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Bayesian Intelligent Tutoring System for Vocational High Schools

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Bayesian Network, Intelligent Tutoring System; Vocational High Schools.

Abstract

The absence of individualized tutorials during regular school hours has resulted in a suboptimal learning method at Vocational High Schools (SMK), limiting students' ability to reach their optimum competency. Several Computerized self-study systems have been created as potential solutions to these challenges. Regrettably, a notable drawback of the system lies in its failure to address students' diverse range of abilities adequately. This study presents a proposed model for an Intelligent Tutoring System (ITS) utilizing the Bayesian Network (BN) at Vocational High Schools. The model aims to assess students' proficiency levels and deliver skill-based instructional materials tailored to individual students' abilities. This type of research is called research and development (R&D), to develop and know the validity of a product. The system under development will undergo trials within the Computer and Network Engineering (TKJ) program at SMK Negeri 4 Gowa. These trials will employ a quasi-experimental approach, explicitly utilizing a one-group pretest-posttest design. The findings indicated that there were notable disparities in the learning outcomes of students following the implementation of the proposed ITS. To put it otherwise, the proposed ITS has improved students' proficiency in Vocational High Schools. The evaluation outcomes suggest that the BN model had a significant level of accuracy, reaching 84%.

1. INTRODUCTION

The Vocational High School (SMK) is an educational program that provides students with theoretical knowledge and practical skills that apply to the professional field. Its primary objective is to generate skilled employees who can effectively meet the community's demands (Khurniawan, 2023). Graduates of vocational schools are anticipated to possess the necessary readiness to actively participate and effectively compete within the corporate realm, which places a premium on requisite skills and competencies. The existing educational approach fails to address the concerns above. The absence of individualized tutorials during school hours has led to students missing crucial learning materials, impeding their progress to subsequent topics. Consequently, the effectiveness of the learning approach has diminished, resulting in suboptimal development of students' competencies. This issue is further exacerbated by time constraints and overcrowding, preventing teachers from adequately addressing the varying levels of understanding and abilities among students.

Empirical evidence indicates that students enrolled in vocational schools have challenges while attempting to meet the minimum proficiency level required to pass competency tests (Saepulloh et al., 2018). According to (Asri et al., 2017), 41.72% of vocational school graduates in Makassar City who participated in the TKJ skills program were classified as having sufficient competency to get a scholarship. The results of the Skills Competency Test (UKK) for the TKJ skills program at Gowa State Vocational School 4 for the 2020/2021 academic year indicate that out of the eighty-one class XII students who participated in the exam, twenty-five students (30.9%) achieved a high level of competency and fifty-six students (69.1%) achieved a sufficient level of competency. This demonstrates the necessity to enhance proficiency, particularly in abilities. To get optimal proficiency, it is imperative to foster learning by considering the varying levels of comprehension among pupils.

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Several Computerized self-study systems have been devised as potential remedies for these issues. For instance (Baharuddin & Dalle, 2017; Majid et al., 2019) have built systems that aim to offer personalized lessons to vocational school students, enhancing their comprehension. The efficacy of this method is attributed to the proliferation of software applications designed to offer personalized instructional guidance. Despite the widespread utilization of computer-based self-learning systems in educational settings, it is essential to acknowledge the limitations associated with these systems. One notable drawback is the lack of individualized attention given to the diverse range of students' skills (Keleş et al., 2009; Ramírez-Noriega et al., 2017). Alternatively, the research posits that the assumption is that the degree of knowledge among all pupils is uniform. Hence, it can be argued that the utilization of this instructional method is suboptimal and fails to facilitate the establishment of personalized guidance and interaction between students and educators.

Intelligent Tutoring System (ITS) is a computer-based educational system that evaluates students' characteristics to tailor instructional content to their requirements according to the principles and objectives of learning (Han et al., 2019; Kulik & Fletcher, 2016). In contrast to other computer-based learning systems, ITS addresses the limitations of neglecting students' diverse skills by tailoring instructional materials to their personal ability levels (Han et al., 2019; He et al., 2009). ITS is a computer-based application designed to address learning challenges, oversee student progress, provide instruction, and offer guidance. Extensive research has demonstrated the efficacy of ITS in enhancing students' skills and capabilities (de Carvalho et al., 2020; He et al., 2009; Karaci et al., 2018; Kularbphettong et al., 2015; VanLEHN, 2011).

