated by law, and (2) retroactive application is prohibited except under Article 1 paragraph (2). Law Number 31 of 1999 adopts the doctrine of material unlawfulness (*materiële wederrechtelijkheid*), explicitly articulated in the elucidation of Article 2 paragraph (1). An act may be punishable even if not expressly regulated, provided it violates societal norms and a sense of justice. Article 2 paragraph (1) stipulates imprisonment of 4–20 years and fines for unlawfully enriching oneself or others causing state financial loss, with the death penalty permissible under certain circumstances. Formal unlawfulness refers to violation of statutory norms, while material unlawfulness concerns harm to protected social interests. Strict adherence to legal certainty must be balanced with substantive justice.(Fadilah et al., 2023)

2.3. Corruption as an Extraordinary Crime

The status of corruption as an extraordinary crime is increasingly questioned following KUHP 2023. The abandonment of the *lex specialis* principle and the reclassification of corruption as a general offense risk diminishing specialized enforcement authority, including the powers of the KPK. Internationally, corruption is recognized as a serious human rights violation and has been proposed as a crime against humanity. UNCAC and international declarations underscore corruption as a global threat to sustainable development.(Junaidi & Subiyanto, 2026)

2.4. Corruption as Ḥadd al-Ḥirābah

In Islamic law, corruption relates to various concepts such as *ḥirābah*, *sariqah*, *ghulūl*, *risywah*, and *khiyānah*. Among these, *ḥirābah* constitutes a *ḥudūd* offense with severe sanctions, including the death penalty. The Indonesian Council of Ulama (MUI) has declared corruption unlawful (*haram*), though without specifying penal sanctions. Classical Islamic criminal law (*fiqh jināyah*) defines *ḥirābah* as violent acts threatening public security and order. Based on Qur'an Surah al-Mā'idah (5):33, *ḥirābah* entails severe punishments. If corruption is understood as *state capture* and a crime against humanity, it may be analogically categorized as *ḥadd al-ḥirābah*, as it constitutes an assault on public rights and state integrity.(Pramudya & Yusuf, 2026)

In Islamic law, the concept of corruption is associated with several derivative terms found in the Qur'an and the Hadith, including: (1) *ḥirābah* (waging war or banditry), (2) *sariqah* (theft), (3) *ghulūl* (embezzlement), (4) *risywah* (bribery), (5) *khiyānah* (betrayal of trust), (6)

suḥt (unlawful gain), and (7) *dalw* (criminal conspiracy). Among these terms, *ḥirābah* and *sariqah* possess comprehensive normative content concerning their legal rules and sanctions; therefore, they are classified as *ḥudūd* crimes within the theoretical framework of Islamic criminal law.(Prasad, 2026) The Indonesian Council of Ulama (*Majelis Ulama Indonesia*-MUI), during its Sixth National Congress held on 23–27 Rabīʿ al-Thānī 1421 H (25–29 July 2000), deliberated on bribery (*risywah*), corruption (*ghulūl*), and gifts to public officials. In its fatwa, MUI determined that: (1) giving and receiving bribes (*risywah*) is unlawful (*ḥarām*); and (2) committing corruption is unlawful (*ḥarām*). MUI employed the terms bribery (*risywah*) and corruption (*ghulūl*). As a religious authority, MUI is limited to issuing normative fatwas in accordance with Islamic legal principles; therefore, no explicit penal sanctions are stipulated in the fatwa, unlike statutory criminal regulations.(Haga & Adhari, 2026)

Within the corpus of Islamic criminal jurisprudence (*fiqh jināyah*), there exist criminal offenses whose rules and sanctions are explicitly prescribed in the Qur'an, known as *jarīmah ḥudūd*. One such offense is *ḥadd al-ḥirābah*. Linguistically, the term *ḥirābah* derives from the verb *ḥaraba–yaḥrubu*, meaning "to wage war," which stands in contrast to peace. Its verbal nouns include *ḥarban*, *ḥarbān*, and *ḥirābatan*. The term *ḥirābah* may also signify the forcible seizure of property, destruction, and devastation. Etymologically, *ḥirābah* refers to *qaṭʿ al-ṭarīq* (cutting off the road), while terminologically it denotes the taking of another's property through violence. At first glance, perpetrators of *ḥirābah* may be described as bandits, highway robbers, or armed assailants. Robbery (*ḥirābah*) constitutes one of the *jarīmah al-ḥudūd*, namely criminal acts whose type, severity, and punishment are determined by divine law (*sharīʿah*). Jurists often refer to it as *qaṭʿ al-ṭarīq* (highway robbery) or *al-sariqah al-kubrā* (grand theft). Muṣṭafā Aḥmad al-Zarqā defines robbery as the seizure of another's property through violence and killing. Similarly, ʿAbd al-Qādir ʿAudah explains that *ḥirābah* may manifest in several forms: first, acts of violence that disrupt public security even without theft or killing; second, violent robbery without homicide; third, violent acts involving killing without successful theft; and fourth, violent acts involving both theft and killing.(Rezah & Sapada, 2026)

The Qur'anic basis for *ḥirābah* is found in Surah al-Māʾidah (5):33:

إِنَّمَا جَزَٰٓؤُا۟ ٱلَّذِينَ يُحَارِبُونَ ٱللَّهَ وَرَسُولَهُۥ وَيَسْعَوْنَ فِى ٱلْأَرْضِ فَسَادًا أَن يُقَتَّلُوٓا۟
أَوْ يُصَلَّبُوٓا۟ أَوْ تُقَطَّعَ أَيْدِيهِمْ وَأَرْجُلُهُم مِّنْ خِلَٰفٍ أَوْ يُنفَوْا۟ مِنَ ٱلْأَرْضِ ۚ ذَٰلِكَ
لَهُمْ خِزْىٌ فِى ٱلدُّنْيَا ۖ وَلَهُمْ فِى ٱلْءَاخِرَةِ عَذَابٌ عَظِيمٌ ﴿٣٣﴾

"Indeed, the recompense of those who wage war against Allah and His Messenger and strive to spread corruption on earth is that they be killed or crucified, or that their hands and feet be cut off on opposite sides, or that they be exiled from the land. That is for them disgrace in this world; and for them in the Hereafter is a great punishment."

According to Muṣṭafā al-Zarqā, the principal element of *ḥirābah* is violent conduct that disrupts public security, whether carried out with weapons or without weapons, and whether occurring in rural areas, urban centers, or public roads used by the community. Scholars of the Ḥanafī school define *ḥirābah* or *qaṭʿ al-ṭarīq* as the act of attacking and forcibly seizing the property of road users, thereby obstructing their passage and effectively cutting off public roads. Such acts may be committed individually or collectively, provided the perpetrators possess the capacity to obstruct public passage. The means employed may include weapons, swords, or other tools such as sticks, stones, or wooden objects, all of which disrupt public order and security. These acts may be carried out through direct cooperation or indirect assistance among perpetrators. Muḥammad Abū Zahrah further elaborates on the technical aspects of *ḥirābah*, including the type of weapons used and the number of perpetrators involved. Jurists differ in

defining who qualifies as a perpetrator of *ḥirābah*. Imām Mālik stated: "According to us, the perpetrator of *ḥirābah* is one who causes public distress, whether in urban or rural areas. Anyone who brandishes weapons and terrorizes people on city streets or outside urban areas must be confronted by the head of state (imam). If such acts are allowed to continue, they will intensify and result in greater harm, including killings and property seizure. If the perpetrators are apprehended before successfully stealing property or taking lives, the punishment shall be *taʿzīr* and detention at the discretion of the authority, as the act constitutes a grave sin. However, if the perpetrators succeed in stealing property that reaches the *niṣāb* threshold, then the imam shall order the amputation of the right hand and left foot." According to ʿAbd al-Qādir ʿAudah, *ḥirābah* constitutes robbery or grand theft. The inclusion of robbery within the conceptual scope of theft is metaphorical rather than literal, as theft involves clandestine appropriation, whereas robbery entails overt seizure. Nevertheless, robbery also contains an element of concealment, namely the perpetrators' evasion of state authority and lawful order. Consequently, the term *sariqah* does not fully encompass robbery without additional clarification, which is why robbery is referred to as grand theft.(Rudi Margono, 2026)

From the foregoing explanations, it becomes evident that *ḥirābah* is a criminal act that constitutes waging war against Allah and His Messenger by spreading corruption on earth, for which the maximum sanction may include capital punishment. If corruption is conceptualized as *state capture* and as an unlawful act against humanity, it may be analogically categorized as *ḥadd al-ḥirābah*, as it constitutes an assault on the rights of Allah and His Messenger-interpreted in this context as an assault on the state, public interest, and collective rights. Despite various scholarly interpretations, no explicit and definitive theorization of corruption exists within classical Islamic law. Several opinions, including the fatwa of the Indonesian Council of Ulama (MUI), explain corruption through Qur'anic and Prophetic terminology that reflects Islamic moral and legal values; however, corruption is not articulated as a concrete legal offense accompanied by specific penal sanctions. Islamic criminal law, which classifies offenses into *ḥudūd*, *qiṣāṣ*, and *taʿzīr*, tends to position corruption primarily as a *taʿzīr* offense, although it should conceptually intersect with *ḥudūd* crimes.(Kandia et al., 2026)

3. CONCLUSION

a) The regulation of corruption offenses following the enactment of Law Number 1 of 2023 on the Criminal Code has the potential to weaken the enforcement of anti-corruption law in Indonesia. The sanctions prescribed under the 2023 Criminal Code are lower than those stipulated in the previous anti-corruption legislation. Moreover, the incorporation of corruption offenses into the new Criminal Code raises serious concerns that corruption is no longer treated as an extraordinary crime.

b) If corruption is conceptualized as *state capture* and as an unlawful act against humanity (*unlawfully against humanity*), it may be categorized as *ḥadd al-ḥirābah*, whereby, at a certain scale, corruption offenders should remain subject to the maximum penalty, including capital punishment (death penalty).

c) The interpretation of corruption as *ḥadd al-ḥirābah* is grounded in the shared characteristics of both offenses, namely the act of plundering and depriving the people of their fundamental rights. As extraordinary crimes, both require persistent and decisive eradication by the state in order to protect public legal interests.

d) The values embedded in Islamic teachings concerning *ḥadd al-ḥirābah* may serve as a normative legal source for the reformulation of corruption crime regulations in Indonesia, as part of a broader effort to strengthen anti-corruption enforcement.

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MECHANICAL PROPERTIES OF GREEN PAVER BLOCK INCORPORATING RAW RIVER WATER TEXTILE DYEING SLUDGE

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Abstract

This study examines the feasibility of utilizing textile dyeing sludge, a byproduct of the textile industry, to produce a Green Paver Block (GP Block). This study examines the mechanical characteristics of eco-friendly paver blocks. Raw river water sludge will serve as the basis for comparison. The primary objective of this study is to determine the physical properties of GP Block when combined with Raw River Water Sludge (RRWS) and to identify the optimal percentage mix ratio of textile dyeing sludge required to produce GP Block. Due to its greater reliance on natural resources, the building industry also raises questions regarding its environmental effects. Mechanical tests were conducted on blocks with varying RRWS content (2.5%–10%). The results showed that increasing RRWS content led to a decrease in density and compressive strength, and an increase in water absorption due to the fine and organic nature of the sludge. However, blocks with 2.5% RRWS maintained acceptable strength, which is 22.19 MPa, density of 1995.3 kg/m³, and water absorption of 11.25%, making them suitable for non-structural applications. Scanning Electron Microscope with Energy Dispersive X-Ray (SEM-EDX) analysis confirmed the presence of calcium and silicon, supporting RRWS's role as a filler material. The study concludes that 2.5% RRWS is the optimal mix ratio for producing environmentally friendly and structurally reliable GP Blocks, contributing to sustainable construction practices and effective waste management.

Keywords: Raw River Water Sludge, RRWS, Green Paver Block, GP Block

1. INTRODUCTION

Paver blocks, commonly used in construction and landscaping, are traditionally made from cement, sand, and aggregates. Due to environmental concerns such as resource depletion and industrial waste, sustainable alternatives like GP Blocks have been developed. These blocks incorporate recycled materials, including wastewater and textile dyeing sludge, to reduce reliance on cement and sand. Interlocking paving stones originated in the Netherlands in the mid-19th century and gained popularity after World War II due to brick shortages. The shift toward concrete pavers was driven by practicality and material availability (Olofinnade et al., 2021). Research shows that using recycled materials not only reduces environmental impact but can also enhance the strength and

durability of paver blocks, making them a viable and eco-friendly option for modern construction.

The construction industry significantly contributes to global economic development but is also a major source of environmental degradation. Concrete production, which relies heavily on cement, water, and aggregates, is both costly and energy-intensive. To address these issues, researchers have explored the use of sludge from water treatment plants as a replacement for fine aggregates. This approach not only reduces construction costs but also helps manage the disposal problem of sludge waste. Reusing sludge in construction can mitigate environmental pollution and health risks associated with improper disposal, as sludge often contains heavy metals like lead and mercury that can contaminate soil and affect its fertility (Ruben et al., 2020)

In this study, GP Blocks incorporating recycled raw water sludge (RRWS) were produced using the ratio method with Ordinary Portland Cement (OPC). The blocks, sized 200mm × 100mm × 60mm, included varying proportions of RRWS as a partial sand replacement, alongside control blocks made with natural sand. After a 28-day curing period, mechanical tests were conducted to evaluate density, compressive strength, and water absorption. Additionally, SEM analysis was used to examine the surface structure and material interactions.

This research identified their fundamental structure and any interactions. Subsequently, the experimental findings were carefully evaluated to ascertain the ideal RRWS ratios to be added to paver blocks. The purpose of this study was to find effective and sustainable ways to include RRWS into building materials to support environmentally friendly building techniques. Table 1 show the mix proportion of RRWS.

Table 1 The mix proportion of RRWS

Mix Name	% of Raw River Water Sludge
Control	0
RRWS 2.5	2.5
RRWS 5	5
RRWS 7.5	7.5
RRWS 10	10

This study highlights the environmental challenges posed by the cement industry, particularly the extraction and processing of non-renewable minerals like limestone. These activities can severely degrade natural landscapes, disrupt ecosystems, and threaten biodiversity. Additionally, the improper disposal of sludge, especially from the textile industry, contributes to soil and water pollution. By reusing sludge as a component in paver blocks, the study presents a practical and eco-friendly solution that reduces waste and supports sustainable construction practices.

2. MATERIAL

2.1 Raw River Water Sludge

RRWS is a waste product of water treatment processes, which has received significant attention for its possible applications in sustainable construction and environmental management. This review investigates its properties and application with a particular focus on its incorporation into construction materials.

RRWS is composed of organic debris, fine particles, heavy metals, and other pollutants filtered from untreated river water during purification. Its composition varies depending on the river source and impurity levels. Before use, the sludge typically has high moisture content. Chemical analysis reveals significant amounts of oxides such as silica, alumina, and calcium oxide, making RRWS a viable supplementary material in construction. The sludge's density, measured using a pycnometer, is approximately 17.1 kN/m^3. These characteristics support its potential for sustainable building applications (Lynn et al., 2015).

(Yan et al., 2024) developed an innovative method to convert textile dyeing sludge into lightweight construction aggregates using a non-sintered process, which is more environmentally friendly than traditional high-heat sintering. The optimal mix included a sludge-to-cement ratio of 2.25, with 5% fly ash and 1% additive, cured over 28 days. This formulation achieved a compressive strength of 6.93 MPa, a bulk density of 753 kg/m^3, and a water absorption rate of 17.98% after one hour. The material's strength and durability were attributed to the formation of calcium silicate hydrate (C–S–H) gel and Ettringite during hydration. Additionally, zinc ions present in the sludge reacted to form stable compounds like $Ca(Zn(OH)_3)_2 \cdot 2H_2O$, which were encapsulated within the C–S–H gel, effectively minimizing the risk of heavy metal pollution. This approach not only promotes the reuse of industrial waste but also supports the production of sustainable building materials aligned with global environmental goals. Figure 1 shows the material of Raw River Water Sludge.



Figure 1: Raw River Water Sludge

2.2 Ordinary Portland Cement (OPC)

Ordinary Portland Cement (OPC) plays a crucial role in the construction of concrete and GP Blocks due to its strong binding properties and widespread availability. In GP Blocks containing RRWS, OPC serves as the primary binder, ensuring structural integrity and durability. Its cost-effectiveness makes it a preferred choice in Malaysian construction. This study emphasizes OPC's interaction with sludge materials, highlighting its importance in maintaining the performance and sustainability of modified paver blocks.

2.3 Sand

Sand is a vital component in the construction of paving blocks, serving as a fine aggregate that enhances mix consistency, compaction, and finishing. It contributes to the density and structural strength of the blocks, ensuring they remain solid and secure after installation. Fine sand, particularly with particle sizes $\leq$ 2.36mm, is preferred for smoother surfaces and better compaction, especially in the top layer of paving stones. Proper selection and proportioning of sand are essential for producing high-quality, durable paving blocks, as supported by BS EN 12620:2002 sieve analysis standards.

2.4 Water

Water plays a crucial role in the paving block mixture, primarily enabling cement hydration to form calcium silicate hydrate which is the key binding agent responsible for strength and durability. Proper water content ensures workability, allowing the mix to be easily moulded and compacted, which eliminates air gaps and results in denser blocks.

During curing, water maintains hydration, preventing shrinkage cracks and enhancing the long-term performance of the material. Effective water management improves surface finish, strength, and resistance to wear, weathering, and mechanical stress.

2.5 Coarse Aggregate

To achieve standards the coarse aggregates will be sieved to ensure a maximum particle size of no more than 10 mm. By using 10 mm aggregates this can reduce fractures and gaps in the concrete mixture. For bigger aggregates it is used to increase the overall strength of the paver block. For the weak aggregates, they are kept clean to maintain specimen performance and quality of the paving block.

3. SPECIMEN PREPARATION

3.1. Collection of Material

The materials used in this study included sand, cement, coarse aggregate, and raw river water sludge, which was used as an additive in green paver blocks. Based on the determined ratios, the amount of raw river water sludge was adjusted for each sample.

3.2. Mix Design

Table 2 provides an overview of the material ratio in this investigation, detailing the quantities of cement, sand and water utilized. Additionally, Table 3 outlines the mix proportions for incorporating Raw River Water Sludge as an admixture in Green Paver Blocks. These proportions were formulated in accordance with the specified guidelines of ASTM Standard C902-15.

Table 2 Ratio of Material

Cement : Sand	1 : 3
Water/Binder Ratio	0.80

Table 3 Percentage mix proportion of RRWS added into sand in GP Block

Mix Name	% of Raw River Water Sludge
Control	0
RRWS 2.5	2.5
RRWS 5	5
RRWS 7.5	7.5
RRWS 10	10

3.3. Mould Preparation

Sample specimens were prepared at the Advanced Material Laboratory using moulds measuring 200mm × 100mm × 60mm for compression and water absorption testing. A total of thirty blocks were cast for both the 7-day and 28-day tests. The moulds were kept in place for at least 24 hours to allow initial hardening before the curing process began. The casting procedure involved several steps: moulds were first cleaned and coated with oil to ease demoulding. Materials including sand, cement, and RRWS were measured according to specified ratios and thoroughly mixed. The mixture was then poured into the moulds, which were gently struck to eliminate air pockets. Each sample was labeled with

a unique number and date for tracking purposes. After one day, the blocks were removed from the moulds and placed in a curing tank to ensure proper hydration and strength development. This curing phase was essential for enhancing the durability and structural integrity of the paver blocks. Figures 2, 3, and 4 show the casting process of block.


Figure 2: Mixed materials


Figure 3: Casting of paver block


Figure 4: Paver block

4.EXPERIMENTAL TESTS

4.1. Density Test

A density test measures the mass of a GP Block per unit volume. The outcome helps determine the block compactness, porosity, and overall durability. Density testing helps measure the uniformity and consistency of materials such as sand, concrete, and RRWS. The density of a GP Block can determine its strength, durability, thermal properties, and suitability for various applications. Density measurements can identify material variations and weaknesses, enabling adjustments to manufacturing techniques and material compositions to meet performance requirements. Each sample was weighed using a precise scale and the density was calculated using the formula:

$$Density = \frac{Mass}{Volume} \quad (1)$$

4.2. Compressive Strength Test

This test was designed to determine the compressive strength of paver blocks. For this reason, paver blocks measuring 200 x 100 x 60 mm were used. After a 24-hour drying and curing period, the samples were removed from the moulds holding the Textile Dyeing Sludge mixture. On days 7 and 28, 30 samples were prepared and analyzed. The guidelines provided in BS EN 12390-3: 2009 were used to evaluate the compressive strength values. Each sample was placed in the compression machine, and the piston was adjusted to contact the surface of the block. The load was gradually applied until cracking occurred, indicating the maximum load capacity. The machine recorded the results in kilonewtons (kN), and the average compressive strength was calculated for all samples. This test provided critical data for assessing the structural integrity and performance of the paver blocks. Figures 5 and 6 show the situation before and after a load is applied to the paver block.



Figure 5: Before load applied



Figure 6: After load applied

4.3. Water Absorption

The water absorption test measured the ability of a paver block to absorb water, which indicated its porosity and durability. The procedure involved drying the paver block in an oven at a specified temperature until a constant weight was achieved, then cooling it to room temperature and weighing it. The block was then immersed in water for a set period, usually 24 hours, after which it was removed, wiped dry, and weighed again. The difference in weight before and after immersion, expressed as a percentage of the dry weight, gave the water absorption rate. This test helped determine the block's resistance to weathering and potential durability in various environmental conditions. The water absorption percentage was calculated using the formula:

$$Water\ Absorbtion\ (\%) = \frac{Final\ Weight - Initial\ Weight}{Initial\ Weight} \quad (2)$$

4.4. Scanning Electron Microscope with Energy Dispersive X-Ray Analysis

SEM is a complex analytical method that produces high-resolution pictures and detailed surface morphology of materials. By directing a focused beam of electrons onto the specimen surface, SEM significantly surpasses the resolution limits of conventional optical microscopy. This approach enables nanoscale visualization, with resolutions ranging from less than 1 nanometre to several nanometres, making it ideal for microstructural investigations in materials research. During SEM analysis, a focused electron beam scans the sample's surface and collects various signals using specialized detectors. These electrons interact with the atoms in the sample, generating signals that provide insights into surface topography and composition. Real-time imaging is facilitated through software that correlates the beam's position with the intensity of electrons detected. Figure 7 shows the instrument for SEM and EDX testing.



Figure 7: Zeiss Evo LS10

5.RESULTS AND DISCUSSION

5.1 Density

A density test measures the mass of a GP Block per unit volume. The outcome helps determine the block compactness, porosity, and overall durability. Density testing helps measure the uniformity and consistency of materials such as sand, concrete, and RRWS. The density of a GP Block can determine its strength, durability, thermal properties, and suitability for various applications. Density measurements can identify material variations and weaknesses, enabling adjustments to manufacturing techniques and material compositions to meet performance requirements. The calculation and result are presented below, highlighting how these values help in understanding the RRWS characteristics and their potential applications. Table 4 shows the data on the density, and Figure 8 shows the bar chart of the density.

Table 4 Data of Density Test

Type of sample		Density (kg/m^3)
Days	Percentage of RRWS	
7	0	2029.2
	2.5	1992.0
	5	1974.7
	7.5	1936.3
	10	1914.8
28	0	2054.2
	2.5	1995.3
	5	1980.0
	7.5	1961.7
	10	1937.1

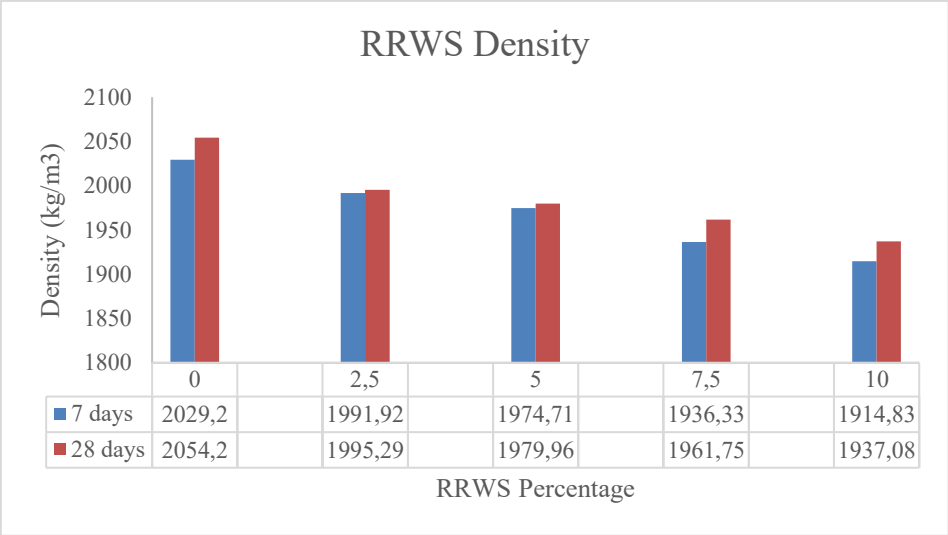


Figure 8: Bar chart of Density test

The density of the paver blocks decreased slightly when RRWS was incorporated into the mix. This is because RRWS typically contains organic matter and fine particles, which are less dense than conventional aggregates, leading to a reduction in overall mass per unit volume. Additionally, RRWS introduces more voids due to its fine and irregular particle structure, further contributing to the decrease in the density of the concrete paver blocks. These findings align with previous research by Lynn et al. (2015), which showed that the density of CPB decreases significantly with the increment of RRWS percentage, and also align with previous research by Govedarica et al. (2022), which showed that RRWS may lead to decreases in mechanical strength.

5.2 **Water Absorption**

The water absorption test was conducted to assess the porosity and potential durability of the paver blocks. This test measures the amount of water absorbed by the blocks, calculated as a percentage of the dry weight. A lower absorption rate indicates a denser and more durable material, better suited to withstand environmental wear and weathering. The results provide valuable insight into the quality and performance of the blocks, with comparisons made against standard values and previous studies to evaluate their effectiveness. Table 5 shows the data of the water absorption, and Figure 9 shows the bar chart of the water absorption.