ITS generally consists of four main components, the Domain Module, Student Module, Pedagogical Module, and Interface Module (Wang et al., 2023). Pedagogical Module contains artificial intelligence and expert knowledge from a field that serves to provide concepts, rules, teaching strategies, and provide standards for evaluating students' abilities (Wang et al., 2023). The Pedagogical Module works with the Domain Module and Student Module to organize strategies and actions for learning. Then, the Interface Module acts to convey information from those three components. The Domain Module or the domain knowledge contains knowledge about the subject taught and actual teaching materials. The Domain module has three parts: Meta-description, Concept of knowledge, and Course unit (de Carvalho et al., 2020).

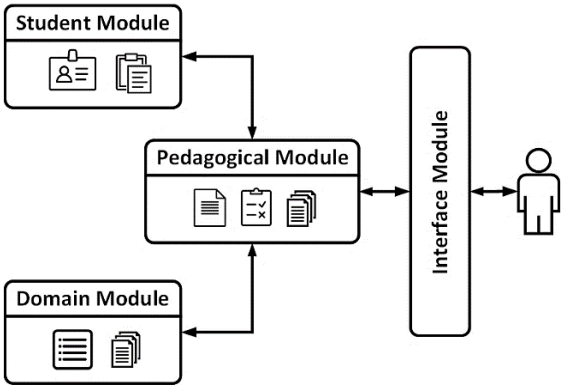

Figure 1. Interaction of ITS components

This domain module aims to store, manipulate, and compile knowledge information, concepts, and learning materials to be taught. The preparation of teaching materials stored in the database can use various models; for example, they are arranged in materials order as seen in a tree diagram or based on the teacher’s name. This teaching material structure model can be developed based on the needs.

The Bayesian Network (BN) is a model of probabilistic graphs that utilizes principles from probability theory and graph theory to facilitate the process of drawing inferences or reaching conclusions (Gelman et al., 2015). BN are graphical models representing a set of variables and their conditional probabilities, allowing for calculating the probability or likelihood of an occurrence. This calculation is based on the principles of Bayes' Theorem (Javidian et al., 2020; Marcot & Penman, 2019). Due to their inherent characteristics, Bayesian networks have been widely employed in several application fields to model knowledge and expert reasoning

(Huang et al., 2021). BN represents structured knowledge in which the domain variables are considered nodes in a graph whose structure describes the dependencies among those nodes (Scanagatta et al., 2019).

This study aims to develop and construct an ITS utilizing BN in the context of Vocational High Schools. This paradigm enables Intelligent Tutoring Systems (ITS) to make individual inferences about students' abilities, thus facilitating personalized learning that may be tailored to each student's specific level of ability.

2. METHODS

2.1 Research Method

The present study employs a quantitative research approach with a quasi-experimental methodology, explicitly utilizing a pretest-posttest design. The primary objective of this research is to investigate the impact of the proposed ITS on enhancing students' competency, as measured by their learning outcomes. Before the commencement of the study, the participants underwent a pretest to assess their initial level of proficiency or comprehension. After being administered the pretest, the students were subsequently provided with the proposed learning intervention utilizing the proposed ITS. Upon the conclusion of the instructional period, the students were administered a post-test to assess their degree of comprehension in the specific area of expertise following the implementation of the proposed ITS. The participants in this research comprised 69 students enrolled in grade XI of the Computer and Network Engineering Expertise (TKJ) Program at SMKN 4 Gowa with the reason that SMK Negeri 4 Gowa is the school with the highest student enrollment in South Sulawesi Province. However, this is not accompanied by an adequate number of teaching personnel. The TKJ skills program, focused on Computer and Network Engineering, consists of 391 students divided into 12 study groups. However, only eight teachers are available, which poses a challenge in meeting the individual needs of all students due to restricted time and the teachers' busy working hours.

2.2 Research Tools

The tools used in this research consist of hardware and software. The hardware consists of a Laptop and a Virtual Private Server (VPS). The software consists of PHP programming language to build Bayesian intelligent tutoring system applications and MySQL as a database manager responsible for storing all the data utilized in the Bayesian intelligent tutoring system, including student data, teaching tactics, and learning data, including lesson materials.

2.3 Materials (Pedagogical Module)

The subject matter is organized to facilitate researchers in creating a clear and systematic structure, ensuring that the subject matter is genuinely in line with the characteristics and curriculum implemented by the school. The subject matter is organized based on 6 Competency Standards, which consist of 39 topics in the XI grade TKJ program, by the predetermined research sample.

The design of lesson materials facilitates researchers in developing a coherent and methodical framework that aligns with the specific characteristics and curriculum of the educational institution. Table 1 displays the six competency standards.

Table 1. Competency

No	Competency	Code
1	Computer Construction	CS-1
2	Installation of Operating Systems via GUI and CLI	CS-2
3	LAN (Local Area Network) Installation	CS-3
4	Network-Connected PC Troubleshooting Diagnosis	CS-4
5	Resetting and repairing the Network Connection	CS-5
6	NOS (Network Operating System)	CS-6

According to the data presented in Table 1, thirty-nine lesson materials have been assembled, each corresponding to a specific competency criterion that has been established. Table 2 illustrates the thirty-nine instructional materials that will be utilized in constructing this intelligent tutoring system.

Table 2. Lesson Materials

Code	Lesson Materials	Code
CS1	Input and Output Device Components	M-1
	Computer Assembly Materials	M-2
	Storage Media	M-3
	Computer Component Layout	M-4
	Computer Casing	M-5
	Computer Assembly Materials`	M-6
	CPU disassembly procedure	M-7
	Installing the motherboard in the casing	M-8
	Installation of a Sound Card, VGA Card, and LAN Card	M-9
	Video of Assembling a computer	M-10
	BIOS and CMOS configuration	M-11
CS2	Basic Concepts of Operating System Installation	M-12
	Types of GUI and CLI-Based Operating Systems	M-13
	GUI-Based Operating System Installation	M-14
	CLI-Based Operating System Installation	M-15
CS3	Basic Concepts of Computer Networks	M-16
	Types and functions of network devices	M-17
	Computer Network Topology	M-18
	Computer Network Protocols	M-19
	IP Address and Network Segmentation	M-20
	LAN Design	M-21
	LAN hardware installation	M-22
	Configuration of LAN Components on the Windows OS	M-23
CS4	Types of interference on LAN devices	M-24
	Classification of Problems in LAN Operation	M-25
	Actions that can be taken to isolate the source of the problem	M-26
CS5	Preparation Reset Network Connection	M-27
	Network Connection Repair	M-28
	Reset Network Connection	M-29
	Checking and Making Reports on the Results of Network Connectivity Improvements	M-30
CS6	Server equipment needs analysis	M-31
	Network OS Installation (Debian)	M-32
	Text Mode Administration	M-33
	Network Configuration Via Text Mode	M-34
	Process Observation	M-35
	Observation Services (services)	M-36
	Event Observation	M-37
	Backup and Restore	M-38
	Backup and Restore via Network	M-39

2.4 Evaluation

An evaluation is carried out to assess the performance of the Bayesian Network (BN) model that has been created, utilizing Cross Validation and Confusion Matrix techniques. Cross-validation is a statistical evaluation approach that involves partitioning the data into two distinct groups: the training and validation sets. Cross-validation is a widely utilized technique for evaluating the performance of a model by assessing its correctness (Marcot & Hanea, 2021). This approach yields the numerical representation of a Confusion Matrix. The Confusion Matrix is a widely used performance-measuring tool in machine learning. It comprehensively represents the anticipated result values and the corresponding actual values (Xu et al., 2022). The Confusion Matrix is a tabular representation that includes four distinct combinations corresponding to the expected outcome and the actual value. These metrics can subsequently be used to assess the accuracy of the BN model.

The evaluation of learning outcomes is designed using a quasi-experimental methodology, namely the one-group pretest-posttest approach, which focuses on improving competence (learning outcomes) after students receive treatment. Simply said, the research design may be observed in Table 3.

Table 3. One-group pretest-posttest design (Sugiyono, 2014).

Pretest	Treatment	Posttest
O_1	X	O_2

In this context, O1 denotes the pretest conducted before implementing Bayesian Intelligent Tutoring Systems (ITS), X represents the administered intervention, and O2 signifies the posttest conducted after implementing ITS. The research participants underwent an initial assessment to ascertain their initial cognitive capacities (comprehension). Following an initial assessment, the students underwent a 4-week educational intervention utilizing a web-based Intelligent Tutoring System including Bayesian Network technology. Upon completing the learning process, students are then administered a final assessment to ascertain the extent of their comprehension and proficiency in the acquired skills.