Table 5 Data of Water Absorption Test

Type of sample			Water Absorption (%)
Days	RRWS Percentage (%)	Weight (kg)	
7	0	10.23	2029.2
	2.5	11.34	1992.0
	5	12.14	1974.7
	7.5	10.75	1936.3
	10	9.36	1914.8
	0	11.32	2054.2
	2.5	11.25	1995.3

28	5	12.31	1980.0
	7.5	12.59	1961.7
	10	11.82	1937.1

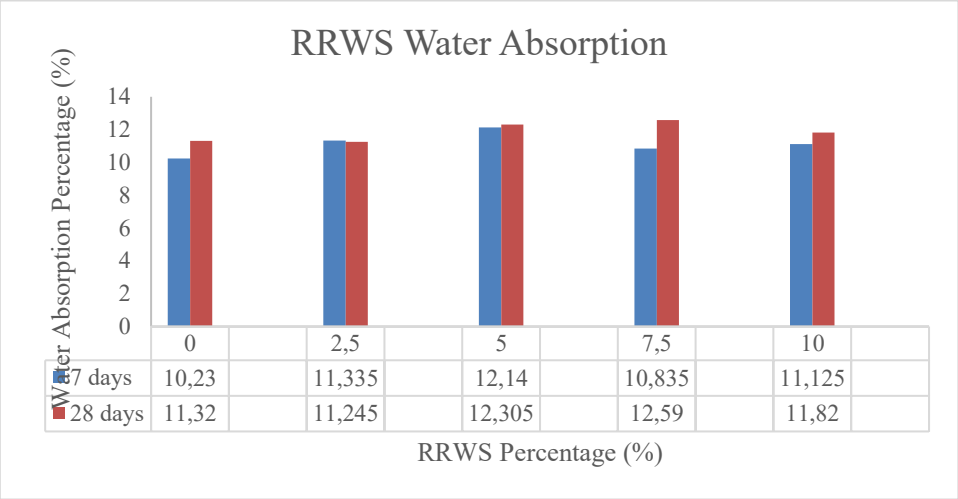


Figure 9: Bar chart of the Water Absorption test

The trend suggests that RRWS increases the water absorption capacity of paver blocks, especially at higher percentages. This is likely due to the organic and fine particulate nature of RRWS, which introduces void into the concrete matrix. These voids allow more water to be absorbed, which can affect the durability and weather resistance of the blocks. However, the non-linear behavior at 7.5% and 10% RRWS indicates that other factors, such as particle distribution, compaction quality, and curing conditions, may influence the results. These findings align with previous research by Kadam et al. (2020), which demonstrated that GP Blocks contain an interconnected void network that enables water to pass through, contributing approximately 15% to 30% of the volume. Table 6 presents the data on compressive strength, and Figure 10 displays the corresponding graph.

5.3 **Compressive Strength**

The compressive strength test was conducted to evaluate the load-bearing capacity and structural integrity of paver blocks, particularly for applications exposed to heavy loads. Blocks measuring 200 mm × 100 mm × 60 mm were prepared using a mix that included Textile Dyeing Sludge. After a 24-hour drying period, the samples were demoulded and cured, with 30 specimens tested on Day 28 to align with standard concrete curing practices. The test followed the BS EN 12390-3:2009 standard, which ensures consistency and reliability in measuring the compressive strength of hardened concrete. Results were analyzed and compared with standard benchmarks and existing literature to assess the performance of RRWS-incorporated paver blocks.

Table 6 Data of Compressive Strength

Type of sample			Compressive strength (MPa)
Days	RRWS Percentage (%)	Weight (kg)	
	0	17.5	2029.2

7	2.5	16.83	1992.0
	5	13.6	1974.7
	7.5	10.75	1936.3
	10	9.36	1914.8
28	0	23.6	2054.2
	2.5	22.19	1995.3
	5	15.58	1980.0
	7.5	15.44	1961.7
	10	12.37	1937.1

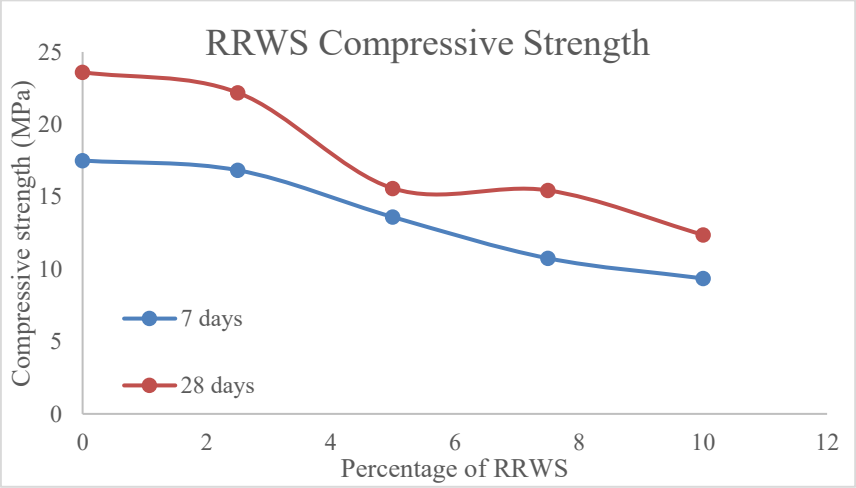


Figure 10: Graph of Compressive Strength test

The compressive strength of paver blocks incorporating varying percentages of RRWS (0% to 10%) was evaluated at 7 and 28 days of curing. Results showed a clear trend: as RRWS content increased, compressive strength decreased. This reduction is attributed to several factors, including interference with cement hydration due to organic compounds in RRWS, increased voids from its fine particle structure, and reduced overall density of the blocks. Despite this decline, the 28-day strength values were consistently higher than the 7-day results, indicating ongoing hydration and strength development over time, albeit at a slower rate in the presence of RRWS.

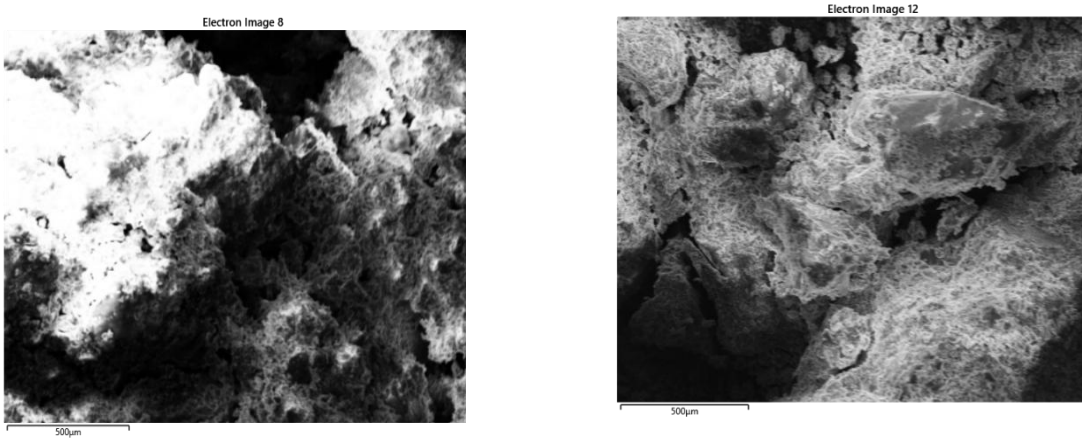
5.4 **Scanning Electron Microscope (SEM) with Energy Dispersive X-Ray Analysis (EDX)**

SEM analysis was conducted on RRWS, to examine the concrete's microstructure. The technique provided detailed insights into the RRWS elemental composition, confirming the presence of key elements, assessing homogeneity, and identifying impurities. Figure 11 shows the image of the Sample GP Block incorporating RRWS, while Figure 12 shows the result of EDX. Table 7 shows the surface morphology of RRWS, while Table 8 shows the summary result of EDX for RRWS.

Table 7 Surface Morphology

Materials	RRWS

Surface	Rough, uneven with granular texture and varying particle sizes.
Pattern	Irregular, asymmetrical with no distinct repeating structures, random particle arrangement.
Shape	Irregular, asymmetrical with no distinct repeating structures, random particle arrangement.



a) sample control b) sample incorporating RRWS

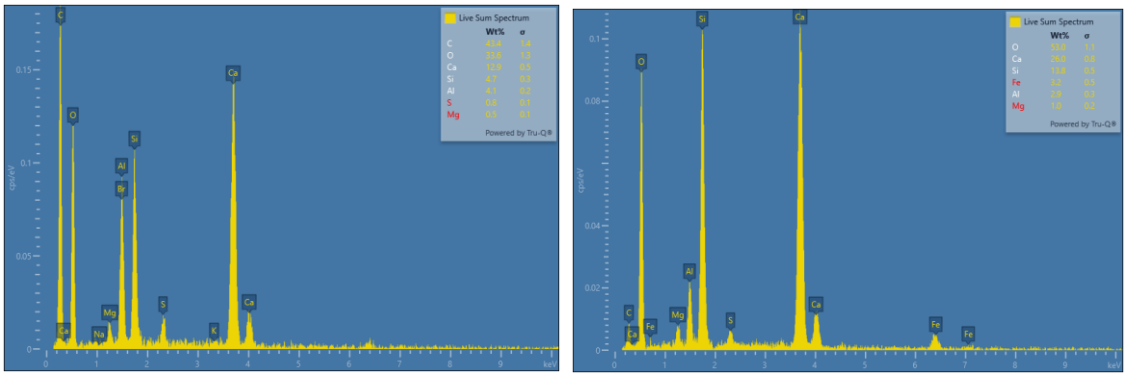
Figure 11: SEM Image for a and b

RRWS material displays a rough, uneven surface with a granular texture and varying particle sizes. This irregular morphology contributes to increased porosity when RRWS is used in paver blocks. The particles are asymmetrical and randomly shaped, lacking any consistent structure, which affects packing density and bonding efficiency within the concrete matrix. These characteristics align with earlier findings that showed reductions in both density and compressive strength when RRWS was incorporated. Despite its non-uniform structure, RRWS can still function effectively as a filler material. However, its influence on mechanical performance necessitates careful control of its content to maintain a balance between sustainability and structural integrity. These observations are consistent with previous research by Lynn et al. (2015), which confirmed RRWS's potential as a filler material in construction applications.

EDX analysis was conducted on RRWS, to examine the concrete's chemical composition. The technique provided detailed insights into the RRWS elemental composition, confirming the presence of key elements, assessing homogeneity, and identifying impurities

Table 8 Summary Result for EDX

Aspect	RRWS
Oxygen Dominance	High organic content, likely from organic binders, or biological matter in the sludge.
Metals Presence	High in calcium
Inorganic Component	Higher oxygen and metal content suggests a mixed origin
Summary	Complex mix of organic and inorganic elements



a) sample control b) sample incorporating RRWS

Figure 12: Result Chemical Properties from EDX for a and b

EDX analysis revealed that RRWS is rich in oxygen, indicating a high organic content. In addition, the presence of inorganic elements such as calcium and silicon supports its potential use as a partial cementitious material. However, the elevated organic load may negatively affect the strength and durability of paver blocks. The data also shows that increasing RRWS content raises the organic composition while slightly reducing mineral content, which corresponds with observed decreases in compressive strength and density.

6. CONCLUSION

The study successfully assessed the mechanical and physical properties of GP Blocks incorporating Recycled Raw Water Sludge (RRWS), revealing that increasing RRWS content led to reduced density and compressive strength, along with higher water absorption due to the fine and organic nature of the sludge, which introduced more voids into the concrete matrix. Despite these effects, blocks with 2.5% RRWS maintained acceptable strength (22.19 MPa), density (1995.3 kg/m³), and water absorption (11.25%), making them suitable for non-structural applications like walkways and driveways. SEM-EDX analysis confirmed the presence of calcium and silicon, supporting RRWS's role as a filler material, though its irregular particle shape and high organic content necessitate careful control to balance sustainability with structural integrity. The study recommends a 2.5% RRWS mix ratio as the optimal ratio, supported by proper curing for at least 28 days and leachability testing to ensure safety and durability. Additionally, it encourages further research to refine material characterization and expand RRWS applications in sustainable construction.

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ANALYSIS OF THE UTILIZATION OF CERAMIC CRACKED WASTE AS A SUBSTITUTE FOR COARSE AGGREGATE IN K-325 GRADE CONCRETE (FC' 28.8 MPA)

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ABSTRACT

The growing demand for building supplies and the rise in construction waste are both impacted by the quick growth of infrastructure. One of the construction wastes that is quite abundant and has not been used to its full potential is ceramic shard trash. This study aims to analyze the effect of the use of ceramic shard waste as a partial replacement of coarse aggregate on the properties of fresh concrete and hardened concrete at the quality of K-325 (fc'28.8 MPa). The research method used is a laboratory experiment with variations in the substitution of coarse aggregate by ceramic shard waste of 0%, 10%, 20%, and 30%. The tests carried out include slump tests and concrete compressive strength tests at the age of 28 days. The results of the study showed that increasing the percentage of ceramic waste caused a decrease in the slump value, but all variations still met the workability requirements of concrete. The highest concrete compressive strength was obtained at 10% substitution of 353.25 kg/cm², higher than normal concrete at 325.33 kg/cm². At 20% and 30% substitution, the concrete compressive strength decreased. The results of this study indicate that ceramic waste fragments can be used as a substitute for coarse aggregate up to an optimal limit of 10% to produce K-325 quality concrete that meets technical requirements and supports the concept of sustainable construction.

Keywords: ceramic waste, coarse aggregate, K-325 concrete, compressive strength, slump

1. INTRODUCTION

1.1. Background

One of the industries that uses the most natural resources is the building sector, especially the natural aggregates used to make concrete. As the main building ingredient, concrete needs a lot of aggregate—roughly 70–75% of the total volume. Broken ceramics are among the substantial amounts of solid trash produced by construction and restoration projects(Mulyadi, Asri; Sanutra 2017). Waste ceramic shards are produced during building construction, installation, and demolition. Inorganic, hard, and non-biodegradable, ceramic materials can harm the environment if they are disposed of improperly. Reusing ceramic waste is therefore necessary in order to add value and lessen its detrimental effects on the environment(Asri;et.al Mulyadi 2018).

As part of the reduce, reuse, and recycle (3R) philosophy, the use of ceramic waste as aggregate in concrete has been extensively researched. Ceramics have a rough surface and a strong compressive strength, which may strengthen their bond with cement paste. However, if ceramics are utilized in excess, their brittle nature may have an impact

on the performance of concrete(Mulyadi, Asri;Suanto, Pengki ;Toni 2022). The purpose of this research was to examine the effects of utilizing ceramic waste in place of some of the coarse aggregate on the characteristics of both fresh and hardened concrete at K-325 quality (fc'28.8 MPa).

1.2. Research Aim

The problems studied in this research include:

1. How does the slump value of K-325 concrete change when ceramic waste is used in place of coarse aggregate?
2. What is the impact on K-325 concrete's compressive strength when coarse aggregate is replaced with ceramic waste?
3. What percentage of ceramic shard debris replaces coarse aggregate to produce the best results?

1.3. Research Objectives

The objectives of this research are:

1. Analyzing the effect of using ceramic waste fragments on concrete workability.
2. To determine the effect of substitution of ceramic waste fragments on the compressive strength of K-325 grade concrete.
3. Determining the optimal substitution percentage of ceramic waste as coarse aggregate.

1.4. Reseacrh Benefits

This research is expected to provide benefits:

1. **As a substitute for coarse aggregate in concrete.**
2. **Reducing construction waste and exploitation of natural aggregates.**
3. **As a reference for sustainable concrete research.**

2. LITERATURE REVIEW

2.1. Concrete and Concrete Quality

Cement, fine aggregate, coarse aggregate, and water make up the composite material known as concrete(Asri; et. al Mulyadi 2019). The compressive strength of concrete at 28 days, which is stated in MPa or class K, determines its quality.

2.2. Coarse Aggregates

The strength and stability of concrete are greatly influenced by the coarse aggregate that serves as a framework. The SNI standards for gradation, cleanliness, and wear resistance must be met by good coarse aggregate(A. S. Mulyadi 2021).

2.3. Ceramic Shards Waste

Ceramic shards are a type of inorganic trash that is brittle, hard, and capable of absorbing some water. These qualities enable them to be utilized in specific ratios as a substitute coarse aggregate.

2.4. Previous Research

Several studies have shown that the use of ceramic waste as aggregate can increase compressive strength at low levels, but reduce workability and strength at high levels.

3. RESEARCH METHODOLOGY

3.1. Research Type

This research is a laboratory experimental research.

3.2. Mixed Variations

Variations of coarse aggregate substitution by ceramic waste:

1. BN : 0%
2. BK10 : 10%
3. BK20 : 20%
4. BK30 : 30%

3.3. Materials and Objects Test

The test object was a 15 x 15 x 15 cm cube. At 28 days of age, the compressive strength test was conducted.

3.4. Testing Method

1. Slump Test (ASTM C143)
2. Concrete compressive strength test (SNI)

4. RESULT AND DISSCUSION

4.1. Slump Test Result

The slump value of concrete decreases as the ceramic waste content increases:

Table 4.1. Slump Value (Source : Result of Slump Test Value)

No.	Concrete	Slump Value (cm)
1	Normal (BN)	9
2	With 10% ceramic waste from the weight of Split Stone (BK10%)	8,7
3	With ceramic waste fragments 10% of the weight of Split Stone (BK20%)	7,7
4	With ceramic waste fragments 10% of the weight of Split Stone (BK30%)	6

This decrease is caused by the rough surface of ceramic waste and higher water absorption capacity.

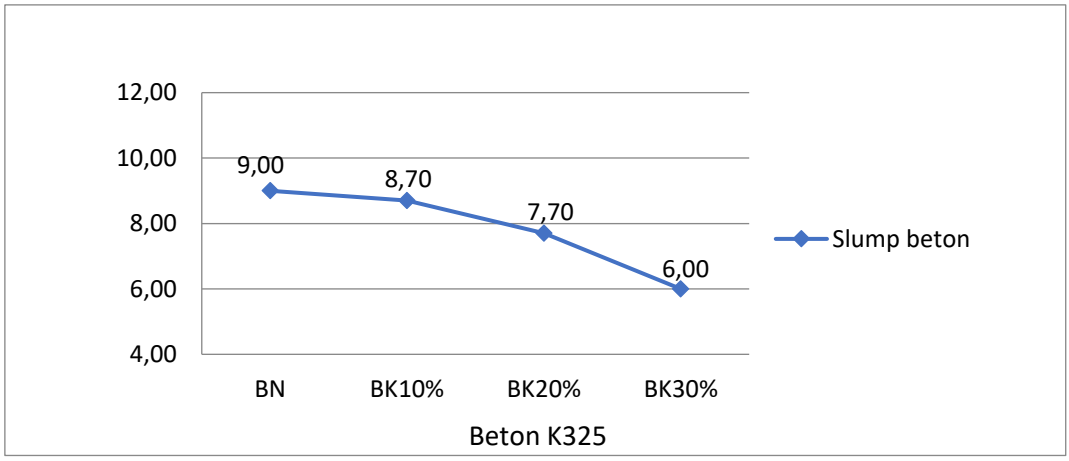


Figure 4.1. Graph of Slump Value
Source : Result of Slump Test Value

4.2. Compressive Strength Test Results

Results of the compressive strength test of 28-day-old concrete:

Table 4.2. Compressive Concrete Strength Test (Source: Result Of Compressive Concrete Strength Testin 28-Day-Old.

No.	Concrete Quality K-325	Average orf s Destroyed (kg/cm^2)
1	BN	325,33
2	BK 10	353,25
3	BK 20	301,93
4	BK 30	281,55

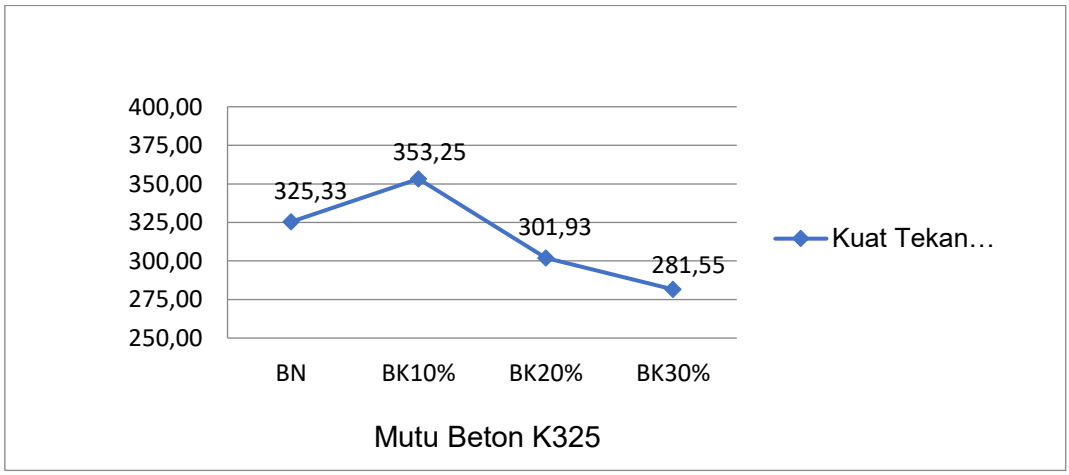


Figure 4.2. Graph of Compressive Concrete Strength Test
Source : Result Of Compressive Concrete Strength Testin 28-Day-Old.

Because of improved aggregate-cement paste interlocking and bonding, a 10% substitution produces the best compressive strength. Because ceramics are brittle, compressive strength drops at increasing replacements.

4.3. Disscusion

According to the study's findings, leftover ceramic shards can be partially utilized as coarse aggregate. Compressive strength is increased with an ideal substitute of 10% without appreciably decreasing workability. This result is consistent with the sustainable concrete and construction waste utilization concepts.

5. CONCLUSSION AND SUGGESTION

5.1. Conclussion

1. The slump value is decreased when ceramic waste particles are substituted, but the concrete workability standards are still met.
2. The compressive strength of K-325 concrete is increased by substituting 10% ceramic waste.
3. Concrete's compressive strength is greatly decreased with substitutions more than 20%.
4. 10% is the ideal proportion to use ceramic waste as coarse aggregate.

5.2. Suggestion

1. The durability of concrete made from ceramic waste requires more investigation.
2. To increase workability, ceramic waste can be combined with chemical additives.
3. To determine whether implementation in the field is feasible, economic and environmental analysis is advised.

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CORROSION OF CONCRETE REINFORCEMENT STEEL IN RELATION WITH W/C RATIO AND PERMEABILITY

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Abstract

Study about the relationship between W/C ratio and concrete permeability and concrete reinforcement steel corrosion already done and some conclusions are drawn. The infiltration of O2 and H2O into concrete body is the way to bring together the corrosive components to the surface of reinforcement steel inside the concrete. Chloride and CO2 infiltration supporting the corrosion process by chemically lowering the concrete pH. Permeability and W/C ratio became important factors beside external factors. Literature studies have shown that concrete reinforcement steel will health when the pH of steel stabilized at 12 and permeability of concrete will at best value of 0.4 and poor at 0.7

Keywords: Corrosion; Concrete steel reinforcement; W/C ratio; Permeability.

1. Introduction

Reinforcing steel is crucial for increasing the strength of concrete. Reinforcing steel is the mainstay of a construction's strength. Its presence makes a concrete structure strong enough to withstand compressive loads, tensile loads, bending moments, and shear forces. This increase in concrete strength cannot be measured qualitatively, as it depends on the size of the reinforcing steel, the binding, and other factors such as the quality of the cement, sand, and aggregates.[1]

Without reinforcing steel, concrete will only have compressive strength, while its tensile strength is very weak. The tensile strength of concrete is typically only around 7% to 10% of its compressive strength [2]. 2. Factors Causing Reinforcing Steel Corrosion divide into these factors i.e. internal factors and external factors. Internal factors include: the water/cement ratio (W/C ratio), concrete shrinkage, and the quality of materials such as sand, coral, and acidic water. [1] Concrete with a high water/cement ratio will be porous. These pores will become entry points for corrosive elements such as water and oxygen, as well as other harmful elements like chloride and sulfate. Furthermore, high concrete porosity will reduce the concrete's physical strength. The infiltration of the corrosive substances will deepen over time and potentially reach the surface of the reinforcing steel and start the corrosion process.

Furthermore, the water used should clean and neutral with a pH of 7. Non-acidic water will give positive impact to the concrete's strength. Sand and other aggregates should preferably be sourced from river rather than seawater. River sand is expected to have a low chloride content.

2. Factors of Concrete Reinforcing Steel Corrosions

To understand the corrosion of concrete reinforcement, several determining factors are discussed below, including: Internal and External Factors. Internal factors include the quality of the concrete itself. Concrete quality is greatly influenced by factors such as the W/C ratio, permeability, and microcracks. External factors include the environment and the forces acting on the structure. Concrete can be in water, soil, or other environments.

2.a. W/C ratio and Concrete Permeability

The W/C (Water-Cement) ratio is the weight of water divided by the weight of cement in a concrete mix, a crucial factor determining concrete's strength, durability, and workability; a lower W/C ratio (e.g., 0.4-0.5) yields stronger, less permeable, more durable concrete, while a higher ratio (e.g., 0.6+) increases workability but reduces strength and increases porosity, with ideal ratios balancing performance needs

Concrete with low cement content will have many pores and easily infiltrated by corrosive agents. High-quality concrete tends to be denser, less permeable, and more resistant to cracking, thus providing better protection for the reinforcing steel from corrosive agents.

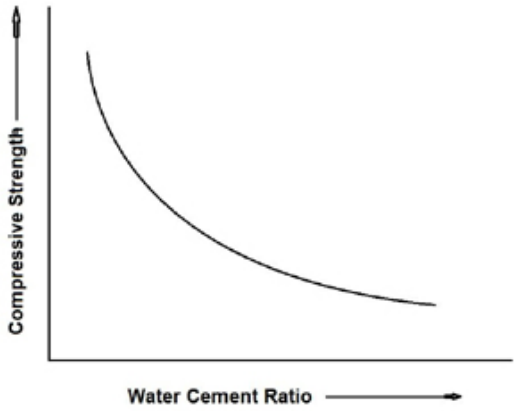


Figure 1. The relationship between W/C ratio and the strength of concrete. (Web-1)

2.b. Permeability and Microcrack

Permeability and microcrack have significant role in facilitating the corrosive agents entering into the concrete and meet the surface of reinforcing steel.

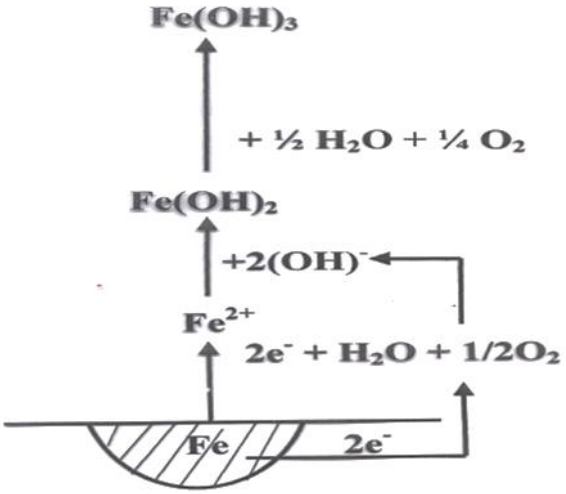


Figure 2. Corrosion of reinforcing steel by water and oxygen at the early stage.