Furthermore, a comprehensive analysis was conducted to assess the impact of the proposed ITS on enhancing students' competencies, namely their learning outcomes. This was achieved by assessing the disparity between the students' pretest and post-test scores. Subjects in the study completed an initial assessment to gauge their initial level of proficiency (comprehension). After administering an initial assessment, the students are provided with an educational intervention using a web-based Intelligent Tutoring System incorporating Bayesian Network technology. Upon completing the learning process, students are then administered a final assessment to ascertain the extent of their comprehension and proficiency in the acquired skills.

The data analysis method employed is Normalized Gain (N-Gain), interpreted based on the criteria for improving learning outcomes specified in Table 4. There are advantages when N-Gain is used as an analytical tool. Considering Hake's proposed rationale, the advantage mentioned is a significantly different measure for each applied learning method while allowing for consistent analysis of both large and small student populations with varying initial conditions. Put simply, this technique can assess the progress of an individual student and that of their peers. One remarkable advantage of a treatment can be attributed to its initial conditions, which can be contrasted. However, there have been numerous complaints surrounding the N-Gain analysis. An early critique is that avoiding linking the student's initial state with the treatment provided is highly challenging. Multiple studies demonstrate a robust association between the beginning conditions and the effectiveness of the treatment. Furthermore, this study fails to consider the pace of decrease. If the post-test score is equal to or lower than the pre-test score, what does efficacy signify in this scenario? When the Normalized Gain is zero, the learning effectiveness is absent, rendering it equivalent to not learning. Alternatively, a negative analysis score indicates a decline in pupils' knowledge following the completion of the learning process (Rahmi Ramadhani & Nuraini Sri Bina, 2021).

Table 4. Interpretation of N-Gain values (Hake, 1998).

Value	Criteria
$g > 0{,}7$	High
$0{,}3 > g \leq 0{,}7$	Medium
$g < 0{,}3$	Low

3. RESULT AND DISCUSSION

3.1 Bayesian Intelligent Tutoring System

The BN module created at ITS aims to offer recommendations of material and assess students' proficiency levels, categorizing them into three groups: low, medium, and high, as depicted in Figure 1. Including a pedagogical module can enable the assessment of pupils' specific abilities. The system utilizes the provided input to generate responses to inquiries posed in the ability test. By obtaining quantitative feedback from students, BN can quantitatively infer grades that represent the students' individual abilities. After administering the ability test to the students, BN gives instructional materials and categorizes the students' ability levels based on the characteristics derived from the ability test results.

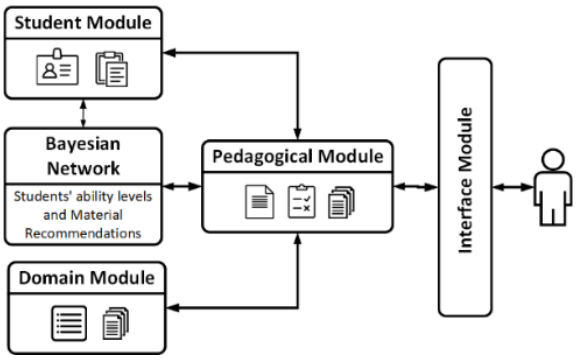

Figure 1. The Proposed ITS

The learner interacts with the Interface Module to establish a connection with the ITS. The interactions can be classified into two distinct sub-modules, specifically the input and output modules. The main aim of the input module is to integrate the evidence derived from the outcomes of the ability tests into the BN to facilitate this process of updating. The student module is designed to store comprehensive student information, including material recommendations and individual levels of understanding. The domain module comprises instructional resources, such as textual documents or video presentations, facilitating knowledge acquisition. This module will offer educational content within the pedagogical framework, utilizing the information contained in the student module.

Using the student ability test results as input, the proposed ITS determines the student's ability level and makes recommendations for material using the BN. The algorithm generates a suggestion of diverse educational materials for individual students, taking into account the likelihood of reaching mastery of the contents. This is described in terms of Figure 2.

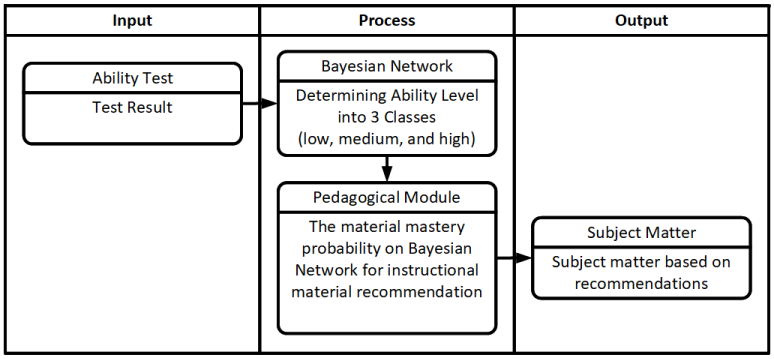

Figure 2. The Information System Framework

3.2 Bayesian Network Model

3.2.1 Structures

Constructing a BN, specifically a Directed Acyclic Graph, involves utilizing ability test results. These tests consist of thirty-five items, representing six Competency Standards (CS) and Subject Matter (M). There

are two Bayesian Network structures used in this research, the first structure is used to describe ability levels with parameters High (H), Medium (M), and Low (L). The second structure is used to provide material recommendations for each student. The BN structure can be seen in Figures 3 and 4.

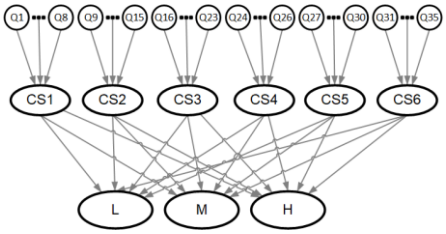

Figure 3. BN structure of ability level classification

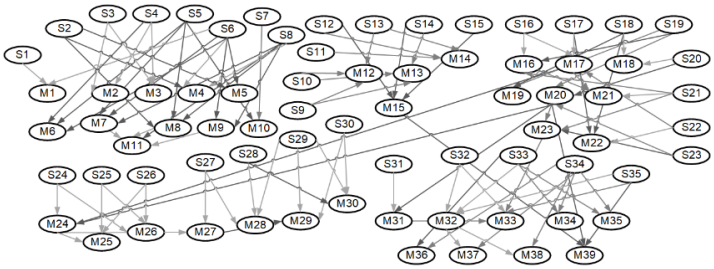

Figure 4. BN structure of material recommendations

3.2.2 Parameters

Once the structure of the BN has been established, the subsequent stage involves determining the prior probability values, also known as parameters, for each variable inside the network. These variables include Questions (S), competency standard (CS), level of ability (H, M, L), and recommendations for each material (M). The designated parameters have been established through the professional opinion and validation of the competent authority (educator). The prior probability values can be seen in the following Tables.

Table 5. Prior Probability Questions

No	Question Number	True	False
1	S-4, S-7, S-10, S-11, S-14, S-15, S-16, S-18, S-19, S-20, S-21, S-23, S-28, S-29, S-30, S-32, S-33	0.7	0.3
2	S-1, S-2, S-3, S-5, S-6, S-8, S-9, S-12, S-13, S-17, S-22, S-24, S-25, S-26, S-27, S-31, S-34, S-35	0.6	0.4

Table 6. Prior Probability Competency Standards

No	Competency Standards	True	False
1	CS-1	0.582	0.418
2	CS-2	0.655	0.345
3	CS-3	0.673	0.327
4	CS-4	0.6	0.4
5	CS-5	0.680	0.320
6	CS-6	0.645	0.355

Table 7. Prior Probability Ability Level

No	Ability Level	Value
1	Low	0.214
2	Medium	0.372
3	High	0.414

Table 8. Prior Probability Recommendation Materials

Material	True	False	Material	True	False
M-1	0.525	0.475	**M-21**	0.317	0.683
M-2	0.6	0.4	**M-22**	0.388	0.12
M-3	0.33	0.67	**M-23**	0.3	0.7
M-4	0.4	0.6	**M-24**	0.362	0.638
M-5	0.4	0.6	**M-25**	0.383	0.617
M-6	0.355	0.645	**M-26**	0.4	0.6
M-7	0.52	0.48	**M-27**	0.395	0.605
M-8	0.4	0.6	**M-28**	0.32	0.68
M-9	0.4	0.6	**M-29**	0.346	0.654
M-10	0.33	0.67	**M-30**	0.3	0.7
M-11	0.424	0.576	**M-31**	0.351	0.649
M-12	0.375	0.625	**M-32**	0.335	0.665
M-13	0.335	0.665	**M-33**	0.337	0.663
M-14	0.351	0.649	**M-34**	0.349	0.651
M-15	0.326	0.674	**M-35**	0.349	0.651
M-16	0.3	0.7	**M-36**	0.349	0.651
M-17	0.385	0.615	**M-37**	0.368	0.632
M-18	0.3	0.7	**M-38**	0.368	0.632
M-19	0.3	0.7	**M-39**	0.346	0.654
M-20	0.3	0.7			