Figure 2 showing the process when the oxygen and the water reacted on the surface of the steel. The steel will undergo the oxidation reaction such as this:

$$Fe \rightarrow Fe^{2+} + 2e^-$$

The reduction process at the cathodic site:

$$2e^- + H_2O + ½\ O_2 \rightarrow 2\ (OH)^-$$

This corrosion process will continued by the water and oxygen form ferri hydroxide ($Fe(OH)_3$ and so forth. Besides, corrosion can also occur by the carbonation process i.e, the reaction between carbon dioxide (CO_2) and calcium hiroxide in concrete ($Ca(OH)_2$).

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

Shrinkage is a cause of crack of concrete during the hardening process. [2] This shrinkage is primarily caused by the evaporation of water content in the concrete. The inhomogeneous shrinkage of concrete will cause hairline cracks (microcracks). These microcracks allow corrosive agents from the outside of the concrete to enter the concrete and reach the surface of the reinforcing steel. External factors such as soil, water, wet air and chemical atmospheric also considered as the external environment. As shown in Figure 1 , water and oxygen that enter the concrete through the pores and microcracks will reach the surface of reinforcing steel and initiate corrosion reaction. These external factors are significantly determined by the maintenance, inspection and supervision of the construction. Maintenance includes the regular inspection of the outer surface of the concrete. Supervision involves controlling the concrete pH and monitoring the interface potential of the steel to keep the reinforcing steels healthy.



Figure 3. Concrete can be in soil, water or wet air and humid environments. (Web-2)

2.c. Chloride Content

Chloride is one of the corrosive agent to the reinforcing concrete steel. Chloride could peeled off the passive film of steel and initiates corrosion by forming FeCl on the surface of steel. Many measurements have conducted, and it is recommended that the best depth of steel is 50 milimeters or more from the surface of concrete.

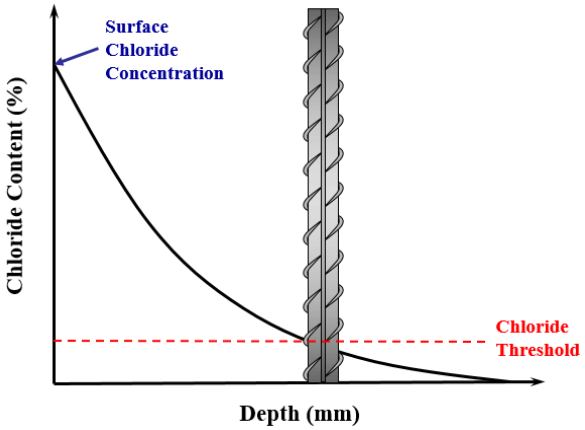
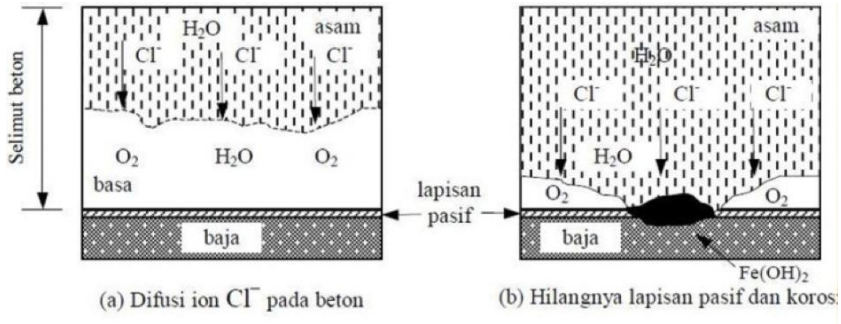


Figure 3. Chloride content and the depth of steel inside concrete. (Web-3)



a. (b)

Figure 4. Chloride diffusion into concrete. (Web-4)
(a). The chloride diffusion into concrete.
(b). the steel passive film peeled off and corrosion initiated.

2.d. Concrete spalling

The oxide that forms on the surface of the reinforcing steel will enlarge and thicken over time. This oxide, in turn, will push and separate the bond between the concrete and the reinforcing steel. This pressure from the oxide, in turn, will create hairline cracks in the concrete.

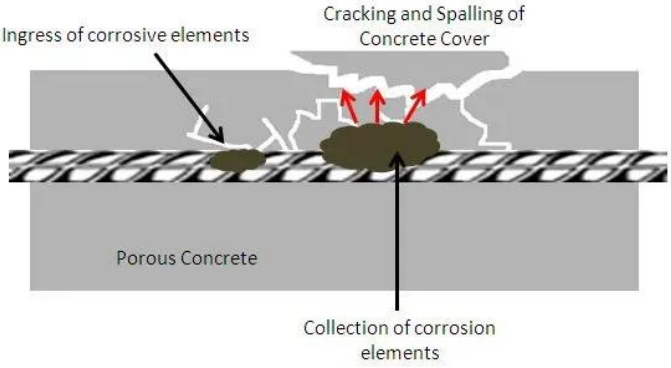


Figure 5. Hairline cracks are created due to the pressure of oxides that form on the surface of the reinforcing steel. (Web-5)



Gambar 6. Concrete collapses due to the pressure exerted by oxides on the surface of the reinforcing steel, which enlarge and thicken over time. (Web-6)

3. The Phases of Concrete Failure

Reinforcing steel corrosion is a process of damage to concrete reinforcement that occurs due to the infiltration of harmful elements from outside the concrete, and the process is a function of time. The process of damage to concrete structures due to corrosion of reinforcing steel can be divided into four stages: the incubation stage, the development stage, the acceleration stage, and the catastrophic stage. The progression from the initial phase to the subsequent phase is characterized by an increasing rate of corrosion in the reinforcing steel. The initial phase begins with the appearance of surface defects in the concrete, such as pitting or microcracks, which allow harmful elements from outside the concrete to penetrate and reach the surface. The most harmful elements to reinforcing steel are water and oxygen. Chloride and sulfate are also present. When chloride reaches the steel surface, it flakes off the passive layer and forms FeCl 2 with the steel. Sulfate can also originate from acid rain, where 2H+ ions react with Fe 2+ to form Fe 2+ and free hydrogen.

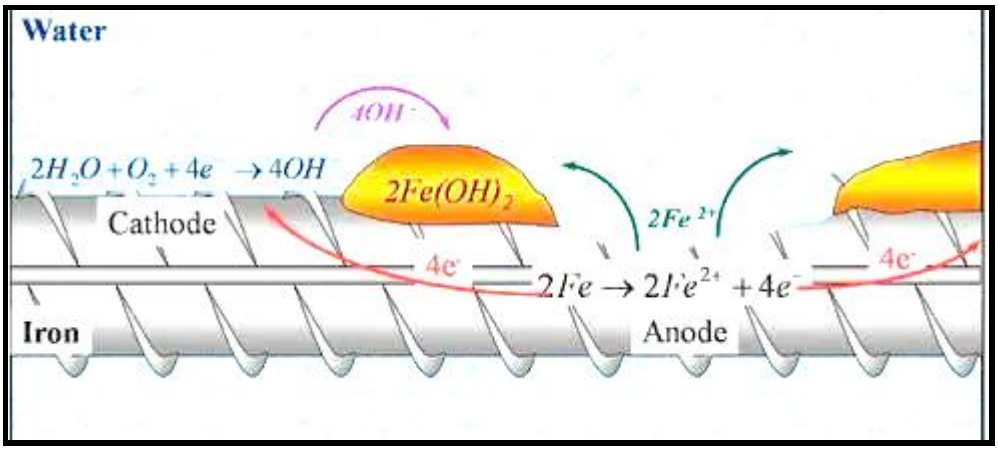


Figure 7. Corrosion process by moisture and oxygen on the surface of reinforcing steel (Web-7)

The initiation phase begins when reinforcing steel is embedded in concrete, where a passive layer forms on the steel surface. This passive layer will then peel off if corrosive

elements that penetrate the concrete reach the steel surface. This passive layer will peel off, and the corrosion process will begin. The propagation phase begins when corrosion of the reinforcing steel has already occurred, causing an increase in the corrosion rate and resulting in a reduction in the cross-sectional area of the reinforcing steel, thus reducing its strength. This reduction in the steel's cross-sectional area will impact the steel's ability to support construction loads. This will ultimately lead to structural damage, where the structure is no longer able to support the loads it carries. This can occur before the structure reaches its intended operational life.



Fig 8. Corroded of reinforcing steels in open atmosphere before constructed (Web-8)

The image above shows reinforcing steel that has been corroded before construction. Based on SNI 2052:2017, only mild corrosion is permitted on reinforcing steel during construction. Severe corrosion, as shown in the image above, is not recommended, because the oxide layer on the steel surface will weaken or even eliminate the bond between the steel and concrete.

4. Conclusions

a. The corrosion on the surface of concrete reinforcing steel could happen by internal factor of concrete such as W/C ratio, permeability dan hairline crack.
b. External factor such as environment, chloride content of the surrounding and maintenance is important factor for the construction.
c. Regular monitoring of the metal interface potential is recommended to ensure the health of the reinforcing steel.

Acknowledgement

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REDUCING GROUNDING RESISTANCE BY THE METHOD OF ADDING AND WELDING GROUNDING ELECTRODES AT DISTRIBUTION SUBSTATIONS

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Abstract

The reliability of the electric power distribution system is greatly influenced by the performance of the grounding system at the distribution substation. Operational data in the work area of the Customer Service Unit in (ULP) the Pendopo area shows that 94% of the 529 transformer units have a grounding resistance above 10 Ω, exceeding the safe limit of PUIL 2011 (≤5 Ω), thus increasing vulnerability to disturbances due to lightning strikes. This study aims to test the effectiveness of the method of adding and welding grounding electrodes in a relay using galvanized pipes in reducing grounding resistance. The field experimental method was applied to five 20 kV distribution substations with a pretest-posttest design. The measurement results showed a significant decrease in resistance from an initial average of 30.53 Ω to a final average of 2.99 Ω, with all samples meeting the standard below 5 Ω. Statistical analysis confirmed a highly significant difference ($p < 0.001$) before and after the intervention. Besides being effective, this method is also more economical (40% lower cost than chemical grounding systems) and efficient in terms of implementation time. Therefore, this method can be a sustainable technical solution to improve the reliability of lightning protection systems at distribution substations in lightning-prone areas.

Keywords: *grounding resistance, electrode welding, distribution substation, lightning protection, relay grounding system .*

1. INTRODUCTION

The reliability of the electric power distribution system is highly dependent on the performance of distribution transformers as the main component that distributes energy from the transmission network to consumers (Lin et al., 2023) . As a high-value asset, the optimal performance of these transformers must be maintained to ensure continuity of electricity supply (Vita et al., 2023) . Disturbances in distribution transformers not only cause electrical energy not to be distributed or blackouts (Gheorghe & Burlică, 2024) , but also cause economic losses and decreased service quality (Obinna Okeke et al., 2024) . Globally, transformer disturbances can be caused by internal factors such as overload , load imbalance, insulation damage, and protection failure (Huang et al., 2025) , as well as external factors such as lightning strikes, physical accidents, and natural disasters (Tajdinian & Samet, 2022) . In the work area of the customer service unit in the Pendopo area, Operational data from 2023 shows that lightning strikes were the dominant cause of disruptions, contributing 37.5% of total incidents. This correlates with the geographic characteristics of the area, which is prone to lightning activity.

Standard mitigation efforts through the installation of arresters often not optimal without adequate grounding system support (Putra, Yani, et al., 2023) . Measurement results in 2023 revealed that 94% of the 529 distribution transformer units in the region had grounding resistance values above 10 Ω , exceeding the 2011 PUIL safety threshold which requires a maximum of 5 Ω (Putra et al., 2024) . This phenomenon indicates the ineffectiveness of conventional grounding methods (parallel systems) in achieving the required performance, especially on soils with high resistivity (Putra, Pardede, et al., 2023) , thus leaving systemic vulnerability to damage due to lightning surges (Yani et al., 2024) .

Based on these problems, effective, economical, and sustainable technical innovations are needed. This study proposes and tests the implementation of a grounding method for a relay circuit welded with pipes **,** a modification of the grounding system that utilizes chain welded joints on galvanized pipes to deepen the electrodes to reach soil layers with better conductivity. The objectives of this study include analyzing the effectiveness of the method in reducing grounding resistance below 5 Ω and evaluating the consistency of implementation results in the field and examining its technical implications for increasing the reliability of lightning protection systems in distribution substations.

2. RESEARCH METHODS

This study uses a field experimental approach to test the effectiveness of the method of adding and welding grounding electrodes in reducing grounding resistance in distribution substations. The research design adopted a one-group pretest-posttest pattern , where resistance measurements were carried out before and after the implementation of the intervention on the same sample . The research location is located at five 20 kV distribution substations in the Pluto Feeder, ULP Pendopo working area **,** which were selected purposively based on the criteria of initial resistance value >10 Ω and a history of locations prone to lightning strikes. Data collection was carried out through direct measurements using a digital earth tester, systematic observation of the implementation process, and study of historical disturbance data documentation.

The implementation procedure consists of:

1. Initial resistance measurements at the arrester, neutral and body points;
2. Planting additional electrodes in a relay manner using galvanized pipe welding techniques;
3. Periodic measurements until the resistance reaches below 5 Ω; and
4. Post-intervention final measurements.

Data were analyzed quantitatively using descriptive statistics and paired sample t-tests to compare significant differences between pre- and post-treatment conditions, with a 95% confidence level. Data validity was ensured through instrument calibration, standardization of measurement procedures, and triangulation of data sources .

3. RESULTS AND DISCUSSION

3.1 Results of Implementation and Analysis of Method Effectiveness

The implementation of the method of adding and welding grounding electrodes at five distribution substations resulted in a significant reduction in grounding resistance. Before the intervention, all samples showed resistance values above 10 Ω, with a range of 10.7 - 79.9 Ω and an average of 30.53 Ω . After the repair, all measurement points (arresters, neutrals, and bodies) successfully achieved values below the standard of 5 Ω, with a new average of 2.99 Ω (range 1.91 - 4.68 Ω). Statistically, the paired sample t-test showed a highly significant difference ($p < 0.001$) between the conditions before and after the intervention.

Table 3.1 Results of Method Implementation on Five Sample Substations

No. Substation	Location	Average Resistance Before (Ω)	Average Resistance After (Ω)	Decrease (%)	Number of Additional Bars
U 0004	Rami Pasai	79.27	3.51	95.6	4
U 0005	Pagar Dewa	17.04	3.38	80.2	4
U 0006	Pagar Dewa	12.1	3.08	74.5	4
U 0007	Betung	12.8	2.68	79.1	4
U 0008	Betung	13.24	2.16	83.7	4

The data shows that the greatest resistance reduction occurs in the substation with the highest initial value (U 0004: 95.6 %), indicating that this method is particularly effective for locations with very poor grounding conditions. The consistent use of 4 additional electrode rods in all samples indicates that the effective depth of the relay system is in the range of 9–12 meters , in accordance with theoretical predictions.

3.2 Reduction Mechanism and Advantages of the Method

The drastic reduction in grounding resistance can be explained by two main mechanisms optimized by this method. Based on the rod electrode resistance equation:

$R=2 \times \pi \times L \times \ln 4 \times La -1 \quad (1)$

Increasing the electrode length (L) significantly reduces the R value, especially in soils with heterogeneous resistivity (ρ). The relay system allows penetration into soil layers with higher water content, which in this study was shown to reduce resistance by up to 86.4 % on average. This result is consistent with previous studies which stated that every 2 meters of additional depth can reduce resistance by 0.5–0.6 Ω in soil with ρ=30 Ωm.

Conventional mechanical connections (bolts) have additional contact resistance (typically 0.5–2 Ω) that is not accounted for in theoretical models. Welding metallurgically fuses the materials, reducing the interfacial resistance to near zero. This explains why the field results (1.91 Ω at substation U 0008) are better than the theoretical predictions (2.662 Ω for a depth of 12 meters).

By achieving resistance below 5 Ω, the footing voltage (voltage that arises when lightning current flows to the ground) can be suppressed below the transformer's insulation level. Calculations show that for a lightning current of 10 kA, the voltage in the old grounding system (30 Ω) reaches 300 kV, far exceeding the BIL (Basic Impulse Level) of a 20 kV transformer (125 kV). After rectification (3 Ω), the voltage drops to 30 kV, so that the surge energy can be safely dissipated through the arrester.

3.3 Technical and Operational Implications

During the three-month post-implementation monitoring period, no substations experienced repeated lightning-related outages. This confirms that reducing grounding resistance is directly proportional to increasing protection reliability. Based on historical data, where 37.5 % of outages are caused by lightning, this method has the potential to significantly reduce the System Average Interruption Duration Index (SAIDI) .

This method uses local materials (galvanized pipe) and costs 40% less than chemical grounding systems. The average implementation time of 6 hours per substation is also faster than conventional methods that require extensive excavation. ROI calculations show that the investment in improvements can be recovered within 1.2 years through reduced transformer repair costs and reduced energy losses.

Implementing this method requires field welding skills and adequate equipment. Results may also vary in soils with very hard bedrock or very low water content. However, the flexibility of the relay system allows for depth adjustments to suit field conditions.

4. CONCLUSION

Based on the identification of the problem of high distribution transformer disturbances due to lightning strikes in the Pendopo area, which was triggered by an average grounding resistance condition of >30 Ω (94% of transformers >10 Ω) so that it did not meet the 2011 PUIL standard (<5 Ω), this study successfully proved that the implementation of the grounding method through the addition and welding of galvanized pipe electrodes in a relay manner—can drastically reduce the grounding resistance to an average of 2.99 Ω (86.4% reduction) while meeting safety standards in all sample substations. This success not only improves the technical performance of the grounding system, but also contributes significantly to reducing the potential for operational disturbances and increasing the reliability of electricity supply, with added value in the form of cost efficiency, use of local materials, and permanent, sustainable solutions to be applied to distribution networks in lightning-prone areas.

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ANALYSIS THE APPLICATION OF GLASS LIGHTBALL WASTE AS A FINE AGGREGATE SUBSTITUTION IN K-175 GRADE CONCRETE MIXTURE (14.5 MPA)

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ABSTRACT

Serious environmental issues are brought on by the growing use of light bulb glass debris as non-biodegradable inorganic trash. Using it as a building material is one way to handle trash sustainably. The purpose of this study is to examine how the properties of FC 14.5 MPa (K-175) quality concrete are affected when light bulb glass debris is used as a partial replacement for fine aggregate. A laboratory experiment with variations in glass waste substitution of 0%, 4%, 6%, and 8% of the fine aggregate weight was the research methodology. Slump tests, concrete specific gravity, and concrete compressive strength after 28 days were all tested. The slump value decreased as the amount of glass waste increased, but it remained within the workability standard limitations, according to the data. With a maximum value of 255.13 kg/cm² at 6% variation, the concrete's compressive strength rose at 4% and 6% substitution before falling at 8% substitution. The study's findings indicate that 6% of the fine aggregate weight is the ideal replacement proportion for lightbulb glass trash. According to this study, recycled lightbulb glass may be utilized in low-quality concrete as an eco-friendly substitute.

Keywords: light bulb glass waste, K-175 concrete, fine aggregate, compressive strength, workability

1. INTRODUCTION

Concrete is becoming more and more popular as a key building material due to rapid infrastructural development. Because of its great compressive strength, longevity, and ease of field application, concrete is the preferred material. However, the overuse of natural aggregates and higher carbon emissions from cement manufacture are the results of this high concrete use(Asri Mulyadi; Saloma; Siti Aisyah Nurjannah, 2025). However, a significant amount of glass trash has been produced by the growing use of glass-based items, especially light bulbs. Glass debris from light bulbs is not biodegradable and takes a very long time to break down naturally. This trash has the potential to contaminate the environment and endanger human health if improperly managed(Mulyadi, 2018).

Glass debris has a significant silica concentration, which could help improve the mechanical qualities of concrete when employed in specific amounts, according to several

studies. It is anticipated that using glass trash in place of fine aggregate will cut waste, preserve natural resources, and promote sustainable building practices.

The application of waste glass light bulbs as a partial replacement for fine aggregate in FC 14.5 MPa (K-175) concrete, which is frequently utilized in non-primary and simple building construction, is the main topic of this study. It is anticipated that this research will contribute both scientifically and practically to the use of glass waste in civil engineering(Mulyadi, 2019).

2. LITERATURE REVIEW

2.1. The Components of Concrete

Concrete is a solid mass with a certain strength that is created by hydrating a mixture of cement, fine aggregate, coarse aggregate, and water. The quality and ratios of the ingredients that make up concrete have a big impact on its properties.

2.2. The Aggregates-Concrete

Aggregates served 60–80% of the volume of concrete and act as its framework. Proper gradation, a normal specific gravity, a low silt content, and regulated water absorption are all characteristics of good aggregates(Asri Mulyadi, Saloma, 2024).

2.3. The Waste Glass Light Bulbs

Silica (SiO_2), which is strong and difficult to breakdown, makes up the majority of light bulb glass waste. Glass debris may be used in place of fine aggregate once it has been crushed to a specific size(Asri Mulyadi, 2020).

2.4. The Effect of Glass Waste on Concrete

Concrete density can be increased and compressive strength may be somewhat increased by using glass waste. On the other hand, overuse can make the concrete less workable and more brittle.

3. RESEARCH METHODOLOGY

3.1. Research Types and Methods

The purpose of this study, which is a lab experiment, is to ascertain how specific treatments affect the characteristics and functionality of concrete. The experimental approach was selected because it enables researchers to methodically manipulate the research variables, enabling a precise and quantifiable examination of the causal links between them.

3.2. Ingredients and Mixture Variations

Portland cement as a binder, fine aggregate, coarse aggregate, water, and leftover lightbulb glass—which served as a partial replacement for the fine aggregate—were the materials utilized in this investigation. To make sure they satisfied the tangible quality requirements of relevant standards, all materials were put through a physical property test in the lab.

The following modifications in the substitution of light bulb glass trash used in this investigation are stated as a percentage of the weight of fine aggregate:
0% waste glass light bulbs (control: regular concrete),
4% of glass waste from light bulbs

6% of glass waste from light bulbs, and
8% of glass waste from light bulbs.

3.3. Testing Preparation and Maintenance

The testing were 15 x 15 x 15 cm cubes. Concrete materials were mixed in accordance with the intended mixture composition for each variant of light bulb glass waste substitution before test specimens were manufactured. The test specimens were taken out of the mold (demolding) and cured by submerging them in water once the concrete had attained its initial hardening. Until the test age of 28 days was achieved, this therapy was administered for 27 days.

3.4. Testing

In this research, tests were carried out to ascertain the properties of both fresh and hardened concrete as a result of differences in the replacement of waste light bulb glass.
The examinations conducted comprised:Slump test (SNI 1972:2008).
Compressive strength test of concrete after 28 days (SNI 1974:2011).
Specific gravity test for concrete.

4. RESULT AND DISSCUSION

4.1. Material Characteristics

The characteristics of the concrete components used in this research were obtained through a series of laboratory tests on fine and coarse aggregates. The fine aggregates used came from the Musi River, while the coarse aggregates came from Lahat. The test results showed that the Musi River fine aggregates had good grain gradation, specific gravity and water absorption that were still within the permitted limits, and mud content that met the provisions of the Indonesian National Standard (SNI). and the Lahat coarse aggregates also showed test results that met SNI specifications, both in terms of gradation, specific gravity, water absorption, and resistance to wear.

4.2. Concrete Workability

According to SNI 1972:2008, slump testing was used in this investigation to assess the workability of the concrete. The purpose of this test is to ascertain the fresh concrete's workability level in each variation of lightbulb glass waste substitution and to guarantee the concrete's ease of workability throughout the casting process. The concrete slump value shows a decreasing trend as the percentage of light bulb glass waste increases, however, all mixture variations are still within the required slump value range of 60–100 mm.

Table 4.1. The correlation between the slump value and the percentage of glass waste (Source : Research Result of Slump Test Concrete K175)

No.	Concrete	Slump Value (cm)
1	Normal (BN)	10
2	Glass light bulb trash makes for 4% of the sand's weight (BB4%).	9,3

3	6% of the weight of sand is made up of used glass light bulbs (BB6%).	8,7
4	8% of the weight of sand is made up of waste glass light bulbs (BB8%).	8

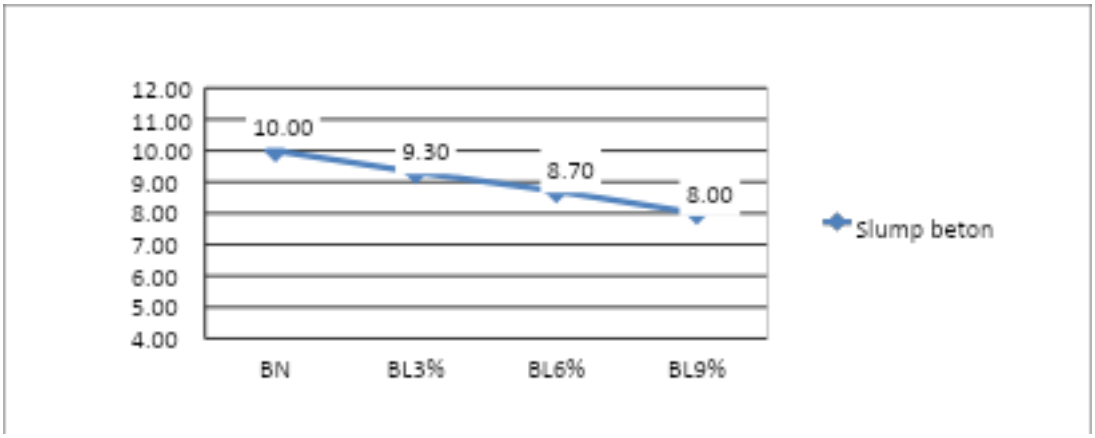


Figure 4.1. Graph of the relationship between the percentage of glass waste and the slump value
Source : Research Result of Slump Test Concrete K175

4.3. Concrete Compressive Strength

In compliance with SNI 03-6805-2002, a cube-shaped test specimen measuring 15 × 15 × 15 cm was used to test the compressive strength of concrete after 28 days. The purpose of this test is to ascertain how different light bulb glass waste substitutions affect concrete's capacity to sustain compressive stresses.

Table 4.2. Results Of Concrete Compressive Strength Test
(Source : Results Of Concrete Compressive Strength Test K175)

No.	Concrete Quality 14.5 Mpa (K175)	Average σ Destroyed (kg/cm2)
1	BN	175,12
2	BL4%	194,74
3	BL6%	255,13
4	BL8%	181,16

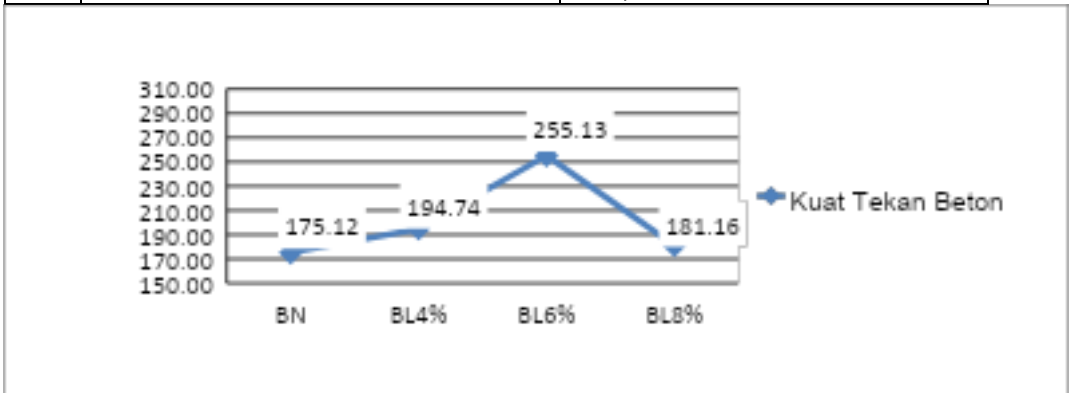


Figure 4.2. Graph of The Results Of Concrete Compressive Strength Test

Source : Results Of Concrete Compressive Strength Test K175

At substitution variations of 4% and 6%, concrete's compressive strength improved dramatically, reaching its maximum value at 6% substitution. Compressive strength dropped at 8% substitution as a result of reduced concrete workability and cement paste efficacy.

4.4. Discussion

The research's findings demonstrated that substituting light bulb glass waste up to a specific percentage limit improved concrete performance, particularly compressive strength, suggesting that light bulb glass waste might be used as a substitute ingredient in concrete mixtures.

5. CONCLUSSION AND SUGGESTION

5.1. Conclussion

1. Concrete's workability and compressive strength are impacted by lightbulb glass trash.
2. A content of 6% of the fine aggregate weight yields the ideal substitution percentage.
3. Every combination variation satisfies the fc 14.5 MPa concrete quality standard (K-175).
4. An eco-friendly substitute material might be made from used glass light bulbs.

5.2. Suggestion

1. Further research is recommended to examine the durability aspects of concrete.
2. More research is required to understand variations in the size of glass waste grains.
3. Application at the field scale is advised.

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SNI 1972:2008 merujuk pada "Cara Uji Slump Beton" yang diterbitkan oleh Badan Standardisasi Nasional (BSN) Jakarta

SNI 03-2834-2000: Tata Cara Pembuatan Rencana Campuran Beton Normal

SNI 03-1974-1990: Metode Pengujian Kuat Tekan Beton.
SNI 03-6805-2002: Metode Pengujian untuk Mengukur Nilai Kuat Tekan Beton pada Umur Awal dan Memproyeksikan Kekuatan pada Umur Berikutnya

RISK OF PROJECT ACCELERATION: A CASE OF AIRPORT CONSTRUCTION

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ABSTRACT

The construction project is one type of project that has a relatively high risk potential compared to other projects. Project risk is an uncertain event or condition, if it occurs has a positive or negative effect on one or more project objectives such as scope, schedule, cost and quality. Risk may have one or more causes and if it does, there may be one or more effects. The cause may be needs, assumptions, constraints or potential conditions that are likely to have negative or positive results (PMBOK, 2013). The process of building a new Yogyakarta airport in Kulon Progo District or New Yogyakarta International Airport (NYIA) continues to accelerate. However, at the end the development of the New Yogyakarta International Airport (NYIA) continued without regard to the dangers or risks that would occur in the future. On identifying a risk, it is done by looking at potential risks that have been seen and will be seen. Then, proceed with classifying each potential risks that can occur as shown below (Fahmi, 2013). On the identification a risk we just need a framework on pavement runway project. Starting from a variety of airside works to focus on runway projects then brings them in the table with variables R1 to R27 on each runway project. After identifying risks and classifying risks, proceed with making a risk chart or what is often referred to as the Risk Breakdown Structure.

Keywords: Construction project, project risk, NYIA, identification.

1. INTRODUCTION

The construction project is one type of project that has a relatively high risk potential compared to other projects. The potential development of construction projects in Indonesia can be seen from the use of new methods and technologies as well as an increase in the number of parties involved. The construction industry, unlike other industries, is more complicated and difficult to manage because it requires special skills and techniques (Jamil, 2008). Project risk is an uncertain event or condition, if it occurs has a positive or negative effect on one or more project objectives such as scope, schedule, cost and quality. Risk may have one or more causes and if it does, there may be one or more effects. The cause may be needs, assumptions, constraints or potential conditions that are likely to have negative or positive results (PMBOK, 2013). Project risk management includes the process of carrying out risk management planning, identification, analysis, response planning, and risk control for a project. The aim of project risk management is to increase the likelihood and impact of positive events, and reduce the likelihood and impact of negative events in the project (PMBOK, 2013).

The process of building a new Yogyakarta airport in Kulon Progo District or New Yogyakarta International Airport (NYIA) continues to accelerate. The document on the

analysis of environmental impacts (Amdal) is still in the process of preparation. Airport development, has implications for productive land grabbing, settlement evictions, lost livelihoods at the site plan and at the location of supporting infrastructure. In fact, there was no study on tsunami risk reduction in the formulation of environmental impact (Amdal), so there is no guarantee of safety (Sandera, 2017). However, at the end the development of the New Yogyakarta International Airport (NYIA) continued without regard to the dangers or risks that would occur in the future. The NYIA development project is a strategic project which is able to attract the attention of ordinary people and show the project's performance can be calculated. However, the reality is inversely proportional and so far the performance of the project has not been maximized to be used because there are still many obstacles that have not been resolved. So, that's why we need to discuss about how to identification the risk due an airport project is running. It makes a reason why to choose this topic as the research.

2. THEORITICAL FRAMEWORK

Project is a complex business activity, is not routine, has limited time, budget and resources and has its own specifications for the products to be produced. With the limitations in working on a project, then a project organization is needed to manage the available resources in order to carry out synchronous activities so that project objectives can be achieved. Project organization is also needed to ensure that work can be completed in an efficient, timely and in accordance with the expected quality.

Efforts or activities organized to achieve important goals, objectives and expectations using budget funds and available resources, which must be completed within a certain period of time (Nurhayati, 2010). A series of tasks directed at a main outcome (Heizer dan Render, 2006). A project is a temporary effort to produce a unique product or service. In general, the project involves several people who are interconnected with their activities and the main sponsor of the project is usually interested in the effective use of resources to complete the project efficiently and on time (Schwalbe translated by Dimiyati and Nurjaman, 2014).

In this research to find the percentage of project acceleration simulation assumptions obtained from the following formula:

RW	d (weeks)
Normal 100%	14
Assumption 50%	A

1. Asumtion 50% = 50% × dnormal ……(1)

Where:

RW = is a variable of percentage simulation on normal duration and asumtion duration.
d = is a duration (weeks).

The airside work consists of five jobs in the form of pavement runway work, parallel taxiway work, holding bay work, rapid exit taxiway work and apron work. However, this study only reviews the impact of risk on pavement runway work. There are

several jobs in working on pavement runway such as flexible work of the runway and flexible work of the runway. In doing the two types of work there are several jobs that must be done such as AC-WC work, CT-BC work, work Crushed Aggregate Subbase, tack coat work and prime coat work. From some of the work we can identify the risks that occur when doing the work. The results of risk identification are entered into a table and then classified in the order of work. After identifying risks and classifying risks, proceed with making a risk chart or what is often referred to as the Risk Breakdown Structure.

3. RESULT AND DISCUSSION

In the results and discussion chapter we get the results of the impact or risk implications of the project acceleration in the form of risk identification, risk analysis, risk categories and risk responses that we can find out the risk implications of accelerating a pavement runway project.

3.1. The Acceleration Simulation on Project Duration Calculation

In this research in accelerating the duration of work using assumptions where the normal duration is 100% 14 weeks, the duration of the assumption is 50% 7 weeks, the duration of the assumption is 40% 6 weeks, the duration of the assumption is 30% 5 weeks and the duration of the assumption is 10% 2 weeks. The step to calculate the project acceleration simulation in this study is to calculate the percentage of assumptions with the duration of the pavement runway work per week.

In this research to find the percentage of project acceleration simulation assumptions obtained from the following formula:

RW	d (weeks)
Normal 100%	14
Assumption 50%	7

1. Assumption 50% = 50% × dnormal
   = 50% × 14 weeks
   = 7 weeks.

3.2. Risk Identification

In identifying a risk there is some data that must be known. Risk is traditionally defined as uncertainty or the possibility of loss. The uncertainty of events is subjective and the existence of "whether or not," "when," "circumstance," and "severity." While the loss caused by the occurrence of an event is objective, emphasizing the possibility of loss. The definition of risk may differ in research but always emphasizes the expected value combining probability and severity.

Detecting risks helps control the occurrence of airport risks during operations. This paper introduces the concept of detection in airport risk management and defines

risk as an expected value combining probability, severity, and detection. In this study, risk identification is obtained from a runway work chart or often called the Work Breakdown Structure in Figure 3.1.

Figure 3.1 explains that the airside work consists of five jobs in the form of pavement runway work, parallel taxiway work, holding bay work, rapid exit taxiway work and apron work. However, this study only reviews the impact of risk on pavement runway work. There are several jobs in working on pavement runway such as flexible work of the runway and flexible work of the runway. In doing the two types of work there are several jobs that must be done such as AC-WC work, CT-BC work, work Crushed Aggregate Subbase, tack coat work and prime coat work.

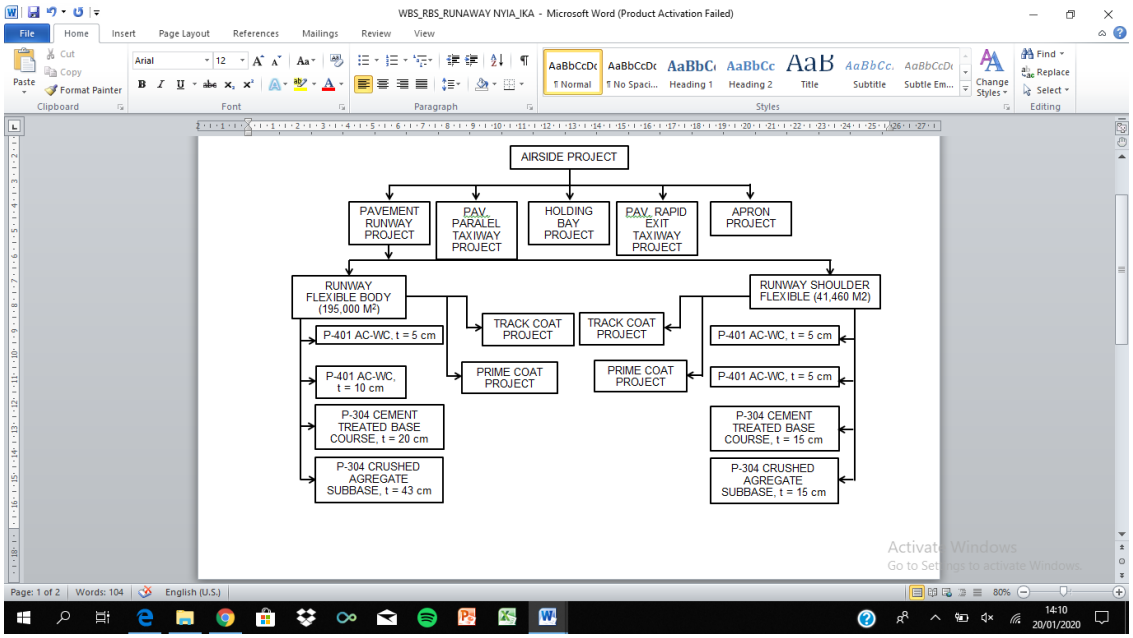


Figure 3.1. Work Breakdown Structure Airside Work

From some of the work we can identify the risks that occur when doing the work. The results of risk identification are entered into a table and then classified in the order of work. In Table 3.1 we can see risk identification in accordance with the order in which each job is replaced by the Rn variable for each risk factor.

After identifying risks and classifying risks, proceed with making a risk chart or what is often referred to as the Risk Breakdown Structure. In Figure 3.2 explains the various possible risks that occur when doing pavement runway work.

Table 3.1. Risk Identification of Pavement Runway Project

Rn	E
R_1	Runway original land contours are uneven
R_2	Soil compaction is not according to specifications
R_3	Uneven runway surface
R_4	Runway shoulder pad runway is not wide enough
R_5	Runway turn pad irregular surface
R_6	The runway slope is not according to specifications
R_7	Unstable runway soil structure
R_8	The earthquake-prone runway area
R_9	Runway area prone to tsunamis
R_{10}	The actual length of the runway surface does not meet aircraft operational requirements
R_{11}	Runway turn pad is not according to specifications
R_{12}	The average texture depth of the new runway surface is less than 1.0 mm
R_{13}	Corrugated runway surface
R_{14}	Runway surface is too slippery
R_{15}	Runway shoulders do not have the same width on both sides
R_{16}	Runway shoulders more than 2.5%
R_{17}	Runway shoulder surface is bumpy / not flat with runway surface
R_{18}	The runway shoulder surface for jet aircraft is not coated in asphalt / bitumen / concrete
R_{19}	The shoulder surface of the runway for the Boeing 737-800 / A380 is not widened by 7 m outside the shoulder
R_{20}	Runway shoulders are not resistant to erosion due to aircraft engine bursts
R_{21}	Inefficient material supply
R_{22}	Aggregate and cement layouts are not optimal
R_{23}	Extreme weather (rainy season)
R_{24}	Asphalt / bitumen spread is not optimal
R_{25}	Limited support machines
R_{26}	Human error due to 24 hours of work

3.3. Risk Breakdown Structure

In this study, the risk of runway work is described in the Risk Breakdown Structure in Figure 3.2 below. Risk Breakdown Structure as the following form:

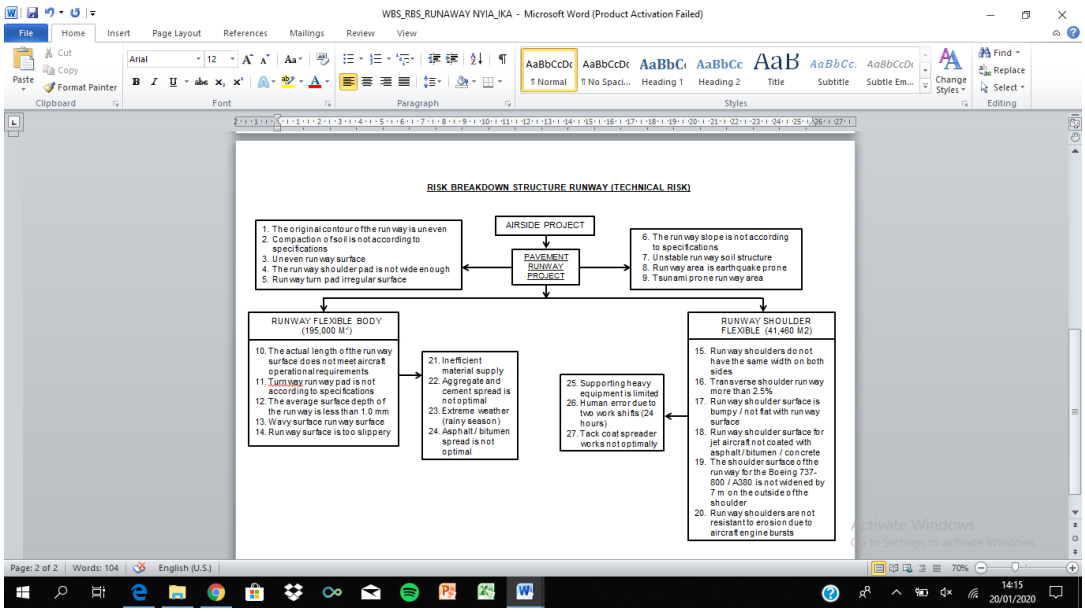


Figure 3.2. Airside Risk Breakdown Structure at the Pavement Runway Work

In Figure 3.2 it is known that there are 27 technical risk factors that might occur in the pavement runway work. These risks have been classified according to their respective sub jobs. After outlining the technical risk factors that might occur into the risk breakdown structure, the next step is to calculate the level of risk from probability and impact. This aims to determine the size of the risk that may occur in the pavement runway.

3.4. Risk Classification

Definition of risk classification is the practice of grouping the risk including similarities in costs for potential losses or damage, how frequently the risk maybe occurred and whether steps are taken to reduce or eliminate the risks.

In this research, after we have identified the risk we have to classify the risk into the table seems like on table 3.2. We can see that if, all risks are classify by works. Starts from variable C.1.1 through C.1.6 and C.2.1. through C.2.6.

Table 3.2. Risk Classification of Pavement Runway Project

No.	Work Item	RF
C.	Pavement Runway Project	
C.1	Runway Flexible Body(195000 m2)	Runway original land contours are uneven
C.1.1	P-401 AC-WC, t = 5cm	Soil compaction is not according to specifications
		Uneven runway surface
		Runway turn pad irregular surface
		The actual length of the runway surface does not meet aircraft operational requirements
		Unstable runway soil structure
		The earthquake-prone runway area
		Runway area prone to tsunamis
C.1.2	P-401 AC-BC, t = 10cm	The runway slope is not according to specifications
		Runway turn pad is not according to specifications

		The average texture depth of the new runway surface is less than 1.0 mm
		Corrugated runway surface
C.1.3	P-304 Cement Treated Base Course, t = 20 cm	Aggregate and cements layouts are not optimal
C.1.4	P-209 Crushed Agregate Subbase, t = 43 cm	Limited support machines
C.1.5	Tack Coat	Extreme weather (rainy season)
C.1.6	Prime Coat	Runway surface is too slippery
		Asphalt/bitumen spread is not optimal
C.2	Runway Flexible Sholulders (41460 m2)	Runway shoulder surface is bumpy / not flat with runway surface
C.2.1	P-401 AC-WC, t = 5cm	The runway shoulder surface for jet aircraft is not coated in asphalt / bitumen / concrete
C.2.2	P-401 AC-BC, t = 5cm	The shoulder surface of the runway for the Boeing 737-800 / A380 is not widened by 7 m outside the shoulder
C.2.3	P-304 Cement Treated Base Course, t = 15 cm	Runway shoulder pad runway is not wide enough
		Runway shoulders do not have the same width on both sides
C.2.4	P-209 Crushed Agregate Subbase, t = 15 cm	Runway shoulders more than 2.5%
		Runway shoulders are not resistant to erosion due to aircraft engine bursts
C.2.5	Tack Coat	Tack coat spreader works not optimal
C.2.6	Prime Coat	Human error due to 24 hours of work

	Inefficient material supply

3.5. Risk Response or Allocation

In this research, how to get the risk response or risk allocation is by interviewing the project manager and also supervisor engineering manager on site. On table 3.3 we can see that if, all risks could be mitigated excepts the earthquake-prone and tsunami-prone runway area also extreme weather (rainy season) couldn't be mitigated or on the other words the risk are avoidance. Because of that, we can reduced the risk by conducting an AMDAL test, Tsunami Wave test and controlling the weather. We have to know the most efficient way to reduce the risk, so that the risk responses are make sense with the project. On table 3.3 we can see that if, there are three responsible parties who can responsive the risk such as owner, consultan planner and contractor. So, here the data of risk response or risk allocation as follows:

Table 3.3. Risk Response or Allocation of Pavement Runway Project

Risk Factor	Risk Categories	Risk Response Strategy	Responsible Party
The original land of runway contour weavy	Mitigate	Do leveling the soil structure / doing excavation.	Contractor
Soil compaction is not according to specifications	Mitigate	Survey of original soil conditions, selection of hill material, compaction layer by layer and inspection of layer by layer compaction.	Contractor
Runway surface is weavy	Mitigate	Do leveling the soil structure / doing excavation.	Contractor
Runway shoulder pad runway is not wide enough	Mitigate	Adjustment of the runway turn pad surface with widening per layer.	Contractor
Runway turn pad irregular surface	Mitigate	Adjustment of the runway turn pad surface by carrying out excavations on the runway.	Contractor
The runway slope is not according to specifications	Mitigate	Do the runway back slope test.	Contractor
Unstable runway soil structure	Mitigate	Carry out treatment on runway soil structure.	Contractor
The earthquake-prone runway area	Avoidance	Conduct an AMDAL test on the runway.	Owner, Consultant

			Planner & Contractor
Runway area prone to tsunamis	Avoidance	Carry out a Tsunami Wave test	Owner, Consultant Planner & Contractor
The actual length of the runway surface does not meet aircraft operational requirements	Mitigate	Do the actual runway surface length test again.	Contractor
Runway turn pad is not according to specifications	Mitigate	Do runway turn pad specifications.	Contractor
The average texture depth of the new runway surface is less than 1.0 mm	Mitigate	Adjustment of runway ground level by carrying out excavations on the runway.	Contractor
Corrugated (weavy) runway surface	Mitigate	Adjustment of runway ground level by carrying out excavations on the runway.	Contractor
Runway surface is too slippery	Mitigate	The addition of material that can increase the friction force so that the runway surface is not slippery.	Contractor
Runway shoulders do not have the same width on both sides	Mitigate	Adjustment of the runway turn pad surface with widening layer by layer.	Contractor
Runway shoulders more than 2.5%	Mitigate	Adjustment of the crossing shoulder surface of the runway by carrying out excavations on the runway.	Contractor
Runway shoulder surface is bumpy / not flat with runway surface	Mitigate	Adjustment of runway ground level by carrying out excavations on the runway.	Contractor
The runway shoulder surface for jet aircraft is not coated in asphalt / bitumen / concrete	Mitigate	Overlay asphalt / bitumen / concrete laying on the runway shoulder surface.	Contractor
The shoulder surface of the runway for the	Mitigate	Adjustment of the runway shoulder surface	Contractor

Boeing 737-800 / A380 is not widened by 7 m outside the shoulder		with widening layer by layer.	
Runway shoulders are not resistant to erosion due to aircraft engine bursts	Mitigate	Survey of original soil conditions, selection of sheet pile material and inspection of runway shoulder endurance against erosion due to aircraft engine bursts.	Contractor
Inefficient material supply	Mitigate	Time management between the distance and the time the material arrived at the site.	Contractor
Aggregate and cement layouts are not optimal	Mitigate	Time management between the distance and the time the material arrived at the site.	Contractor
Extreme weather (rainy season)	Avoidance	Control the weather.	Owner, Consultant Planner & Contractor
Asphalt / bitumen spread is not optimal	Mitigate	Time management between the distance and the time the material arrived at the site.	Contractor
Limited support machines	Mitigate	Use that machines effectively and alternately / add heavy equipment.	Contractor
Human error due to 24 hours of work	Mitigate	Increased work motivation and adjustment of work time.	Contractor
Tack coat spreader works not optimal	Mitigate	Operate the tool regularly so that there is no damage to the tack coat spreader.	Contractor

4. CONCLUSION AND RECOMENDATION

In short, we can conclude that if on the identification a risk we just need a framework on pavement runway project. Starting from a variety of airside works to focus on runway projects then brings them in the table with variables R1 to R27 on each runway project.

So, in carrying out a project if you want to accelerate the time of project implementation, it should pay attention to the risks that may occur and the impact of the

risks when the project is implemented and after the project is completed by considering the strategy or risk response allocation so that the risk can be minimized.

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ANALYSIS OF SUCCESS FACTORS IN IMPLEMENTINGTHE BIM–LEAN CONSTRUCTION APPROACH IN CONSTRUCTION PROJECTS IN SOUTH SUMATERA

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ABSTRACT

Building Information Modeling (BIM) and Lean Construction are two strategies that are being used more and more to address these problems in tandem with the advancement of global construction technology. In order to apply BIM-Lean building to building projects in South Sumatra, it is necessary to determine the critical success factors (CSFs). Contractors, consultants, and project owners must understand these success characteristics in order to implement a BIM-Lean approach successfully, sustainably, and with a major influence on project performance. Lean Construction is the application of Lean Manufacturing concepts to construction project management. This strategy focuses on improving workflow, cutting waste, and boosting process efficiency in order to add value for clients. In contrast to traditional management techniques, which frequently place an emphasis on individual productivity, Lean Construction places a strong emphasis on teamwork, planning dependability, process stability, and information transparency throughout the project. The structural equation modeling–partial least squares (SEM–PLS) method is used in this study's quantitative methodology. The research aims of investigating causal links between latent constructs and predicting important factors influencing the success of BIM-Lean deployment are best served by this approach, which is why it was selected. Based on a Google Form questionnaire of 119 respondents, findings indicate strong support for the implementation of BIM-Lean Construction through management policies, HR competency, technology readiness, and communication. A significant 52.6% rated management policies as crucial, while 84.2% affirm teamwork supports continuous improvement. Technology assessments show strong reliability, with effective internet connectivity rated at 89.5%. Collaboration is also highlighted, with 57.9% agreeing on project information accessibility and 79% noting improved teamwork through BIM. Furthermore, a Lean culture is evident, with 57.9% strongly agreeing on adhering to work standards and 52.6% on waste reduction. Overall, the internalization of efficiency principles within the organization supports the effective integration of BIM technology, linking technical tools with a culture of continuous improvement for project success.

Keywords: Building Information Modeling (BIM), Lean Construction, Structural Equation Modeling–Partial Least Squares (SEM–PLS).

1. INTRODUCTION

One area that is essential to the expansion of the national economy is the building industry. Public infrastructure, housing, transportation, energy, and social facilities are all made possible by Indonesia's construction industry, which also makes a substantial contribution to the country's GDP. The national construction industry nevertheless faces

a number of fundamental issues despite its strategic position, such as low productivity, excessive project delays, material waste, high rework rates, and a lack of stakeholder integration. The primary drivers of cost and time variations in building projects are process and coordination inefficiencies, according to numerous studies(Fitriani & Bangun, Br, Prasetio, 2021).

Building Information Modeling (BIM) and Lean Construction are two strategies that are being used more and more to address these problems in tandem with the advancement of global construction technology. BIM reduces design flaws, minimizes coordination conflicts (clash detection), and improves the accuracy of cost and time calculations by enabling the multidimensional and collaborative visualization and integration of building information. In the meantime, Lean Construction, which is based on the Lean Manufacturing concept, concentrates on cutting waste, streamlining the value stream, boosting process effectiveness, and fostering a continuous improvement-oriented workplace culture (Fitriani et al., 2021) .

Strong synergies have been demonstrated when BIM and Lean Construction ideas are combined. Lean supports BIM implementation techniques through methodical work process improvements, while BIM offers a digital platform that makes applying Lean concepts simpler and more scalable. Projects that combine these two strategies minimize waste, boost productivity and quality, and speed up decision-making, according to numerous worldwide studies(Fitriani et al., 2021).

Regulations, such as those requiring BIM for specific government projects, have started to promote the use of BIM in Indonesia. Simultaneously, the construction professional community is gradually adopting Lean Construction. Nevertheless, the application of both strategies—particularly their integration—remains inadequate. Inadequate training, reluctance to change, insufficient technology infrastructure, a lack of implementation standards, a weak collaborative culture, and poor human resource readiness are common problems(Fitriani et al., 2022).

The province of South Sumatra, which is seeing substantial infrastructural development, likewise faces this circumstance. Toll highways, bridges, government buildings, industrial facilities, and large-scale housing projects are examples of projects that highlight the critical need for a more effective, integrated, and digitally oriented approach to project management. Despite the fact that a number of South Sumatra construction enterprises are familiar with BIM and Lean, their use is still dispersed and not yet strategically integrated(Fitriani et al., 2019).

In order to apply BIM-Lean building to building projects in South Sumatra, it is necessary to determine the critical success factors (CSFs). Contractors, consultants, and project owners must understand these success characteristics in order to implement a BIM-Lean approach successfully, sustainably, and with a major influence on project performance. The lack of empirical research on BIM-Lean Construction integration in Indonesia, especially in a regional setting like South Sumatra, makes this study pertinent. In addition to offering an implementation model that stakeholders may use as a guide, this study is anticipated to make scholarly and practical contributions about the elements impacting the success of BIM–Lean integration in construction projects.

2. THEORITICAL FRAMEWORK

A digital model-based project management technique called Building Information Modeling (BIM) combines diverse data into a single, collaborative platform that is available to all parties involved. In addition to creating three-dimensional (3D) geometric

representations, BIM also generates non-geometric data, including material specifications, technical characteristics, cost information (5D), project scheduling (4D), and building lifespan projections (6D). With these integrative features, BIM becomes the primary basis for more efficient and uniform asset management, design coordination, decision-making, and building performance analysis.

Because all stakeholders work from a single source of truth, BIM is seen in international literature as a shared knowledge resource that functions throughout the building lifecycle, from conceptualization, planning, analysis, construction, operation, and demolition. This approach allows for a more structured decision-making process; consequently, BIM can lower the possibility of errors, increase data accuracy, improve interdisciplinary coordination, and ensure information consistency across all project phases.

Lean Construction is the application of Lean Manufacturing concepts to construction project management. This strategy focuses on improving workflow, cutting waste, and boosting process efficiency in order to add value for clients. In contrast to traditional management techniques, which frequently place an emphasis on individual productivity, Lean Construction places a strong emphasis on teamwork, planning dependability, process stability, and information transparency throughout the project.

The Lean concept is based on the idea that any activity that does not benefit the customer should be reduced or eliminated. Implementing Lean principles is essential for lowering process variability, enhancing schedule reliability, and maximizing coordination between project stakeholders in the construction industry, which is known for its high levels of complexity and uncertainty. This leads to more effective and efficient work execution.

The structural equation modeling–partial least squares (SEM–PLS) method is used in this study's quantitative methodology. The research aims of investigating causal links between latent constructs and predicting important factors influencing the success of BIM-Lean deployment are best served by this approach, which is why it was selected. This research was carried out in the province of South Sumatra, which is seeing a notable increase in building and infrastructure development. The province is promoting the use of contemporary construction technology, such as Building Information Modeling (BIM) and the Lean Construction methodology, especially for critical government and industry projects, which is why this site was selected. Companies and organizations that are involved in the planning, execution, and oversight phases of building projects are among the research objects. These include:

1. The physical execution of the work is the responsibility of contractor firms of all sizes.
2. Consultants for planning and supervision are essential to design preparation, technical coordination, and project quality assurance.
3. The policies and tactics for deploying project technology, including BIM-Lean, are set by project owners, both public and commercial.
4. Lean workflows and BIM model coordination are crucial for specialist contractors (MEP, structural, finishing, etc.) who are directly involved in technical work.

The research focuses on the following kinds of projects:

1. Roads, bridges, clean water systems, and drainage are examples of infrastructure projects that are extremely complicated and necessitate interdisciplinary cooperation.

2. Building projects, such as commercial, governmental, educational, and industrial structures, are typically the first industries to use BIM extensively.
3. Large-scale housing projects, which demand time and cost efficiency as well as quality consistency, make them relevant to the Lean approach.
4. Due to the necessity for precise design and interdisciplinary integration, EPC projects and the energy sector (where available) have been global leaders in the adoption of BIM and lean-based management.

3. RESULT AND DISCUSSION

A total of 119 respondents participated in this study, according to the results of data collection using a Google Form questionnaire. The distribution of respondents by gender reveals that the majority of respondents were male, at 84.2%, while female respondents were 15.8%. This dominance of male respondents reflects the actual conditions in the construction industry sector, particularly in areas related to Building Information Modeling (BIM) and Lean Construction, which are still dominated by male professionals.

This is understandable given the characteristics of construction work that call for technical, operational, and strategic decision-making involvement in project management. Because the respondents are from professional groups that are directly involved in the planning, execution, and management of construction projects, their gender composition is deemed representative to support the analysis of success factors for BIM–Lean Construction implementation using the Structural Equation Modeling (SEM) method. Therefore, it is anticipated that the collected data will be able to characterize respondents' opinions and real-world experiences with respect to the examined research variables.

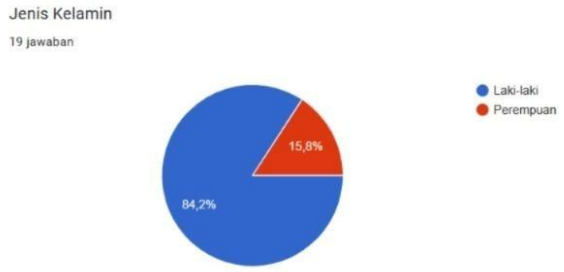


Figure 3.1. Gender graphic respondence
Source: Google Form Asri Mulyadi

The distribution of responders by job title or position within the project revealed a varied composition, according to data gathered via a Google Form questionnaire. The majority of respondents (52.6%) fell into the "Other" category, which reflects the involvement of a variety of professional roles outside of the primary occupations indicated, such as technical staff, owner representative, implementing contractor, or other supporting positions in building projects.

Additionally, 21.1% of respondents had the title "Project Manager," compared to 10.5% each for Site Manager and Planning/Supervisory Consultant. At 5.3%, the Site

Engineer position got the lowest percentage. The categories "BIM Engineer/BIM Modeler," "Quality Engineer," and "Planner/Scheduler" had no responders.

This position composition indicates that the majority of respondents play both strategic and operational roles in construction project management. The involvement of respondents at various management and technical levels provides a comprehensive perspective on the factors contributing to the success of BIM–Lean Construction implementation, from planning and coordination to field implementation.

The variety of respondents' perspectives enhances the quality of the research data in the context of Structural Equation Modeling (SEM) analysis because the perceptions gathered represent the actual conditions across roles in construction projects. As a result, it is anticipated that the analysis results will be able to more accurately and representatively identify causal relationships between latent variables regarding BIM–Lean Construction implementation practices in construction projects.

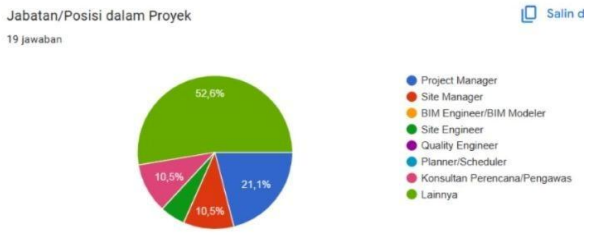


Figure 3.2. Characteristic of respondence
Source: Google Form Asri Mulyadi

Based on data collected through a Google Form questionnaire, of the 119 respondents involved in this study, the distribution of respondents based on the type of project they frequently handle indicates that the majority of respondents are involved in infrastructure projects, such as roads, bridges, airports, ports, and railways, with a percentage of 52.6%. This indicates that the implementation of BIM–Lean Construction in this study is largely perceived from the perspective of infrastructure projects, which generally have a high level of complexity and require intensive interdisciplinary coordination.

Furthermore, 26.3% of respondents handle educational and government projects (universities, schools, and government buildings). 10.5% of respondents are involved in building projects (offices, shopping centers, hotels, and the like) and residential projects. Meanwhile, no respondents reported frequently handling industrial, factory, or healthcare projects.

The dominance of infrastructure and public projects among these respondents provides a strong context for this research, given that these projects tend to have high demands for time, cost, and quality efficiency, making the application of the BIM–Lean Construction approach highly relevant. From a Structural Equation Modeling (SEM) analysis perspective, this variety of project types enriches respondents' perspectives on the success factors for BIM–Lean Construction implementation, including technology, process, management, and organizational aspects.

Thus, the results of this study are expected to comprehensively describe the key success factors for BIM–Lean Construction relevant to various types of construction

projects, particularly infrastructure and public projects, which were the primary focus of respondents.

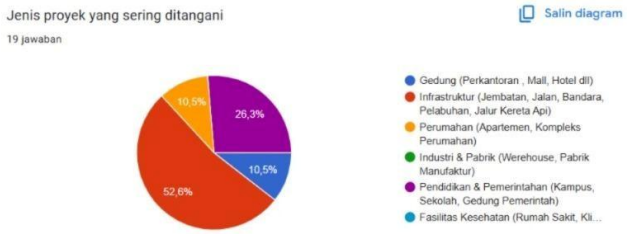


Figure 3.3. Type of projects respondence
Source: Google Form Asri Mulyadi

3.1. Management Supportting Respondence

Based on the results of a Google Form questionnaire completed by 119 respondents, responses to indicator X1.1: "Management provides formal policies to support BIM–Lean implementation" showed a very positive trend. The majority of respondents (52.6%) rated the policy on a scale of 5 (strongly agree), indicating that more than half of respondents considered the existence of formal management policies to be a very important factor and were already perceived in the implementation of BIM–Lean Construction.

Furthermore, 31.6% of respondents rated the policy on a scale of 4 (agree), indicating a strong perception that management support through formal policies was working well, although there was still room for strengthening or improvement. Meanwhile, 10.5% of respondents rated the policy neutral (scale 3), and only a small proportion rated the policy slightly disagree (scale 2). No respondents strongly disagreed (scale 1).

This distribution of responses indicates that respondents generally agreed that management support in the form of formal policies is a crucial element in the successful implementation of BIM–Lean Construction. From a Structural Equation Modeling (SEM) perspective, indicator X1.1 has the potential to contribute strongly to forming the Management Support latent variable, as it demonstrates a high level of agreement and consistent perceptions among respondents. Thus, these results reinforce the research's assumption that top management commitment, manifested through formal policies and internal regulations, plays a significant role in driving the successful integration of BIM and Lean Construction in construction projects.

Table 3.1. Management Supportting Respondence

Variable	Factor	Validation
X1.1	Formal policies are provided by management to facilitate the deployment of BIM-Lean.	Approved
X1.2	A sufficient budget is set aside by management for the use of BIM technology.	Approved
X1.3	The management actively promotes HR development and training linked to BIM-Lean.	Approved

X1.4	The project's BIM-Lean deployment is directly assessed by management.	Approved
X1.5	The shift from traditional to digital and lean work techniques is supported by management.	Approved



Figure 3.4. Management Supportting Respondence
Source: Google Form Asri Mulyadi

3.2. Human Resources (HR) Competence

Based on the results of a questionnaire with 119 respondents, the analysis of the Human Resources (HR) Competency factor indicates a very good level of readiness in supporting the integration of BIM and Lean Construction. In the technical capability indicator (X2.1), the majority of respondents (52.6%) strongly agree that personnel have mastered BIM software, which technically minimizes the risk of modeling errors. In line with this, in the work process analysis capability indicator (X2.5), there is an accumulation of 84.2% of respondents who assess the team is capable of continuous improvement. Within the Structural Equation Modeling (SEM) framework, high achievements in these two indicators indicate that the HR Competency variable has a strong foundation to support workflow efficiency and waste reduction in the field, so it is predicted to make a significant contribution to the loading factor value and the success of the overall model implementation.

Table 3.2. Human Resources (HR) Competence

Variable	Factor	Validation
X2.1	Project HR is technically proficient in using BIM software.	Approved
X2.2	HR is aware of the Lean Construction project implementation principles.	Approved
X2.3	The organization regularly offers BIM and lean construction training.	Approved
X2.4	HR have the necessary BIM certification or experience.	Approved
X2.5	The project team has the ability to evaluate and constantly enhance work procedures.	Approved



Figure 3.5. Human Resources (HR) Competence
Source: Google Form Asri Mulyadi

3.3. Technology Proficiency

The analysis results of the Technology Readiness variable (X3) show very strong infrastructure support in the implementation of BIM-Lean Construction, where the majority of respondents gave positive assessments on all technical indicators. In depth, the availability of adequate hardware (X3.1) and cloud-based storage systems or easily accessible servers (X3.5) received a strongly agree response of 47.4% and 52.6%, respectively, which are the backbone for massive project data management. Smooth collaboration is also supported by an effective internet connection (X3.4) with an accumulated score of agree and strongly agree reaching 89.5%, as well as the ability to integrate data between platforms (X3.3) which was considered good by the majority of teams (42.1% strongly agree). Although there is a small note on the official software licensing aspect (X3.2) which still recorded 10.5% disagreement, overall this data shows that the technology factor has high reliability in the SEM model. In the context of Lean, this technological readiness plays a crucial role in reducing non-value added activities due to technical constraints and accelerating information flow, thereby strengthening the validity of variable X3 as a significant predictor of project success.

Table 3.3. Technology Proficiency

Variable	Factor	Validation
X3.1	The BIM application can run on the hardware that was used.	Approved
X3.2	The BIM program has an official license and is readily available.	Approved
X3.3	Platforms and software can effectively integrate project data.	Approved
X3.4	Effective BIM collaboration is supported by the network and internet connectivity.	Approved
X3.5	Systems for storing data, including servers and clouds, are widely available and simple to use.	Approved



Figure 3.6. Technology Proficiency
Source: Google Form Asri Mulyadi

3.4. Collaboration and Communication

Based on questionnaire data from 119 respondents, the Collaboration and Communication (X4) variable showed very solid performance as a key factor for the success of BIM-Lean Construction integration, marked by the accessibility of project information (X4.2) which reached the highest level of strong agreement at 57.9%. The effectiveness of coordination was supported by the implementation of structured regular meetings (X4.4) where 52.6% of respondents agreed, as well as the collaborative decision-making process (X4.5) which was also agreed by the majority of the team at 52.6% strongly agreed. The use of the BIM model was proven to increase the effectiveness of teamwork (X4.3) with an accumulation of positive responses reaching 79%, while interdisciplinary communication (X4.1) ran smoothly although there were still 21.1% of respondents who were neutral. In the Structural Equation Modeling (SEM) analysis, the high values of these indicators strengthen the validity of the latent variable X4, which indicates that information transparency and synchronization between stakeholders are the main drivers in reducing communication barriers and accelerating the project work cycle according to Lean principles.

Table 3.4. Collaboration and Communication

Variable	Factor	Validation
X4.1	The project's interdisciplinary communication operates smoothly and successfully.	Approved
X4.2	All pertinent parties have easy access to project information.	Approved
X4.3	Project teamwork is more productive when BIM models are used.	Approved
X4.4	Meetings for project coordination are organized and conducted on a regular basis.	Approved
X4.5	Stakeholders work together to make decisions pertaining to the project.	Approved



Figure 3.7. Collaboration and Communication
Source: Google Form Asri Mulyadi

3.5. Lean Culture and Continuous Improvement

Based on questionnaire data from 119 respondents, the Lean Culture and Continuous Improvement variables (X5) showed a very good level of internalization of the efficiency philosophy in the project environment, with the indicator of work activities based on clear standards (X5.2) recording the highest level of strong agreement at 57.9%. The organization's commitment to reducing waste (X5.1) and the implementation of periodic evaluations (X5.3) also showed predominantly positive results with a strong agreement figure of 52.6%, supported by management's openness in facilitating input from the workforce (X5.4) which was agreed upon by 47.4% of respondents on the maximum scale. Although the internalization of Lean principles as values and norms of organizational culture (X5.5) had a slightly lower distribution in the strong agreement category (36.8%), cumulatively positive responses still dominated the model. In the context of Structural Equation Modeling (SEM), these data indicate that the Lean Culture variable has strong validity to act as a catalyst in optimizing the use of BIM technology, where successful implementation depends not only on technical tools but also on a structured continuous improvement mentality to achieve overall project success.

Table 3.5. Lean Culture and Continuous Improvement

Variable	Factor	Validation
X5.1	The company actively incorporates waste reduction techniques into the planning and execution of projects.	Approved
X5.2	Project tasks are completed in accordance with precise, recorded, and uniform work standards.	Approved
X5.3	Periodically, work processes are evaluated in order to find areas for improvement.	Approved
X5.4	Employees are encouraged and assisted in offering suggestions or ideas for enhancing productivity and process effectiveness.	Approved
X5.5	Lean Construction principles have become part of the project organization's values, norms, and culture.	Approved



Figure 3.8. Lean Culture and Continuous Improvement
Source: Google Form Asri Mulyadi

3.6. Successful BIM–Lean Implementation

Based on questionnaire data from 119 respondents regarding the Lean Culture and Continuous Improvement (X5) variables, there is a strong internalization of efficiency principles where the indicator of implementing activities based on clear work standards (X5.2) recorded the highest level of strongly agree at 57.9%. The organization's commitment to waste reduction practices (X5.1) and the implementation of periodic evaluations for process improvement (X5.3) showed consistently positive results with a strong agreement rate of 52.6% each. Management support for workforce input (X5.4) was also rated very good by 47.4% of respondents, although the Lean principle aspect as part of the organizational cultural norms (X5.5) had a slightly lower distribution in the strongly agree category at 36.8%. Within the Structural Equation Modeling (SEM) analysis framework, the high trend in scores on these indicators indicates strong construct validity for variable X5 as a key driver of BIM effectiveness, where a culture of continuous improvement is a crucial foundation for the successful implementation of technology in the field.

Table 3.6. Successful BIM–Lean Implementation

Variable	Factor	Validation
Y1	Project implementation can be made more cost-effective by implementing BIM-Lean.	Approved
Y2	When compared to traditional approaches, BIM-Lean adoption speeds up project completion.	Approved
Y3	Rework and waste were significantly reduced.	Approved
Y4	Using BIM improves coordination between the design and construction phases.	Approved
Y5	Following the use of BIM-Lean, project team productivity rose.	Approved
Y6	The application of BIM-Lean has enhanced the overall quality of construction outcomes.	Approved

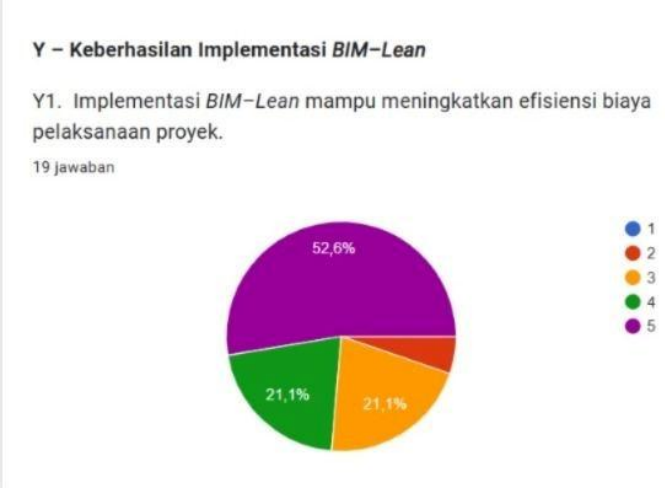


Figure 3.9. Successful BIM–Lean Implementation
Source: Google Form Asri Mulyadi

4. CONCLUSION AND RECOMENDATION

In short, we can conclude that if, based on a Google Form questionnaire of 119 respondents, findings indicate strong support for the implementation of BIM-Lean Construction through management policies, HR competency, technology readiness, and communication. A significant 52.6% rated management policies as crucial, while 84.2% affirm teamwork supports continuous improvement. Technology assessments show strong reliability, with effective internet connectivity rated at 89.5%. Collaboration is also highlighted, with 57.9% agreeing on project information accessibility and 79% noting improved teamwork through BIM.

Furthermore, a Lean culture is evident, with 57.9% strongly agreeing on adhering to work standards and 52.6% on waste reduction. Overall, the internalization of efficiency principles within the organization supports the effective integration of BIM technology, linking technical tools with a culture of continuous improvement for project success.

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OPTIMIZATION OF POWDER METALLURGY PROCESSING PARAMETERS OF AL/GRAPHENE/FLY ASH COMPOSITES USING THE TAGUCHI METHOD

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Abstract

Aluminum (Al)-based composites reinforced with graphene and fly ash are promising materials due to their low density and high hardness. One of the critical factors in achieving optimal mechanical properties is the powder preparation stage prior to the sintering process. This study aims to optimize the powder preparation parameters of Al/graphene/fly ash composites with respect to density and hardness using the Taguchi method. The process parameters investigated include reinforcement contents of 5%, 10%, and 15%, milling times of 2 h, 4 h, and 6 h, sintering temperatures of 500 °C, 550 °C, and 600 °C, and holding times of 0.5 h, 1 h, and 1.5 h. The experimental design was conducted using a Taguchi orthogonal array to determine the most influential parameter combinations. The results indicate that increasing the graphene/fly ash reinforcement fraction enhances hardness but reduces density due to increased material porosity. Milling time significantly contributes to the homogeneity of powder dispersion, while sintering temperature and holding time act as dominant factors in interparticle bonding and final densification of the composite. Optimization based on the signal-to-noise (S/N) ratio reveals that the optimal parameter combination for simultaneously maximizing density and hardness consists of a reinforcement content of 10%, a milling time of 4 h, a sintering temperature of 600 °C, and a holding time of 1 h. Experimental validation confirms an increase in density by 7.8% and hardness by 11.4% compared to the initial, non-optimized condition. This study demonstrates that the Taguchi method is effective in identifying optimal powder preparation parameters in the fabrication of Al/graphene/fly ash composites to enhance density and hardness. These findings provide a valuable reference for the development of lightweight, high-performance composite materials for engineering applications.

Keywords : Aluminum; Graphene; Fly ash;; Taguchi method; Density; Hardness

1. INTRODUCTION

1.1 Background

`Aluminum matrix composites (AMCs) have been widely developed for aerospace and automotive applications due to their high specific strength and corrosion resistance (Miracle, 2005). The addition of graphene as a reinforcement significantly enhances hardness and load transfercapability (Rashad et al., 2015), while fly ash provides a cost-effective approach to reduce density and improve wear resistance (Rohatgi et al., 2004). However, the final properties of AMCs are strongly influenced by powder preparation and sintering parameters. Therefore, systematics optimization using statistical methods such as the Taguchi approach is essential (Taguchi, 1990).

Aluminum-based metal matrix composites (Al-MMCs) have attracted increasing attention for industrial applications requiring a high strength-to-weight ratio, such as automotive and aerospace components. The incorporation of micro- and nano-scale particulate reinforcements into an aluminum matrix has been shown to enhance hardness, strength, and wear resistance without a significant increase in mass, thereby motivating extensive research into effective and cost-efficient reinforcement combinations. (Fei Lin et all,,2025)

1.2. Use of Graphene as a Reinforcement

Graphene, or graphene nanoplatelets (GNPs), has been reported to significantly improve the mechanical and thermal properties of Al-MMCs owing to its exceptionally high strength and elastic modulus. Several recent review articles and experimental studies have documented notable improvements in hardness, stiffness, and wear resistance of Al/graphene composites when uniform dispersion and strong interfacial bonding are achieved. However, major challenges remain, including the tendency of graphene to agglomerate, its reactivity at elevated processing temperatures leading to the formation of undesirable phases such as Al_4C_3, and difficulties in achieving adequate densification during consolidation and sintering. Consequently, careful selection of graphene content and processing parameters plays a critical role in determining the final composite properties (Jiayu Liu et.all ,2023)

1.3. Use of Fly Ash as a Low-Cost Hybrid Reinforcement

Fly ash, a by-product of fossil fuel–based power generation, has been widely investigated as a micro- or ultra-micro-scale reinforcement in Al-MMCs. Its main advantages include low cost and wide availability. Experimental studies have shown that fly ash reinforcement can reduce the density of aluminum composites, which is beneficial for light weight applications, and in some cases improve hardness and wear resistance when adequate dispersion and interfacial bonding are achieved. The combination of graphene (nano-scale) and fly ash (micro-scale) as hybrid reinforcements offers the potential to integrate the superior mechanical performance of graphene with the economic advantages of fly ash. Nevertheless, such hybrid systems require careful process optimization to avoid reductions in density caused by agglomeration or increased porosity. (Suni Kumar Tiwari,2021)

1.4. Influence of Processing Parameters (Milling and Sintering) on Density and Hardness

In powder metallurgy processing routes, milling time strongly influences particle size refinement, reinforcement dispersion, and the accumulation of plastic deformation energy in the powder, which in turn affects sinterability, porosity, and hardness of the consolidated material. Previous studies have reported that increasing milling time can refine grain structure and improve reinforcement dispersion; however, excessive milling may promote oxidation and the formation of undesirable phases if processing conditions are not properly controlled. Sintering temperature and holding time are key parameters governing densification through interparticle diffusion and microstructural evolution. While higher temperatures and longer holding times generally enhance densification, they may also intensify interfacial reactions (e.g., intermetallic formation), thereby influencing the resulting hardness. Studies examining the effects of milling time, sintering temperature, and sintering duration on relative density and mechanical properties consistently highlight the necessity for comprehensive optimization of these parameters. (Houruna Sethi, et all, 2021)

1.5. Taguchi Method for Process Optimization

he Taguchi method, based on orthogonal arrays, has proven to be an efficient approach for reducing the number of experiments required in full factorial designs while simultaneously identifying the relative influence of process parameters and their interactions on quantitative responses such as relative density and hardness. Several recent studies have successfully applied the Taguchi method to Al-MMCs for optimizing milling and sintering parameters, demonstrating that the combined use of Taguchi design with signal-to-noise (S/N) ratio analysis and ANOVA facilitates the identification of dominant factors. Therefore, the Taguchi approach is well suited for the proposed multi-parameter optimization involving reinforcement content (5, 10, and 15 wt%), milling time (2, 4, and 6 h), sintering temperature (500, 550, and 600 °C), and holding time (0.5, 1, and 1.5 h). [Lit 10]

1.6. Research Gap

Although numerous studies have independently investigated Al/graphene composites, Al/fly ash composites, the effects of milling time, and the optimization of sintering parameters in Al-MMCs, systematic research integrating graphene and fly ash as hybrid reinforcements in an aluminum matrix remains limited. In particular, comprehensive optimization of (i) reinforcement content (5, 10, and 15 wt%), (ii) milling time (2, 4, and 6 h), (iii) sintering temperature (500, 550, and 600 °C), and (iv) holding time (0.5, 1, and 1.5 h) with respect to relative density and hardness has not been extensively reported. This gap is significant because the interactions among these parameters are non-linear and may lead to trade-offs, such as improved densification accompanied by the formation of mechanically detrimental phases. [Lit 11]

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2. EXPERIMENTAL PROCEDUR

2.1 Composite Material Fabrication Process

The fabrication of the composite material was carried out using a powder metallurgy route. Initially, fly ash and graphene powders underwent a pre-treatment process by heating at 200 °C for 1 h to remove moisture and surface contaminants. Subsequently, each powder was sieved separately using a sieve shaker with particle sizes ranging from 100 to 400 mesh.

The processed powders were then weighed according to the designated volume fractions of aluminum, graphene, and fly ash, namely (95% : 1% : 4%), (90% : 2% : 8%), and (85% : 3% : 12%). The measured powders were immersed in a 10% ethanol solution for 10 min to improve wetting and dispersion. After immersion, the powders were combined in a single container and mixed using a jar test machine employing a shear-mixing mechanism for 60 min at a rotational speed of 300 rpm to obtain a homogeneous graphene-containing mixture.

The resulting slurry was subsequently filtered using filter paper and dried in a furnace at 100 °C for 20 min to remove residual ethanol from the mixture. The dried powder mixture was then subjected to ball milling with varying milling times of 10, 30, 60, and 90 min. Following the ball milling process, the powders were compacted under pressure to form green compacts with a controlled density prior to further consolidation.

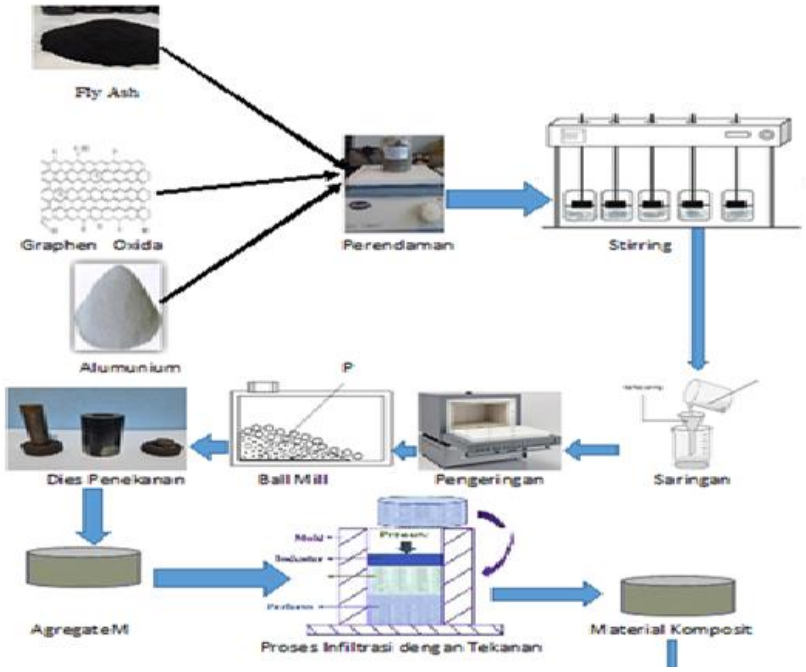


Figure.1. Fabrication Process of Conposites

2.2. Selection of the Orthogonal Aray

he study involves four factors, each with three levels; therefore, the L9 (3^4) orthogonal array was selected as an appropriate experimental design. Table X presents the factors and their corresponding levels used in determining the orthogonal array.

Table.1.Factor and Level Taguchi

Factor		**Level**		
Fraksi volume penguat (Graphene/Fly Ash)	A	5%	10%	15%

Lama penggilingan (Mechanical milling)	B	2 hour	4 hour	6 hour
Temperatur sintering	C	500°C	550°C	600°C
n (holding time)	D	0,5 hour	1 hour	1,5 hour

Table.2. Orthogonal Array L9 (3^4)

No	A Fraksi Volume (%)	B Milling (hour)	C Sintering (°C)	D Holding (hour)
1	5%	2	00	0,5
2	5%	4	550	1,0
3	5%	6	600	1,5
4	10%	2	550	1,5
5	10%	4	600	0,5
6	10%	6	500	1,0
7	15%	2	600	1,0
8	15%	4	500	1,5
9	15%	6	550	0,5

3. Materials and Testing

The materials used in the fabrication of the composite consisted of Aluminum 2021 as the matrix material. Graphene, synthesized and supplied by CV Idiora, was employed as one of the reinforcing materials, while fly ash reinforcement was obtained from coal combustion waste collected from a coal-fired power plant (PLTU) at PT Pusri Palembang. The volume fractions of the matrix and reinforcements were varied according to the following aluminum/graphene/fly ash compositions: (95% : 1% : 4%), (90% : 2% : 8%), and (85% : 3% : 12%). Mechanical and physical characterization of the composites included Vickers hardness testing and density measurement using the Archimedes method. Process optimization analysis was carried out using the Taguchi method, while analysis of variance (ANOVA) was employed to evaluate the significance and contribution of each processing parameter based on the corresponding mathematical formulations.

$$\frac{}{} = -10 \frac{1}{} \sigma_{=1} ^2$$

(1)

result and discusson

3.1. Hardness and Density Result

Based on the results of the hardness and density tests conducted at the Materials Laboratory of the Department of Mechanical Engineering, Faculty of Engineering, Universitas Sriwijaya, hardness measurements were performed using the Vickers hardness test in accordance with ISO 6507 and ASTM E384 standard testing procedures. Density measurements were carried out using standard laboratory methods. It seen in Table 3 below

Table.3. Hardness and Density Result

Run	A: Fraction Volume (%)	B: Milling (Hour)	C: Sintering (°C)	D: Holding (Hour)	Vicker Hardness (Vhn)_				Density (gram/cm3)		
1	5%	2	500	0,5	1	49.1	49.9	39.5	2,49	2,5	2,5
2	5%	4	550	1	2	48,54	49.1	48.9	2,49	2,51	2,49
3	5%	6	600	1,5	3	49.3	49.1	49,2	2,56	2,55	2,55
4	10%	2	550	1,5	4	49.3	29,5	49,6	2,54	2,55	2,55
5	10%	4	600	0,5	5	47.9	48.1	48,4	2,54	2,55	2,56
6	10%	6	500	1	6	48.8	48,,3	49.2	2,55	2,56	3.54
7	15%	2	600	1	7	50.1	49.9	49.9	2,54	2,54	2,55
8	15%	4	500	1,5	8	49.1	48,2	49.1	2,57	2,56	2,55
9	15%	6	550	0,5	9	50,2	50,1	49.9	2,54	2,46	2,48

The main effect plots demonstrate that reinforcement volume fraction has the strongest influence on hardness, followed by milling time. Increasing graphene and fly ash content enhance strengthening mechanisms such as load transfer and grain refinement (Fogagnolo et al., 2003). Density is primarily affected by milling time and sintering temperature, which govern particle packing and diffusion during sintering (German, 2005). Three-dimensional response surface plots further clarify the combined effects of process parameter conclusions should state concisely the most important propositions of the paper as well as the author's views of the practical implications of the results.

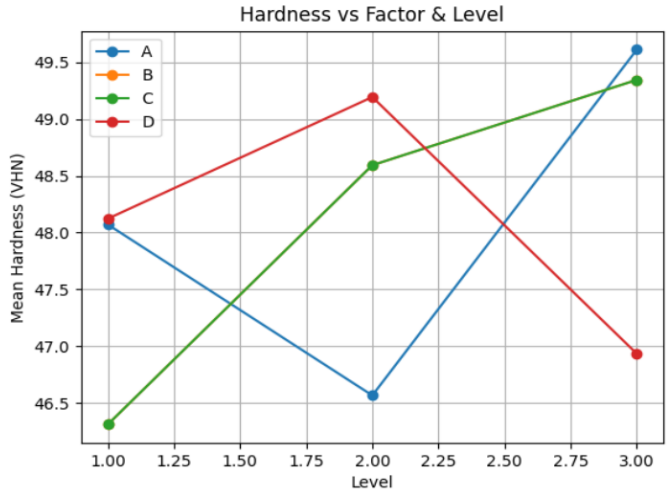


Fig. 2 Main effect plot of hardness versus factor levels.

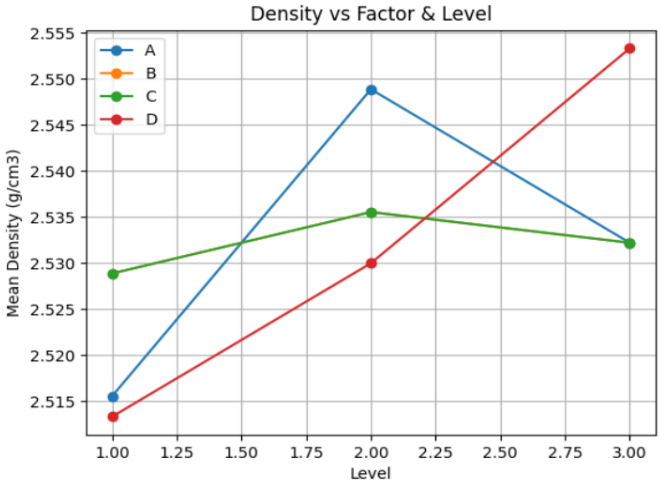


Fig. 3 Main effect plot of density versus factor levels.

The reinforcement volume fraction (graphene and fly ash) has a significant influence on the hardness and density of the composite. Increasing the reinforcement fraction from 5% to 15% tends to enhance the Vickers hardness. The highest hardness value was achieved at a reinforcement content of 15%, with a maximum value of approximately 50.2 VHN (Run 9). However, higher reinforcement fractions may also increase material porosity; therefore, the density does not increase in a strictly linear manner.

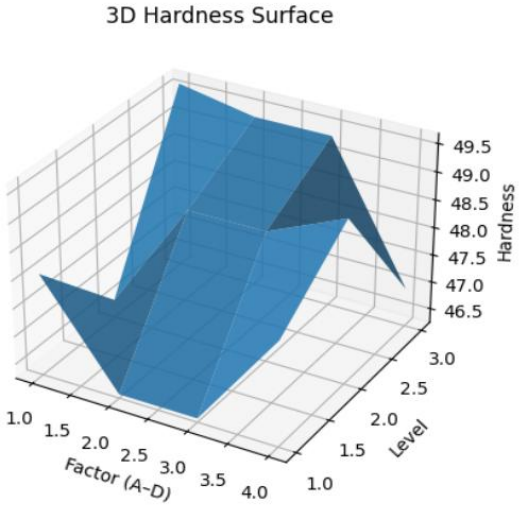


Fig. 4. Three-dimensional response surface of hardness.

Sintering temperature is the dominant factor influencing the improvement of both density and hardness. Sintering at higher temperatures, particularly at 600 °C, tends to produce superior density and hardness values compared to sintering at 500 °C and 550 °C. This behaviour is attributed to enhanced interparticle diffusion and the formation of stronger bonding during the sintering process.

Holding time contributes to densification and microstructural development. Medium to long holding times (1–1.5 h) generally result in more stable density and

hardness values than shorter holding times (0.5 h), as they allow diffusion and densification processes to proceed more effectively.

The experimentally determined optimal combination of processing parameters for achieving high hardness with relatively stable density is as follows: a reinforcement fraction of 15%, a milling time of 6 h, a sintering temperature of 550–600 °C, and a holding time of 0.5–1 h. Under these conditions, the composite attains a hardness of approximately 50 VHN with an average density in the range of 2.5–2.55 g/cm³.

The Taguchi method proved to be effective in evaluating the influence of processing parameters and determining the optimal parameter combination with a limited number of experiments. Further analysis using the signal-to-noise (S/N) ratio and analysis of variance (ANOVA) enables the identification of the most dominant factors, which in this study are estimated to be the sintering temperature and reinforcement fraction.

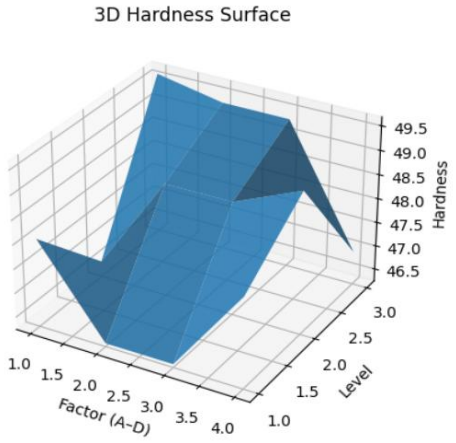


Fig. 4. Three-dimensional response surface of density.

1. conclusion

The Taguchi optimization method was successfully applied to determine the optimal powder preparation parameters for Al/Graphene/Fly Ash composites. Reinforcement volume fraction was identified as the most dominant factor affecting both hardness and density. The optimize parameter combinations provide valuable guidelines for the development of high-performance aluminum-based hybrid composites.

The Taguchi method successfully optimized powder preparation parameters for Al/Graphene/FlyAsh composites. Reinforcement volume fraction was identified as the most significant factor influencing both hardness and density. The results confirm that statistical optimization is aneffective tool for developing high-performance aluminum matrix composites.

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RISK MANAGEMENT IN A REGIONAL DRINKING WATER COMPANY IN OGAN KOMERING ILIR REGENCY USING THE HOUSE OF RISK (HOR) METHOD

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Abstract

Water is an important factor in human life. Fulfilling the need for clean water is very important for the government to achieve prosperity in society. PDAM (Regional Drinking Water Company) is an agency created as a government effort to fulfill the community's need for clean water. PDAM Tirta Agung plays a role in providing clean, healthy drinking water that meets health requirements in the Ogan Komering Ilir Regency. In order for this role to be realized, actions are needed to prevent risks in the company's supply chain from getting worse which results in a decrease in product quality. This study aims to identify risks and risk sources to determine priority risk sources and also propose a mitigation plan to reduce the impact of risks. The method used in this study is the Supply Chain Operations Reference (SCOR) to identify risks in the company's business processes and also the House of Risk (HOR) to find priority risk sources and then create appropriate mitigation strategies. In the process of identifying the company's business processes, 17 risk events and 37 risk sources were found in PDAM Tirta Agung, Ogan Komering Ilir Regency. Based on the results of the House of Risk stage 1 calculation, from 37 risk sources (Risk Agents) in the company's supply chain identification process, 5 priority risk sources (Risk Agents) were obtained. The selection of priority risk sources (Risk Agents) was based on the largest to smallest Aggregate Risk Potential (ARP) value. The selected priority risk sources (Risk Agents) were non-compliance with SOP (A22), damaged production machines (A27), lack of maintenance (A23), poor maintenance by second parties (A4), late payment by customers (A2).

Keywords: Risk Management, House of Risk, Supply Chain Operations Reference, PDAM

1. INTRODUCTION

Water is one of the most essential resources for human survival, as daily activities and healthy living depend on the availability of clean and high-quality water (Tiri et al., 2018; Ahamed et al., 2015). However, the provision of potable water in developing countries has been declining rapidly due to increasing demand and limited resources (Ezugwu et al., 2019). Public drinking water services play a critical role in converting raw water sources into safe and consumable water supplies through conventional treatment processes (Vorstius et al., 2019).

In Indonesia, Regional Drinking Water Utilities (**Perusahaan Daerah Air Minum**—PDAM) are mandated to ensure access to safe drinking water, as regulated by

the Decree of the Minister of Home Affairs No. 690/7027/SJ (1991), which targets 75% coverage in urban areas and 60% in rural areas (Maser et al., 2017). Nevertheless, empirical evidence shows that PDAM performance remains uneven. Lagu et al. (2016) reported that only 50% of PDAMs are classified as healthy, while the remainder exhibit varying degrees of operational inefficiency. This condition indicates that the performance of PDAMs as providers of Drinking Water Supply Systems (**Sistem Penyediaan Air Minum**—SPAM) has not yet reached an optimal level.

Rapid changes in both internal and external environments—such as globalization, technological advancement, increasing service quality requirements, regulatory changes, socio-political dynamics, and pandemic conditions—have significantly increased business risk complexity. Consequently, the implementation of a formal, structured, and integrated risk management system is essential to enhance organizational resilience and support Good Corporate Governance. Risk identification, covering both internal and external sources, is a critical initial step (Durst et al., 2019). Previous studies have demonstrated that the House of Risk (HOR) method is effective in identifying risk events and risk agents through systematic risk mapping in HOR Phase 1 and Phase 2 (Cahyani et al., 2016; Magdalena & Vannie, 2019).

Risk refers to uncertainty regarding the occurrence of an event within a certain period, where such an event may result in losses, ranging from minor and insignificant losses to major losses that can affect the sustainability of a company (Ennouri W., 2013).

Risk management is a system of risk control and protection of assets, property rights, and profits of organizations or individuals against potential losses arising from risk exposure. Risk management is not a static process; rather, it is a dynamic process that evolves in response to changing conditions to address risks that may affect the achievement of organizational objectives (Merna & Al-Thani, 2005).

The objectives and targets of risk management must be aligned with the overall objectives of the company (Ward, 2001). The main objectives of risk management include identifying potential losses, evaluating potential losses through appropriate assessment, and selecting suitable strategies to mitigate such losses (Ennouri W., 2013).

Risk refers to factors that hinder company operations within the supply chain and may occur at the supplier, manufacturing, distribution, and consumer levels. These risks are commonly associated with uncertain events that may occur within a specific period of time (Immawahyu & Oktiarso, 2022; Jüttner et al., 2003). Risks can be avoided, minimized, or even eliminated through appropriate risk management practices (Pujawan & Geraldin, 2009), which primarily aim to identify and evaluate potential losses (Sofyan, 2005). The House of Risk (HOR) method is applied to systematically identify risks and develop mitigation plans through two sequential phases. HOR Phase 1 focuses on identifying risk agents and potential risks, followed by the assessment of risk severity, occurrence probability, and the correlation between risks and risk agents, while HOR Phase 2 determines and selects appropriate risk mitigation strategies based on the prioritized risk agents (Oktiarsol et al., 2022).

The House of Risk (HOR) method is used to identify and analyze potential risks affecting companies and the surrounding environment within supply chain activities. Developed by Pujawan and Geraldin (2009), HOR consists of two phases: Phase 1 focuses on identifying risk causes and formulating mitigation strategies, while Phase 2 prioritizes the implementation of appropriate mitigation actions to address the identified risk sources (Kusmantini et al., 2015; Purwaningsih et al., 2021).

2. METHODOLOGY

Data were processed using the House of Risk (HOR) method, a supply chain risk management approach that combines the House of Quality and Failure Modes and Effects Analysis (FMEA) to manage supply chain risks. FMEA was used because it provides a systematic way to identify and evaluate potential failure modes.

The data processing consisted of three main stages: risk event identification, HOR Phase 1, and HOR Phase 2. Risk events were identified and evaluated using FMEA to determine their severity and occurrence levels. HOR Phase 1 was applied to analyze the relationship between risk agents and risk events and to prioritize risk agents based on their Aggregate Risk Potential (ARP) values. The prioritized risk agents were then used in HOR Phase 2 to determine priority preventive actions. Further analysis and discussion were conducted for the selected risk agents and preventive actions (Ratnasari et al., 2018).

The House of Risk (HOR) method proposed by Pujawan and Geraldin (2009) comprises two stages: HOR 1 and HOR 2. HOR 1 prioritizes risk agents based on their Aggregate Risk Potential (ARP), while HOR 2 supports management in prioritizing risk mitigation actions derived from HOR 1 results. Although the HOR framework is computationally straightforward, its application involves subjective judgment; therefore, cross-functional expert involvement is necessary to enhance assessment reliability (Pujawan & Geraldin, 2009).The steps in the House of Risk method are as follows:

2.1. House of Risk (HOR) phase I

In the first stage of the HOR method, the HOR 1 model is applied, and its framework is presented in Table 1.

Table 1. House of Risk Phase I

Business Proseses	Risk Event (E_i)	Risk Agents (A_j)							Severity Risk Event (S_i)
		A_1	A_2	A_3	A_4	A_5	A_6	A_7	
Plan	E_1								S_1
	E_2								S_2
Source	E_3								S_3
	E_4								S_4
Make	E_5								S_5
	E_6								S_6
Deliver	E_7								S_7
	E_8								S_8
Return	E_9								S_9
Occurance of Agent j		O_1	O_2	O_3	O_4	O_5	O_6	O_7	
Aggregate Risk Potential j		AR P_1	AR P_2	AR P_3	AR P_4	ARP 5	ARP 6	ARP 7	
Priority rank of agent j									

Source: (Pujawan & Geraldin, 2009).

The HOR 1 framework is applied to determine which risk agents should be prioritized for subsequent risk prevention. By adopting the House of Quality (HOQ) concept, HOR 1 is conducted through the following steps:

1. Identification of business process activities, followed by the identification of risk events occurring within these processes. In the HOR 1 framework shown in Table 1., risk events are listed in the leftmost column and denoted as *Ei*.
2. Assessment of risk event severity if the risk occurs. The assessment uses a scale ranging from 1 to 10, where a value of 10 represents an extreme or catastrophic impact. In the HOR 1 framework shown in Table 1, the severity score for each risk event is placed in the rightmost column and denoted as *Si*.
3. Identification of risk agents and assessment of the probability (occurrence) of each identified risk agent. The assessment scale ranges from 1 to 10, where a value of 1 indicates that the risk agent rarely occurs and a value of 10 indicates frequent occurrence. In the HOR 1 framework shown in Table 1, risk agents are denoted as *Aj* and listed in the top row, while the occurrence values are placed in the bottom row and denoted as *Oj*.
4. Assessment of the correlation between risk agents and risk events, denoted as *Rij* in Table 1., using values of 0, 1, 3, and 9. A value of 0 indicates no correlation, 1 indicates low correlation, 3 indicates moderate correlation, and 9 indicates high correlation.
5. Calculation of the Aggregate Risk Potential (ARP_j) for each risk agent.
6. Ranking of risk agents based on their ARP values from highest to lowest.

2.2.House of Risk (HOR) Phase II

After obtaining the ARP ranking of risk agents from highest to lowest in HOR Phase I, the second stage, namely HOR Phase II, is conducted. The HOR Phase II framework is presented in Table 2. HOR Phase II aims to support management or the company in prioritizing effective risk mitigation actions.

Tabel 2. *House of Risk* Fase II

To be Treated Risk Agent (Aj)	Preventive Action (PAj)					Aggregate Risk Potential
	PA_1	PA_2	PA_3	PA_4	PA_5	(ARP_J)
A_1						ARP_1
A_2						ARP_2
A_3						ARP_3
A_4						ARP_4
Total Efectiveness of action k	TE_1	TE_2	TE_3	TE_4	TE_5	
Degree of difficulty performing action k	D_1	D_2	D_3	D_4	D_5	
Efectiveness to difficulty ratio	ETD1	ETD_2	ETD_3	ETD_4	ETD_5	
Rank of Priority	R_1	R_2	R_3	R_4	R_5	

Source: (Pujawan & Geraldin, 2009).

The working steps applied in the HOR Phase II framework are as follows:

1. Selection of risk agents (sources or causes of risk) with the highest Aggregate Risk Potential (ARP) values, which may also be identified through Pareto analysis. In Table 2, these values are presented in the rightmost column and denoted as ARP_j.
2. Identification of preventive actions considered effective in controlling and preventing the selected risk agents. It should be noted that a single risk agent may be addressed by one or more preventive actions, and a single preventive action may simultaneously

reduce the probability of multiple risk agents. In Table 2, preventive actions are listed in the top rows as responses to the question "How" in the HOR framework.

3. Assessment of the correlation between preventive actions and risk agents, using correlation scores of 0, 1, 3, and 9, which have the same interpretation as in HOR Phase I. In Table 2., the correlation between preventive action *k* and risk agent *j* is denoted as *Ejk*.
4. Calculation of the total effectiveness (TE_k) of each preventive action using the following formula:

$$TE_k = \Sigma j \; ARP_j \; Ej_k$$

5. Assessment of the level of difficulty in implementing each preventive action, denoted as D_k. The difficulty scale may follow a Likert scale (1–5) or other appropriate scoring systems. This assessment considers the availability of resources and the costs required to implement the preventive actions.
6. Calculation of the effectiveness-to-difficulty ratio (ETD_k) using the following formula:

$$ETD_k = TE_k/D_k$$

7. Prioritization and ranking of preventive actions (R_k) based on the ETD_k values. The highest ETD_k value indicates the highest priority action. Preventive actions ranked at the top represent those that should be implemented first, as they provide high effectiveness with relatively manageable resource and cost requirements.

3. RESULT

The first step in the HOR Phase 1 model is to identify risks occurring in the business activities of PDAM Tirta Agung. This risk identification is conducted through interviews and direct field observations. After the identification process, the severity value is determined to represent the level of impact caused by each identified risk. Table 3 presents the assigned severity ratings. The next step is to assess the occurrence of the identified risk agents. This assessment is conducted using a scale of 1–10. Table 4 presents the assigned occurrence ratings.

Table 3. Risk Events and Severity Weights

Risk Event	Code	Severity
Errors in demand and sales data calculation	E1	2
Errors in maintenance scheduling for machinery and pumps	E2	3
Errors in production planning	E3	5
Errors in chemical procurement calculations	E4	4
Delays in chemical orders	E5	1
Insufficient chemical supply	E6	8
Poor raw water quality	E7	4
Raw water depletion	E8	7
Delays in raw water distribution	E9	6
Insufficient availability of machinery and pumps	E10	8
Delays in machinery and pump orders	E11	4
Production process errors	E12	8
Machinery failure	E13	9
Turbid drinking water	E14	8

Risk Event	Code	Severity
Interruption of drinking water supply to customers	E15	7
Water losses in the distribution network (non-revenue water)	E16	8
Customer complaints	E17	4

Table 4. Risk Agents and Occurrence Ratings

Risk Agent	Code	Occurrence
Customer demand cannot be accurately forecasted	A1	2
Delays in customer bill payments	A2	8
Inaccurate determination of maintenance schedules	A3	3
Poor quality of maintenance services provided by third-party contractors	A4	6
Errors in production data calculation	A5	2
Inaccurate estimation of chemical and material requirements	A6	2
Supplier-related errors	A7	4
Unavailability of chemicals at suppliers	A8	2
Poor quality of chemicals supplied	A9	2
Damage during storage and warehousing	A10	2
High rainfall at raw water intake sources	A11	5
Raw water contamination	A12	9
Low rainfall at raw water intake sources	A13	2
Raw water distribution pump failure	A14	9
Leakage in raw water transmission pipelines	A15	9
Scarcity of required machinery and pumps	A16	1
Delays in the delivery of machinery and pumps	A17	1
Human error by treatment plant operators	A18	7
Failure of measuring and monitoring instruments	A19	8
Errors in chemical dosing operations	A20	6
Failure to use personal protective equipment (PPE)	A21	2
Non-compliance with standard operating procedures (SOPs)	A22	2
Insufficient preventive maintenance	A23	6
Excessive equipment usage (overloading)	A24	7
Errors in water quality measurement	A25	6
Backwashing process not performed	A26	4
Production equipment malfunction	A27	6
Absence of distribution pipelines to customer locations	A28	3
Errors during new service connection installation	A29	4
Leakage in distribution pipelines	A30	9
Water tanker units unavailable or non-operational	A31	2
Failure of raw water intake/distribution pumps	A32	8
Power outages	A33	7

Risk Agent	Code	Occurrence
Errors in water meter recording by operators	A34	5
Changes in customer tariff rates	A35	2
Long lead time for new service installation	A36	4
Poor drinking water quality	A37	8

Next, the correlation between risks and risk agents is assessed. The correlation assessment uses a scale of 0, 1, 3, and 9. A high correlation between a risk and a risk agent is indicated by a correlation value of 9, while a value of 0 indicates no correlation. The correlation assessment was conducted by the Director of CV. Ladang Management. After obtaining the severity, occurrence, and correlation values for each risk and risk agent, the next step is to calculate the Aggregate Risk Potential (ARP). The resulting ARP values help indicate the level of potential threat posed by each risk agent. Tables 5 present the calculations for the HOR Phase 1 model.

In the risk evaluation stage, the priority risk sources to be addressed first are identified. The prioritization process is conducted by referring to the ARP values obtained from the previous House of Risk Phase 1. Risk agents with the highest ARP values are given the highest priority for risk treatment, and vice versa. Table X presents the priority levels of the risk sources (risk agents). After obtaining the ARP values, the next step is to group the priority risk agents using a Pareto diagram. In this risk evaluation, the 30:70 Pareto principle is applied, indicating that addressing the top 30% of priority risk agents is expected to contribute to approximately 70% of the overall improvement in managing other risk sources. The Pareto diagram illustrating the prioritized risk agents for risk mitigation is presented below.

Tabel 5. House of Risk Phase I

Risk Event	*Risk Agent* (Aj)																		Saverity
(Ej)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	(Si)
E1	9	0	0	0	9	0	3	0	0	0	0	0	0	0	3	0	0	3	2
E2	0	9	9	3	3	0	3	0	0	0	0	3	0	9	0	9	3	3	3
E3	3	9	1	3	1	3	3	0	0	1	0	0	0	1	0	0	0	3	5
E4	0	0	0	0	9	9	3	0	3	0	0	3	0	0	0	0	0	3	4
E5	0	3	0	0	1	9	3	9	1	0	0	0	0	0	0	0	0	3	1
E6	0	9	0	0	3	9	3	9	3	9	3	9	0	0	0	0	0	0	8
E7	0	9	0	0	0	0	0	0	9	9	9	9	1	0	0	0	0	0	4
E8	0	0	0	0	0	0	0	0	1	1	0	0	9	0	3	0	0	0	7
E9	3	0	3	3	0	3	9	0	1	1	0	0	9	9	9	9	9	3	6
E10	3	9	9	9	1	0	3	0	0	0	1	0	0	9	1	9	9	1	8
E11	0	9	9	1	0	0	3	0	0	0	0	0	0	1	0	9	9	1	4
E12	3	0	0	3	9	9	9	9	9	3	1	9	3	0	0	0	0	9	8
E13	1	0	9	9	1	1	3	0	0	0	1	3	0	9	0	9	9	3	9
E14	0	3	0	0	0	9	9	9	9	9	9	9	9	0	0	0	0	9	8
E15	0	9	3	9	3	0	9	0	0	0	0	0	0	9	9	9	9	3	7
E16	3	0	9	9	3	0	9	0	0	0	0	0	0	0	9	1	1	3	8
E17	9	3	3	9	3	3	9	9	9	9	3	9	9	9	9	9	9	3	4
Occurrence (Oj)	3	9	4	9	4	4	7	2	1	2	7	9	2	9	9	1	1	7	
ARPj	504	3510	1376	3546	956	1260	3507	522	266	516	1183	3024	506	3078	2340	377	359	2121	
Ranking	29	5	18	4	23	19	6	26	33	27	21	9	28	8	14	31	32	15	

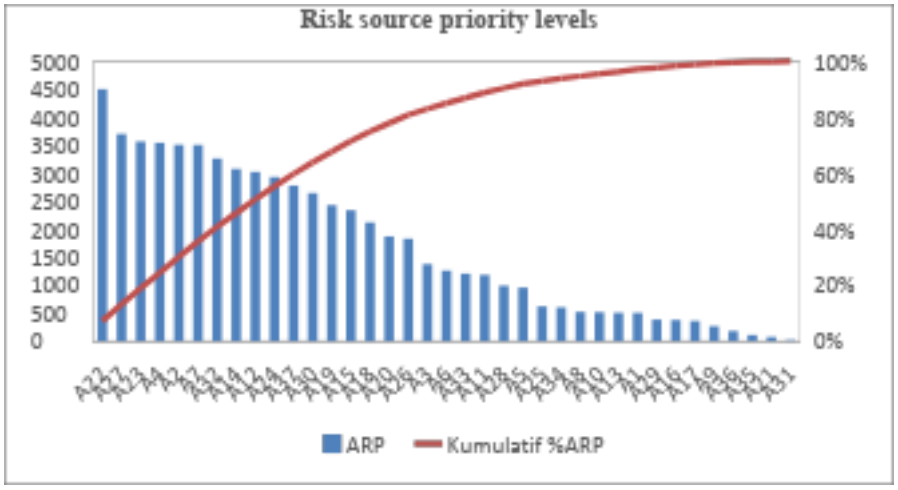


Figure 1. Pareto diagram of risk source priority levels

The House of Risk (HOR) Phase 2, analysis focuses on evaluating priority risk agents in order to determine appropriate mitigation actions to minimize their impacts. The first step involves designing mitigation strategies to achieve an ideal condition for addressing the main risk agents. Next, the correlation between risk agents and mitigation strategies is assessed to determine the effectiveness of each preventive action. Subsequently, the level of difficulty of each mitigation strategy is evaluated using the Degree of Difficulty (Dk) assessment, which aims to measure how challenging a mitigation strategy is to implement. Table 6 presents the Degree of Difficulty ratings for each planned mitigation strategy.

Table 6. Degree of Difficulty (Dk)

Risk Agent	Mitigation Strategy	Code	Dk
Non-compliance with standard operating procedures (SOPs)	• Enforcement of disciplinary sanctions	PA1	4
	• Review and revision of SOPs	PA2	4
	• Enhancement of SOP dissemination and operator training programs	PA3	3
	• Periodic monitoring and internal audits	PA4	5
Production equipment malfunction	• Temporary shutdown of affected equipment	PA5	3
	• Routine inspection and condition assessment	PA6	5
	• Development of SOPs for equipment operation and emergency handling	PA7	4
Insufficient preventive maintenance	• Establishment of a structured maintenance management system	PA8	5
	• Implementation of monitoring and evaluation systems	PA9	5
	• Scheduling of routine preventive maintenance	PA10	5

Risk Agent	Mitigation Strategy	Code	Dk
Poor quality of maintenance services by third-party contractors	• Performance evaluation of maintenance vendor	PA11	4
	• Review and enforcement of contracts and service level agreements (SLAs)	PA12	5
	• Development of internal backup maintenance capabilities	PA13	4
Delays in customer bill payments	• Professional and systematic customer communication	PA14	4
	• Issuance of formal billing and reminder notices	PA15	4
	• Enforcement of penalty or sanction clauses	PA16	5

The final results in the House of Risk Phase 2 table are used to determine the priority of mitigation strategies based on the ranking of the Effectiveness-to-Difficulty Ratio (ETDk). Mitigation strategies with the highest ETDk values are assigned the highest priority for implementation. The results of the House of Risk Phase 2 table 7 are presented below.

Tabel 7. *House of Risk* Phase II

Risk Event	*Risk Agent* (Aj)																			Saverity
(Ej)	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	A32	A33	A34	A35	A36	A37	(Si)
E1	9	0	0	3	0	9	0	0	0	9	3	3	0	0	0	9	9	0	0	2
E2	0	0	0	3	9	0	0	1	9	0	0	0	0	9	0	0	0	0	0	3
E3	3	3	0	3	1	9	0	9	9	3	3	0	0	0	0	1	0	0	0	5
E4	3	9	0	3	0	3	1	0	0	0	0	0	0	0	0	0	0	0	3	4
E5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	1
E6	3	3	0	0	0	0	3	9	0	0	0	0	0	0	0	0	0	0	9	6
E7	0	0	0	9	0	0	9	0	9	0	0	0	0	0	0	0	0	0	9	5
E8	0	0	0	1	0	9	0	0	9	0	3	9	0	9	9	0	0	0	0	8
E9	3	0	0	9	9	9	0	0	9	9	3	9	1	9	9	0	0	0	0	6
E10	0	0	0	3	9	9	0	0	9	9	0	0	0	9	0	0	0	0	0	6
E11	0	0	0	1	3	3	0	9	3	3	0	0	0	3	0	0	0	0	0	2
E12	9	9	1	9	3	9	3	3	3	9	0	0	0	0	0	1	0	0	9	8
E13	3	0	0	9	9	3	0	9	9	9	0	0	0	9	1	0	0	0	0	9
E14	0	9	0	9	0	1	3	9	1	0	0	0	0	0	0	0	0	0	9	7
E15	0	0	0	9	9	0	0	3	9	9	0	9	0	9	9	0	0	0	0	7
E16	9	0	0	9	9	3	0	0	1	9	0	9	0	0	0	3	0	0	0	8
E17	3	3	0	9	9	3	3	3	9	9	9	9	1	9	3	3	9	9	9	4
Occurrence (Oj)	9	8	9	8	8	7	5	5	7	2	4	9	2	8	6	9	2	5	9	
ARPj	2430	1872	72	4504	3568	2933	620	1830	3703	990	384	2646	20	3264	1206	603	108	180	2781	
Ranking	13	16	36	1	3	10	24	17	2	22	30	12	37	7	20	25	35	34	11	

House of Risk Phase 2 is a continuation of House of Risk Phase 1. In this phase, mitigation strategies (preventive actions) are formulated based on the priority risk agents identified in Phase 1. The mitigation strategies are developed through discussions with experts and by reviewing relevant references related to the previously identified priority risk agents. Each mitigation strategy is formulated for each priority risk agent identified in the previous phase.

From the five priority risk agents identified in Phase 1, a total of 16 mitigation strategies (preventive actions) were formulated in House of Risk Phase 2, including imposing sanctions (PA1), conducting routine inspections (PA6), enhancing socialization and training programs (PA3), scheduling routine maintenance (PA10), developing a structured maintenance system (PA8), implementing monitoring and evaluation systems

(PA9), enforcing penalty and sanction clauses (PA16), establishing standard operating procedures for machine handling (PA7), maintaining professional communication (PA14), conducting periodic monitoring and audits (PA4), strengthening internal capabilities (PA13), increasing socialization and training activities (PA3), reviewing and enforcing contracts/service level agreements (PA12), issuing official billing letters (PA15), shutting down machine operations when necessary (PA5), and evaluating vendor performance (PA11).

4.CONCLUSION

This study concludes that supply chain risk management at PDAM Tirta Agung, Ogan Komering Ilir Regency, can be effectively analyzed using the House of Risk (HOR) framework. The identification process revealed 17 risk events and 37 risk agents. Based on HOR Phase 1, five priority risk agents were selected according to their Aggregate Risk Potential (ARP) values, including issues related to standard operating procedures, machine conditions, maintenance performance, third-party services, and customer payment delays.

In HOR Phase 2, 16 preventive actions were formulated and prioritized using the Effectiveness-to-Difficulty (ETD) ratio. Key mitigation strategies include strengthening enforcement mechanisms, improving inspection and training activities, implementing routine maintenance schedules, and establishing structured maintenance management systems. These strategies provide practical recommendations for enhancing operational reliability and risk resilience in public water utility supply chains.

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METHOD FOR REDUCING ARRESTER GROUNDING RESISTANCE IN DISTRIBUTION SUBSTATIONS TO MINIMIZE THE OCCURRENCE OF GROUND POTENTIAL RISE (GPR)

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ABSTRACT

An effective arrester grounding system in distribution substations is crucial for safely discharging lightning currents and preventing dangerous Ground Potential Rise (GPR). At the PD.0431 (160 kVA) Distribution Substation, the measurement results showed a grounding resistance value of 6.7 Ω, which exceeded the maximum limit of 5 Ω according to the 2011 PUIL standard. This condition indicates a risk of equipment damage and safety hazards in the form of high touch and step voltages. This study used field experiments and computational simulation methods. Improvements were made by modifying the grounding system configuration by adding parallel rod electrodes. The effectiveness of the method was analyzed by comparing resistance measurements before and after the repair using an Earth Tester. Safety risk analysis was carried out by simulating the distribution of GPR, touch voltage, and step voltage using CYMGrd software**,** assuming a lightning fault current of 1000 A. The implementation of the addition of four rod electrodes successfully reduced the grounding resistance from 6.08

Ω to 1.97 Ω, thus meeting the standard. Simulations show that this improvement successfully reduces GPR by 52.7 % (from 359.14 V to 169.71 V). A more significant reduction occurs in the immediate safety parameters, namely the touch voltage decreased by 73.9 % (from 427.96 V to 111.48 V) and the step voltage decreased by 74.7% (from 297.05 V to 75.12 V). The post-improvement ground potential contour also shows a more even and gentle distribution. This study proves that optimizing the grounding configuration by adding parallel electrodes is an effective method to reduce resistance and, more critically, drastically mitigate the risk of human safety hazards due to GPR**.** This method is recommended as a practical solution to improve system reliability and personnel safety at distribution substations with similar conditions.

Keywords : Grounding resistance, Ground Potential Rise (GPR), Distribution Substation, Arrester, PUIL 2011

1. INTRODUCTION

The electric power distribution system, which delivers power from generating plants to consumers through transmission lines(Paul et al., 2024), substations, and medium-voltage overhead lines(Swain et al., 2022), is a critical infrastructure vulnerable to disruptions(Rachunok & Nateghi, 2020). Among the various types of disruptions, lightning strikes occupy a significant position as a non-technical threat. To mitigate the impact of lightning surges, the installation of arresters supported by an effective grounding system is essential(Nunes, 2023). The grounding system not only functions to channel lightning currents safely to the ground but also serves as a protective foundation for maintaining reliable operation and equipment safety(Permal et al., 2020).

The primary threat from improperly managed lightning discharges is *Ground Potential Rise* (GPR)(Taryo et al., 2025). GPR is a phenomenon where the electrical potential at a ground electrode increases drastically and unevenly compared to the surrounding reference ground(Putra et al., 2023). This local potential rise creates a dangerous voltage gradient across the ground surface, triggering two major safety risks: *touch voltage* (the danger of touching equipment in contact with the ground)(Hu et al., 2024), and *step voltage* (the danger resulting from the voltage difference between two standing points)(Fitriani et al., 2024). Therefore, the performance of the grounding system directly correlates with the level of human safety around the distribution substation(Farooq et al., 2021).

The key to a grounding system's performance lies in its resistance value. The 2011 PUIL standard sets a maximum grounding resistance limit for distribution substations of 5 ohms(Putra et al., 2024). High resistance impedes the flow of lightning current to the ground, causing surge energy to seek alternative paths(Yani et al., 2024). This can trigger reflected waves that propagate to metal equipment, increasing the risk of overvoltage and insulation damage. In other words, exceeding the standard ground resistance not only reduces the effectiveness of the arrester but can actually exacerbate the effects of GPR and turn the protection system into a source of danger.

Based on initial measurements at the PD 0431 Distribution Substation, it was found that the arrester grounding resistance value had exceeded the permitted limit. This finding indicates the installation's vulnerability to protection failure during a lightning strike, as well as a potential safety threat to personnel and the surrounding community. This condition implies that the design or implementation of the existing grounding system

is no longer adequate, requiring technical intervention to improve soil characteristics or electrode configuration.

Therefore, this research is focused on analyzing and proposing an effective and applicable method for reducing grounding resistance at the PD 0431 Distribution Substation. The goal is to restore the performance of the arrester protection system to standard, thereby minimizing the risk of equipment damage due to lightning surges. Furthermore, this research is directed at mitigating the potential for GPR, which ultimately aims to improve the level of life safety by reducing the dangers of touch voltage and step voltage at the distribution substation location.

2. RESEARCH METHOD

The research on reducing the arrester grounding resistance at the 20 kV Distribution Substation PD.0431 was motivated by the high frequency of lightning strikes at the location, which increases the vulnerability to disturbances and the potential for *Ground Potential Rise* (GPR). The initial stage of the research began with field observations and a comprehensive literature study. Observations were conducted to ensure the selection of the right location, while the literature study was used to collect relevant references and previous methods, in order to build a strong theoretical foundation.

Next, an initial grounding resistance measurement was performed as baseline data. This measurement used the three-point method (*Fall of Potential Method*) with a 4015A Digital Earth Teste(Putra et al., 2025), in accordance with applicable measurement standards. The results of this initial measurement were then analyzed to determine the improvement strategy. Based on the analysis, the chosen improvement method was the addition of *a driven rod* electrode. The design of this electrode configuration was calculated using the Dwight Formula (based on IEEE Std 81-2012**)** to predict the final resistance value theoretically (IEEE Power and Energy Society - Substations Committee, 2012). This prediction is important to determine the optimal number, depth, and spacing between electrodes before physical implementation.

After the repair method was implemented in the field, repeat measurements were performed to verify the resistance reduction. To assess safety aspects, a Ground Potential Rise (GPR) analysis was performed using CYMGrd simulation software. This simulation aims to model the distribution of ground potential after the repair, in order to evaluate the effectiveness of the system in mitigating the risks of touch voltage and step voltage.

- For one electrode rod, it is implanted perpendicularly.

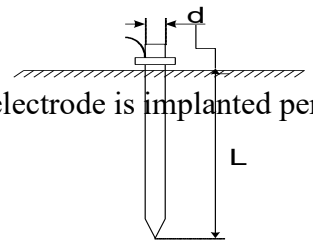


Figure 1. The rod electrode is implanted perpendicularly

$$R = \frac{2}{2\pi L}\ln\left(\frac{2L}{r}\right) \quad (1)$$

- For four electrode rods implanted perpendicularly (placed anywhere)

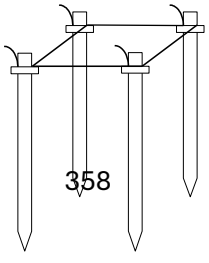


Figure 2. Four electrode rods are implanted perpendicularly.

$$R = \frac{2}{2\pi L}\ln\left(\frac{2L}{\sqrt[4]{2^{1/2}a^3r}}\right) \quad (2)$$

3. RESULTS AND DISCUSSIONS

Based on initial measurements using the three-point method with *the 4015A Digital Earth Tester*, data obtained showed that the arrester grounding resistance value at the PD.0431 Distribution Substation (160 kVA Transformer) was 6.7 Ω. This result has exceeded the maximum limit of 5 Ω set in the 2011 PUIL standard, as summarized in Table 1.

Table 1. Results of arrester grounding resistance measurements

Substation Code	Soil Type	Location	Resistance Ω
PD. 0431	Clay	Jl. Silaberanti	6.7

The high resistance value is due to the characteristics of the location. This substation sits on clay soil, which tends to be damp due to the rainy season. Literature indicates that clay soils have a wide range of resistivity, generally in the range of 20 - 100 Ωm. Initial measurements of 6.7 Ω indicated that the existing ground electrode configuration was no longer adequate for the soil resistivity conditions at the location.

To design an effective solution, a calculation analysis is performed to predict the electrode requirements as described in Table 2. This calculation refers to the Dwight Equation (UB. Dwight). This equation models the grounding resistance for one or more *driven rod electrodes* installed in parallel. For a single driven rod electrode, the grounding resistance can be estimated using formula (1), using one driven electrode rod:

Table 2. Field Parameters

Parameter	Mark	Unit
ρ : Clay Resistivity	20 to 100	Ωm
ρ : Assumed soil resistivity	35	Ωm
L: Length of embedded stem	10	m
d : Electrode rod diameter	0.02	m
r : Radius of the electrode rod	0.01	m

Table 3. Results of Arrester Grounding Resistance Comparison

PUIL 2000 Standard	Measurement (Ω)	Calculation (Ω)
5	6.7	4.84

Table 3. The results of the initial calculation analysis using the Dwight Equation for the arrester grounding system at the PD.0431 Distribution Substation (160 kVA) produced a higher value than the field measurement results of 6.7 Ω. This difference may occur because the assumption of soil parameters in theoretical calculations (such as homogeneous resistivity) has not fully represented the actual conditions in the field, which are more complex. However, both the measurement results (6.7 Ω) and the initial calculation results have both exceeded the maximum limit of 5 Ω set in the 2011 PUIL standard. This condition confirms that the existing grounding system is inadequate and requires immediate repair intervention.

This high resistance phenomenon is exacerbated by environmental conditions. Measurements were conducted at a location with clay soil that was humid due to the rainy season. Although humidity generally reduces soil resistivity, the existing single-electrode configuration was still unable to achieve safe resistance values. This indicates that a technical solution is needed to overcome the limitations of the existing system, regardless of weather conditions.

Therefore, a repair design was carried out by adding rod electrodes. which are installed in parallel to form a grid configuration with the existing electrodes. The analysis begins by calculating the performance of one additional electrode using the Dwight Equation. As a result, the resistance value obtained is still outside the standard limits. Therefore, the simulation is continued by increasing the number of electrodes. Based on the equation for the parallel arrangement (equation 2)**,** the calculation with four grounding electrodes produces a theoretical resistance value of 1.68 Ω**.**

The final value of 1.68 Ω has met and is even far within the tolerance limit of the PUIL 2011 standard (0–5 Ω) added. This configuration of four parallel electrodes is theoretically able to expand the contact area with the ground and create a more effective grounding path, so that it can flow fault currents (especially lightning currents) more efficiently. Achieving this value shows that the method of adding electrodes in parallel is a feasible and effective solution to reduce the grounding resistance of distribution substations in similar soil conditions.

Table 4. Calculated Grounding Resistance Values

PUIL Standard 2011	**Calculation Results Grounding Resistance (Ω)**	
	1 Electrode Rod	**4 Electrode Rods**
5	4.84	1.68

Based on the implementation of the addition of rod electrodes in the field, the results of the arrester system grounding resistance measurements showed a significant decrease, as presented in Table 5. Measurements were carried out on two tested configurations: the old system with 1 rod electrode and the repair system with 4 electrode rods installed in parallel.

Table 5. Grounding Resistance Values from Field Measurements

PUIL 2000 Standard	**Grounding Resistance Measurement Results (Ω)**	
	1 Electrode Rod	**4 Electrode Rods**
5	6.08	1.97

The data confirms that increasing the number of electrodes is inversely proportional to the final resistance value. The 4 electrode configuration successfully reduced the resistance from 6.08 Ω to 1.97 Ω, which meets and is well within the safe limits of the PUIL standard (maximum 5 Ω). This downward trend is clearly visualized in Figure 1, which shows a curve of the relationship between increasing the number of electrodes and the resulting resistance.

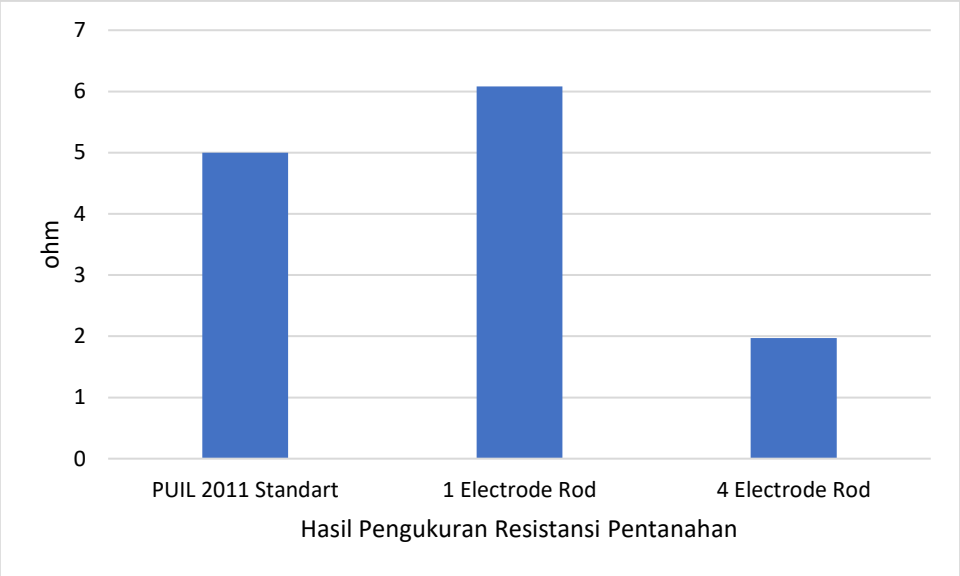


Figure 1. Graph of grounding resistance reduction with field measurements.

It should be noted that there is a difference between the resistance value from the previous theoretical calculation (1.68 Ω) and the actual measurement result (1.97 Ω). This difference is normal and can be caused by several field factors, such as variations in inhomogeneous soil resistivity, imperfect electrode depth and contact conditions, or the influence of higher soil moisture during the rainy season. This moisture factor is actually beneficial because it reduces soil resistivity, thus contributing to the achievement of lower resistance values.

After confirming that the resistance value has met the standard, the next critical step is to evaluate the safety aspect by analyzing the Ground Potential Rise (GPR) potential**.** This analysis was performed using CYMGrd software simulations for two scenarios: a system with four electrodes at a depth of 3 meters and a system with a depth of 10 meters. The simulations were performed assuming a lightning fault current of 1000 Amperes flowing into the ground.

Table 6. Ground Potential Rise (GPR)

Research Description	**GPR**	**Touch Voltage**	**Step Voltage**
	Volts (V)		
Before Repair	359.142	427.962	297.05
After Repair	169.712	111.482	75.12

The data in Table 6 shows a very significant decrease in the three safety parameters after the improvement of the grounding system with the addition of 4 electrode rods. The GPR value decreased by 52.7% (from 359.142 V to 169.712 V). A more drastic decrease occurred in the direct hazard parameters to humans. Touch Voltage decreased by 73.9% (from 427.962 V to 111.482 V), and Step Voltage decreased by 74.7% (from 297.05 V to 75.12 V).

The decrease in these values is directly due to the decrease in grounding resistance from 6.08 Ω (1 bar) to 1.97 Ω (4 bars). Based on Ohm's law, this 67.6% decrease in resistance causes the potential arising at the ground electrode (GPR) to also decrease proportionally for the same fault current. The new parallel electrode configuration also creates a more even and gentle distribution of ground potential**,** so that the voltage

gradient at the ground surface, which is the source of the danger of step voltages, decreases drastically. A visualization of this potential distribution is shown in Figure 2. The potential contour before the repair (Figure 2a) shows a very steep gradient and a high potential area concentrated around a single electrode point. In contrast, the contour after the repair (Figure 2b) shows a wider, smoother distribution pattern and a much lower maximum potential value. This visual difference strengthens the conclusion that the new grounding system has succeeded in improving grounding effectiveness and distributing fault energy better**.**

Overall, the simulation analysis proves that the grounding system repair not only successfully meets the resistance standards but also substantially improves the safety level of the site**.** The post-repair touch and step voltage values (111.482 V and 75.12 V) have been at a much safer level, which significantly reduces the risk of serious injury or fatality for operation and maintenance personnel around the PD.0431 Distribution Substation.

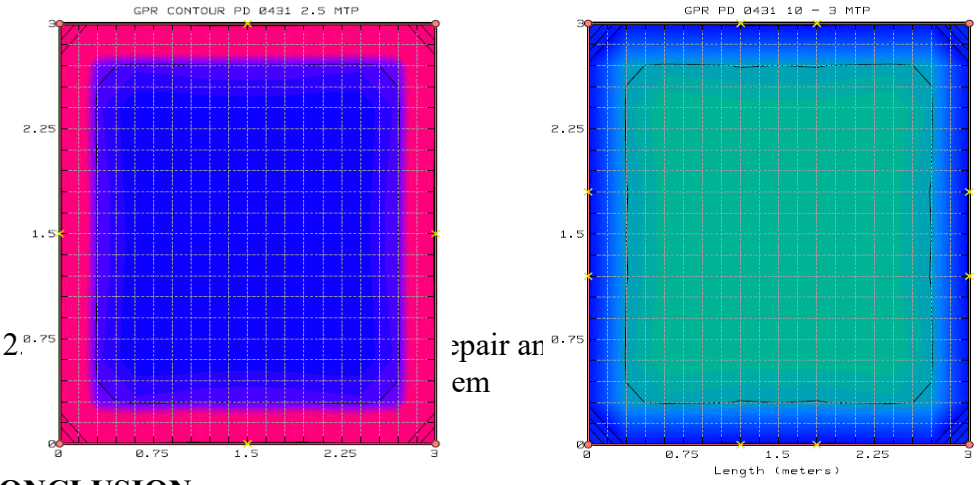


Figure 2. epair an em

4. CONCLUSION

Based on the research conducted, it can be concluded that the method of adding rod electrodes in parallel successfully reduced the arrester grounding resistance at the PD.0431 Distribution Substation from 6.08 Ω to 1.97 Ω. This result has met the PUIL 2011 technical standard, which requires a maximum resistance value of 5 Ω. This system configuration improvement proves that physical optimization of the grounding system is an effective solution to overcome high ground resistance at locations with moist clay soil characteristics. Furthermore, the reduction in resistance has a direct and significant impact on improving safety. Simulations show that the system improvement successfully reduced the Ground Potential Rise (GPR) by 52.7 %, as well as reducing the touch voltage and step voltage by 73.9% and 74.7%, respectively. Thus, this study not only focuses on the technical compliance aspect but also confirms that effective grounding is a critical step in protecting humans from the dangers of electric shock, while improving the reliability of the electric power distribution system as a whole.

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ANALYSIS OF THE USE OF CONE ASH AS A SUBSTITUTION FOR FINE AGGREGATE AND SIKACIM CONCRETE ON THE MIX DESIGN OF CONCRETE QUALITY FC'31.2 MPA

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ABSTRACT

The development of modern infrastructure necessitates the use of building materials that address environmental and economic sustainability in addition to technical needs. The heavy reliance on river sand, a natural fine aggregate whose mining affects aquatic ecosystems and environmental degradation, is one of the major issues facing the concrete industry. Therefore, alternative fine aggregate materials derived from industrial waste and available sustainably are needed. Crusher dust is a byproduct of the stone crushing industry. It has a fine grain size and a rough surface texture, making it potentially useful as a partial substitute for fine aggregate in concrete mixes. The purpose of this research is to examine the effects of adding SikaCim Concrete additive and substituting fly ash for fine aggregate on the mix design, compressive strength, and workability of K-350 class concrete (fc' = 31.2 MPa). This study employs a quantitative experimental design with fly ash substitutions of 0%, 15%, 30%, and 45% of the fine aggregate weight. The fixed dosage of SikaCim Concrete admixture is 37.5 milliliters. Concrete cubes of 15 × 15 × 15 cm are used as test specimens. They are manufactured, cured in accordance with SNI guidelines, and evaluated after 28 days. Test parameters include a slump test to evaluate the workability of fresh concrete and a concrete compressive strength test. The results of the study showed that the substitution of fly ash significantly affected the properties of concrete. A 30% substitution of fly ash with the addition of SikaCim Concrete resulted in an average compressive strength of 400.05 kg/cm², an increase of approximately 14% compared to normal concrete. The addition of SikaCim Concrete was able to maintain the workability of the concrete even though the fly ash content increased. However, at a 45% substitution of fly ash, there was a decrease in the compressive strength of the concrete due to the excess fine material which increased water requirements and reduced the effectiveness of the cement paste bond. This research confirms that the use of fly ash up to a certain limit, specifically 30%, combined with SikaCim Concrete can produce concrete with optimal performance and support the concept of sustainable construction.

Keywords: concrete, fly ash, crusher dust, SikaCim Concrete, compressive strength, workability, mix design.

1. INTRODUCTION

1.1. Background

Because of its excellent durability, great compressive strength, and convenience of use, concrete is the most widely utilized building material in infrastructure development. The requirement for concrete has grown significantly as a result of Indonesia's infrastructure development, which has an immediate effect on the country's growing need for natural aggregates, especially fine aggregates like river sand. Excessive exploitation of river sand has led to various environmental problems, such as erosion, river silting, ecosystem damage, and a decline in environmental quality. Finding substitute materials that can partially replace natural fine aggregate without sacrificing concrete performance has become necessary as a result of this circumstance. The stone-crushing business produces a lot of crusher dust, which is a waste product that is frequently underutilized. The characteristics of crusher dust, including its fine particle size, angular shape, and rough surface texture, offer potential for use as a fine aggregate substitute in concrete. The use of crusher dust is expected to increase concrete density through its filler effect and reduce dependence on natural sand. Admixtures, on the other hand, are now an essential component of contemporary concrete technology. SikaCim Concrete is a water-reducing additive that lowers the water-to-cement ratio and increases the workability of concrete. The combination of fly ash and admixtures is expected to produce K-350 grade concrete with good mechanical performance, ease of work, and greater environmental friendliness.

1.2. Research Objectives and Contributions

This research aims to:

1. Analyzing the effect of coal ash substitution on the mix design of K-350 quality concrete.
2. Evaluating the effect of fly ash and SikaCim Concrete on concrete workability.
3. Analyzing the effect of coal ash substitution on the compressive strength of 28-day-old concrete.

The use of fly ash as a substitute for fine aggregate in medium-quality structural concrete has a scientific foundation thanks to this study.

2. LITERATURE REVIEW

2.1. Concrete and Mix Design

The process of figuring out the ideal ratios of cement, aggregate, water, and admixtures to create concrete with a certain performance is known as concrete mix design. Compressive strength, workability, durability, and cost effectiveness are important factors in mix design. The primary factor affecting the compressive strength of concrete is the water-to-cement ratio.

2.2. Rock Ash as a Substitute for Fine Aggregate

According to several studies, at specific concentrations, rock dust can improve the density and compressive strength of concrete. Rock dust's filling function can strengthen the binding between particles and decrease the porosity of concrete. On the other hand, too much rock dust can make things less workable and demand more water.

2.3. The Role of Admixtures in Concrete

Water-reducing admixtures, such as SikaCim Concrete, reduce the amount of water needed for mixing by dispersing cement particles. Concrete's compressive strength and durability are enhanced by lowering the water-to-cement ratio.

2.4. Research Gap

The majority of earlier research looked at rock dust without any additives. Thus, by investigating the combination of rock ash and SikaCim Concrete in K-350 grade concrete, this study closes this gap.

3. RESEARCH METHODOLOGY

3.1. Research methods

This research uses a quantitative experimental method conducted in the laboratory.

3.2. Ingredients and Mixture Variations

Type I Portland cement, Musi River sand, fly ash, PDAM water, crushed stone up to 20 mm in size, and SikaCim Concrete are among the ingredients utilized. Variations in mixtures:

a. BN: Normal Concrete (0% Rock Ash)
b. BA15: Rock Ash Subtitution 15%
c. BA30: Rock Ash Subtitution 30%
d. BA45: Rock Ash Subtitution 45%

3.3. Testing Method

a. Slump Test (SNI 1972:2008)
b. Compressive strength test at 28 days (SNI 1974:2011)

4. RESULT AND DISSCUSION

4.1. Concrete Workability Analysis

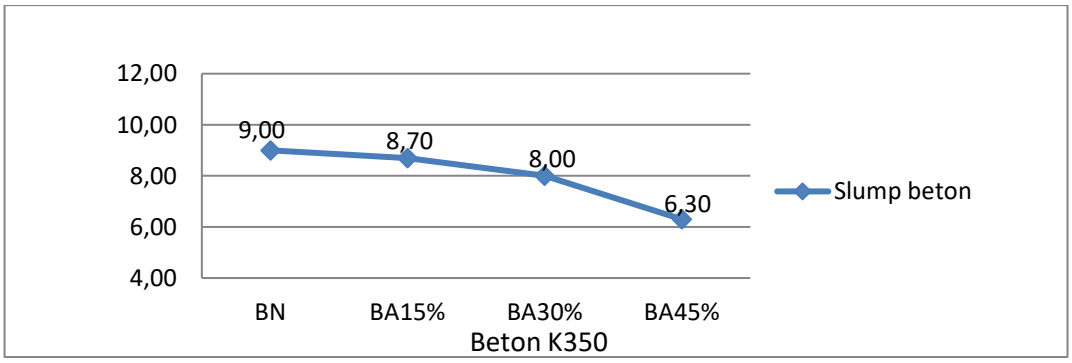


Figure 4.1. Graph Relationship Of Slump Value
Source : Test Results of the Use of Rock Ash as a Substitute for Fine Aggregate and Sikacim Concrete

The slump value displayed in Figure 4.1 illustrates the findings of the new concrete workability test. The concrete slump value, according to the test findings, is between 6.3 and 9 cm, which is still within the intended slump range of 6 to 10 cm for structural concrete. This shows that all mixture modifications are still reasonably workable for the field's casting and compaction procedures. It has been demonstrated that using SikaCim Concrete may keep concrete workability within reasonable bounds.

4.2. Concrete Compressive Strength Analysis

Up to 30% coal ash substitution increased the compressive strength of concrete; at 45% substitution, it decreased. BA30 had the highest compressive strength rating, 400.05 kg/cm².

4.3. Implications for Mix Design

A universal compression testing equipment with sufficient capacity was used to test the compressive strength of 15 × 15 × 15 cm cube specimens that had been cured in compliance with SNI 1974:2011 after 28 days. To determine a typical average compressive strength value for each change of the concrete mixture, three specimens were examined. The results of this test serve as a crucial foundation for examining the effects of employing fly ash on the mix design of K-350 quality concrete since concrete compressive strength is the primary metric used to assess the structural performance of concrete.

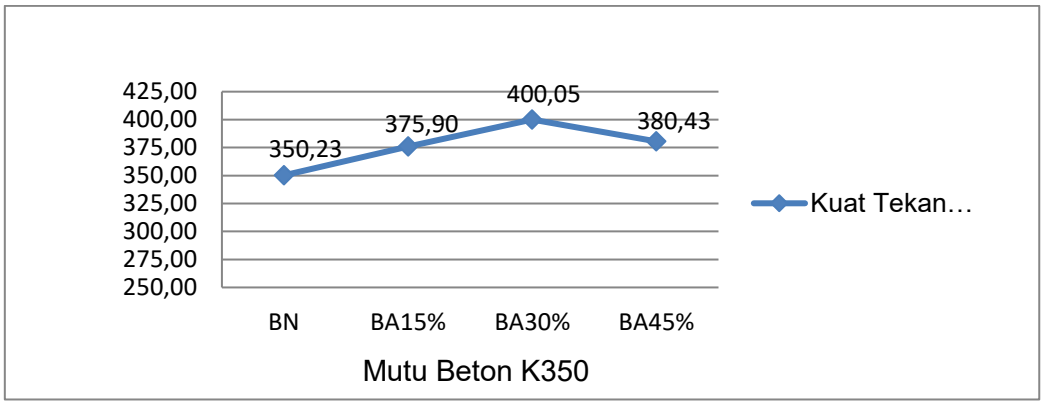


Figure 4.2. Average Compressive Strength Relationship Graph
Source : Test results for the use of fly ash as a substitute for fine aggregate and Sikacim concrete

According to Figure 4.2, concrete's compressive strength rises as the proportion of coal dust substitution increases up to a certain point before declining at higher substitution levels. In comparison to the ideal mixture, concrete with 30% rock ash substitution has the highest average compressive strength, whereas concrete with 45% substitution has a lower compressive strength. This pattern suggests that the proportion and balance of components in the concrete mix design are directly impacted by the usage of rock ash.

4.4. Discussion of Concrete Behavior Mechanism

The increase in compressive strength is caused by:

a. The effect of rock ash filling
b. More even distribution of cement paste
c. Effective water-cement ratio reduction

The decrease in compressive strength in BA45 occurs due to excess fine material which increases water requirements and reduces the effectiveness of the cement paste

bond.

5. CONCLUSSION AND SUGGESTION

5.1. Conclussion

Several conclusions can be made based on the findings of laboratory testing and analysis of the addition of SikaCim Concrete additive to K-350 quality concrete (fc' = 31.2 MPa) and the use of fly ash as a fine aggregate substitute.

1. The workability of fresh concrete, the compressive strength of hardened concrete, and mix design planning are all greatly impacted by the partial replacement of fine aggregate with fly ash. Fly ash changes the material's properties, hence the mix proportions must be adjusted, especially with relation to water requirements and additive usage.
2. Concrete performance is somewhat enhanced by the substitution of rock ash. In order to achieve the best concrete compressive strength while preserving workability that satisfies the requirements for structural concrete applications, the ideal substitution ratio is 30% of the fine aggregate weight.
3. By regulating a more constant water-to-cement ratio, the inclusion of SikaCim Concrete additive helps achieve higher concrete compressive strength and has been shown to improve concrete workability without the need for mixing water.
4. Fly ash and SikaCim Concrete together have the potential to produce K-350 quality concrete that is more sustainable, eco-friendly, and efficient because they can use waste from the stone crushing industry and lessen reliance on natural fine aggregates without compromising the concrete's structural performance.

5.2. Suggestion

The following recommendations might be made for additional study and field implementation based on the findings of the completed research:

1. To have a more complete view of the ideal limitations for the use of rock ash in structural concrete, more research is required with more different variants of rock ash substitution, such as at levels of 10%, 20%, 40%, or more than 45%.
2. To guarantee long-term concrete performance with the use of fly ash, more research is advised to look at characteristics of concrete durability, such as resistance to sulfate attack, carbonation, water permeability, and water absorption.
3. Fly ash quality must be carefully taken into account in field applications, particularly with regard to grain gradation, mud content, and water content, as differences in these material properties can impact concrete's workability and compressive strength.
4. In order to ensure that the proportions of the mixture used are actually in line with the anticipated concrete quality and implementation conditions in the field, the usage of admixtures like SikaCim Concrete should be adjusted to local material circumstances and a trial mix should be conducted beforehand.

REFERENCES

ANALYSIS OF THE EFFECT OF RICE HUSK ASH AS A PARTIAL CEMENT SUBSTITUTE ON THE COMPRESSIVE STRENGTH OF CONCRETE GRADE FC 24.0 MPa (K-275)

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ABSTRACT

Because Portland cement is used so frequently as a concrete binder, the modern building sector confronts serious environmental sustainability issues. The manufacture of cement uses a lot of energy and produces a lot of carbon dioxide emissions. As a result, creative building materials that satisfy technical specifications while being affordable and ecologically friendly are required. Because it includes pozzolanic amorphous silica, rice husk ash (RASH), a plentiful agricultural waste in Indonesia, may be able to partially replace cement. The purpose of this study is to examine how the workability and compressive strength of FC 24.0 MPa (K-275) concrete are affected when RASH is used in place of some cement. A quantitative laboratory experiment was employed as the research method. 0%, 5%, 10%, and 15% of the cement weight was substituted with rice husk ash. SNI 03-2834-2000 with a water cement factor of 0.53 is referred to in concrete mixture planning. The test specimens were 150 x 150 x 150 mm concrete cubes that were cured using the water immersion method and tested for compressive strength after 28 days. The workability of fresh concrete was assessed using slump testing. The findings demonstrated that the workability and compressive strength of concrete were significantly impacted by the addition of rice husk ash. Concrete's compressive strength rose with 5% and 10% ASP variations, reaching a maximum of 355.52 kg/cm² at the 10% difference. The compressive strength dropped at the 15% ASP fluctuation, but the design concrete quality was still met. As the ASP content increased, the slump value trended downward, but all mixture variations remained within the necessary workability range. The study's findings show that adding up to 10% rice husk ash to concrete improves its performance and may help create more sustainable and ecologically friendly concrete.

Keywords: natural pozzolan, workability, compressive strength, rice husk ash, and eco-friendly concrete

1. INTRODUCTION

Concrete's strong compressive strength, good durability, and shape flexibility make it the most popular building material in the world. Buildings, roads, bridges, dams, and other vital infrastructure frequently employ concrete. However, Portland cement is the main binder used in ordinary concrete, and its manufacture has a big environmental impact. Because of the high-temperature clinker firing and limestone calcination processes, Portland cement manufacture accounts for 7–8% of the world's carbon dioxide emissions. Additionally, the quest for more cost-effective and ecologically friendly alternative materials is fueled by increasing energy use and comparatively high cement prices. One of the most important ways to achieve sustainable construction is to use less cement. Burning rice husks produces rice husk ash (RASH), a waste product with a high amorphous silica concentration. Due to Indonesia's strong national rice production, rice husks are generated in vast numbers. Reducing agricultural waste and Portland cement use can be achieved by using RASH as a natural pozzolanic material. Calcium hydroxide ($Ca(OH)_2$) created during cement hydration can combine chemically with the amorphous silica in rice husk ash to make calcium silicate hydrate (C-S-H). This substance is essential for raising concrete's microstructural density and compressive strength. However, the planned concrete quality, material properties, and cement replacement percentage all have a significant impact on ASP's efficacy. This research focuses on examining the effect of using rice husk ash as a partial cement replacement on the compressive strength of FC 24.0 MPa (K-275) concrete, which is commonly used in building construction. The research results are expected to provide scientific and practical contributions to the development of environmentally friendly concrete in Indonesia.

2. LITERATURE REVIEW

2.1. Mechanical and Concrete Properties

Cement, fine aggregate, coarse aggregate, and water make up the composite material known as concrete. The material quality, mixing and curing procedures, and mix proportions all have a significant impact on its performance. Concrete's 28-day compressive strength, which serves as the foundation for structural design, is the main metric used to evaluate its quality. Workability and durability are crucial factors that influence concrete performance in the field, in addition to compressive strength. While durability refers to the concrete's capacity to withstand environmental impacts, workability refers to how easily concrete can be mixed, transported, cast, and compacted.

2.2. Rice Husk Ash as Pozzolan Material

A naturally occurring pozzolan with reactive silica is rice husk ash. Pozzolans are chemically non-cementitious minerals, but under humid conditions, they can react with calcium hydroxide to generate a compound that has binding qualities. According to a number of earlier research, the compressive strength of concrete can be increased at specific levels by partially substituting rice husk ash for cement. However, because there is less active cement in the combination, using too much rice husk ash can lower compressive strength.

2.3. Pozzolan Reaction Mechanism of Rice Husk Ash

Compared to the hydration process of cement, the pozzolanic reaction of rice husk ash happens more slowly. In ASP, amorphous silica combines with $Ca(OH)_2$ to generate secondary C-S-H, which fills the concrete's pores and increases the concrete's microstructural density and compressive strength over time.

3. RESEARCH METHODOLOGY

3.1. Research Methods and Design

In this research, a quantitative laboratory experiment was used. Rice husk ash was substituted for cement at ratios of 0%, 5%, 10%, and 15%.

3.2. Materials and Mix Planning

Type I Portland cement, water, rice husk ash, fine aggregate, and coarse aggregate are among the ingredients utilized. With a water-to-cement ratio of 0.53, the concrete mix design is based on SNI 03-2834-2000.

3.3. Test Specimen Production and Testing

Concrete cubes of 150 x 150 x 150 mm were used as test specimens. They were created and cured using a water immersion procedure until they were 28 days old. Slump testing was used to assess the workability of fresh concrete, and compressive strength testing was carried out using a compression testing equipment.

4. RESULT AND DISSCUSION

4.1. Material Characteristics

All materials satisfy regulatory standards and are appropriate for use in concrete mixtures, according to the results of tests on rice husk ash and aggregate.

4.2. Concrete Workability Analysis

Slump testing is used to gauge how easily concrete can be worked, including how simple it is to mix, transport, cast, and compact.

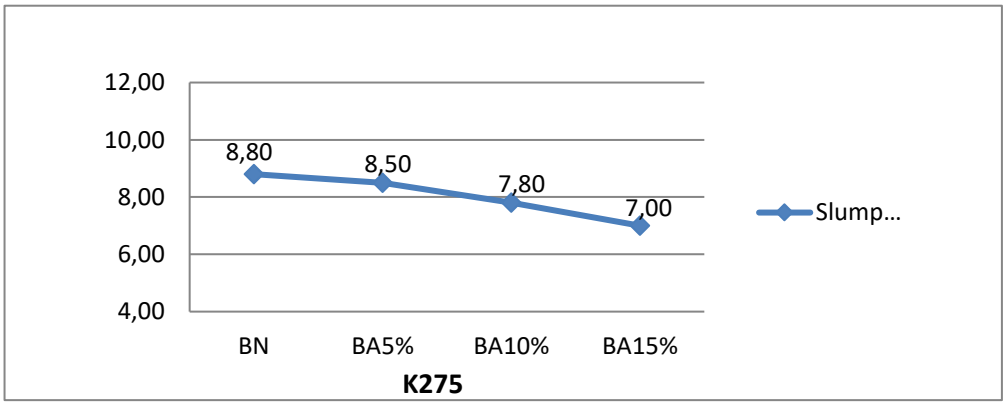


Figure 4.1. Graph Of The Corelation Between Slump Value And Rice Husk
Source : Test Results Of The Effect Of Rice Husk Ash as A Partial Cement Substitute

As the ASP content rose, the slump value exhibited a declining tendency. This problem is brought on by ASP's large surface area, which raises water needs. Nevertheless, all mix variations still met workability requirements.

4.3. Concrete Compressive Strength Analysis

The concrete compressive strength test results at 28 days for each percentage of cement replacement with rice husk ash (ASP) are shown in this section. A crucial factor in assessing concrete's resistance to compressive stresses is compressive strength testing.

To make interpretation and analysis easier, these test findings are displayed graphically. An overview of the impact of ASP use on concrete compressive strength and its suitability for the intended concrete quality will be provided by an analysis of these test findings.

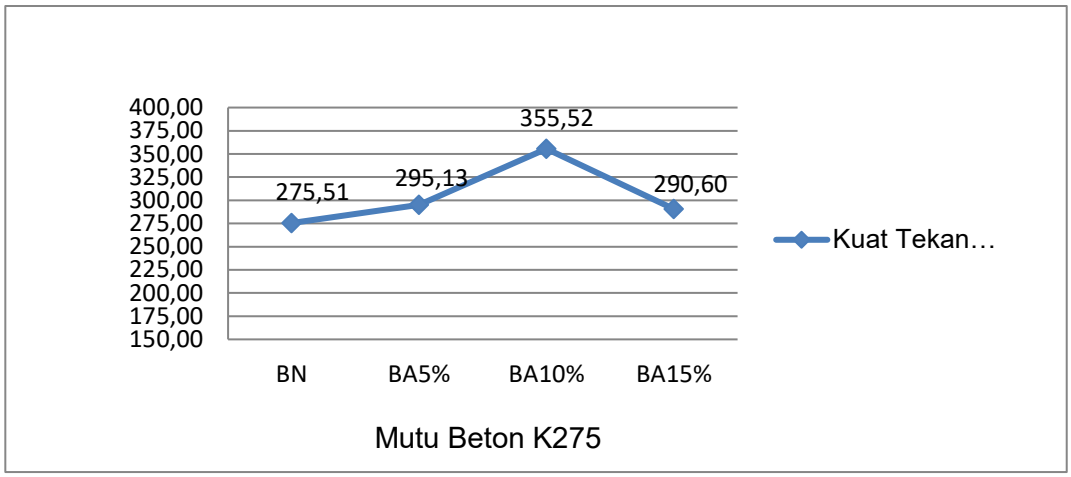


Figure 4.2. Graph Of Average Relationship Between Compressive Strength Concerete
Source : Results of experiments using rice husk ash as a partial cement substitute

Concrete's compressive strength dropped at a 15% fluctuation and rose up to a 10% ASP variation. A 10% ASP variation of 355.52 kg/cm² yielded the maximum compressive strength rating. These findings suggest that the usage of ASP in FC 24.0 MPa concrete has an ideal limit.

4.4. Discussion and Comparison with Previous Research

The results of this research align with previous studies that reported increased concrete compressive strength when using rice husk ash up to a certain limit. Differences in optimum values are influenced by ASP characteristics, concrete quality, and mix design methods.

5. CONCLUSSION AND SUGGESTION

From a technological and environmental standpoint, there is a lot of promise for using rice husk ash in place of some cement. Through a pozzolanic reaction mechanism, rice husk ash can theoretically improve compressive strength performance in concrete mixtures up to a specific proportion. In terms of the environment, using rice husk ash helps reduce the need for Portland cement while making use of agricultural waste that hasn't been used to its full potential. As a result, adding rice husk ash to concrete mixtures can be a substitute ingredient that promotes sustainable growth.

5.1. Conclussion

Concrete's workability and compressive strength are affected when rice husk ash is used as a partial cement substitute, according to test and analytical results. Up to a particular replacement percentage, concrete performance improves; the ideal condition is reached when 10% of the cement weight is replaced with rice husk ash. This proportion allows the concrete to meet workability criteria while achieving the maximum compressive strength. As a result, rice husk ash may be utilized in the production of

structural concrete as an eco-friendly substitute.

5.2. Suggestion

For further research, it is recommended that further studies be conducted on the effect of rice husk ash on concrete durability, including resistance to aggressive environments, permeability, and shrinkage. Furthermore, compressive strength testing at longer concrete ages is necessary to more comprehensively evaluate the development of pozzolanic reactions. Further research may also consider the use of chemical admixtures to improve concrete workability, particularly at higher rice husk ash replacement percentages.

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