3.2.3 Conditional Probability

The conditional probability of the competency standards (CS) students possess based on the question answers (S) can be calculated using Equation 1 below.

$$P(CS|S_i \dots S_n) = \frac{P(S_i \dots S_n \cap CS)}{P(CS)} = \sum_{i}^{n} \frac{P(S_i|CS).P(CS)}{P(CS).P(S_i|CS) + P(\neg CS).P(\neg S_i|CS)} \qquad (1)$$

Where:

S_i	: Question item-i
S_n	: Question item-n
CS	: Competency Standards
$P(CS \mid S_i \dots S_n)$	: Probability of CS based on conditions S_i to S_n
$P(S_i \dots S_n \cap CS)$	: Joint Probability S_i and CS
$P(CS)$	: Probability CS
$P(S_i \mid CS)$	: Probability S_i to CS
$P(\neg CS)$	: The opposite probability of CS
$P(\neg S_i \mid CS)$	: The opposite probability of S_i against CS

Then the conditional probability of ability level (TK) or probability of student ability level (low/medium/high) based on the competency standard probability value (CS) can be calculated using the following Equation 2.

$$P(TK|CS_1 \dots CS_6) = \sum_{i=1}^{6} \frac{P(CS_i \dots CS_n \cap TK)}{P(TK).P(CS_i|TK) + P(\neg TK).P(\neg CS_i|TK)} \qquad (2)$$

Where:

TK	: Ability Level
$CS_{1\dots} CS_6$	: Competency Standards $CS_{1\dots} CS_6$
$P(TK \mid CS_{1\dots} CS_6)$	: Ability Level probability based on conditions $CS_{1\dots} CS_6$
$P(CS_{i\dots} CS_n \cap TK)$	: Joint Probability $CS_{i\dots} CS_n$ and TK
$P(TK)$	: Probability of Ability Level
$P(CS_i \mid TK)$	: Probability of the CS-i against ability level

$P(\neg TK)$: The opposite probability of TK
$P(\neg CS_i \mid TK)$: The opposite probability of the *CS*-i on the level of ability

The process of probabilistic inference or classification of ability levels within a sample involves evaluating the probability values associated with each ability level and subsequently determining the highest probability value as the conclusion. The conditional probability of material recommendations or the probability of recommending a material (M) based on the answer to the question (S) can be calculated using Equation 3 below.

$$P(M|\, S_i \ldots S_n) = \sum_{i}^{n} \frac{P(S_i \ldots S_n \cap M)}{P(M).P(S_i|M) + P(\neg M).P(\neg S_i|M)} \quad (3)$$

Where:

M : Material
$P(M \mid S_i \ldots S_n)$: Probability of M recommendation based on conditions S_i to S_n
$P(S_i \ldots S_n \cap M)$: Joint Probability S_i and M
$P(M)$: Probability of M recommendation
$P(S_i \mid M)$: Probability of S_i based on M recommendation
$P(\neg M)$: Opposite probability of M recommendation
$P(\neg S_i \mid M)$: Opposite probability S_i of M recommendation

3.2.4 Joint Probability Distribution (JPD)

The joint probability in Equation 2 is noted in Equation 4, and the joint probability in Equation 3 can be calculated using Equation 5.

$$P(CS_i \ldots CS_n \cap TK) = \sum_{i=1}^{6} P(CS_i|TK).P(TK) \quad (4)$$

Where $P(CS_i \mid TK)$ is Probability of the ith *CS* against ability level (TK), and $P(TK)$ is the probability of ability level.

$$P(S_i \ldots S_n \cap M) = \sum_{i}^{n} P(S_i|M).P(M) \quad (5)$$

Where $P(S_i \mid M)$ is the Probability of the i-th question based on material recommendations, and $P(M)$ is the Probability of material recommendations.

3.3 Implementation

The Bayesian ITS can be accessed via the website https://its-smk.online/ using web browsers on both laptops and smartphones. This is made possible by implementing a responsive display feature in the created system, facilitating convenient access for students anytime and anywhere. The following Figure provides an overview of the developed appearance of the ITS.

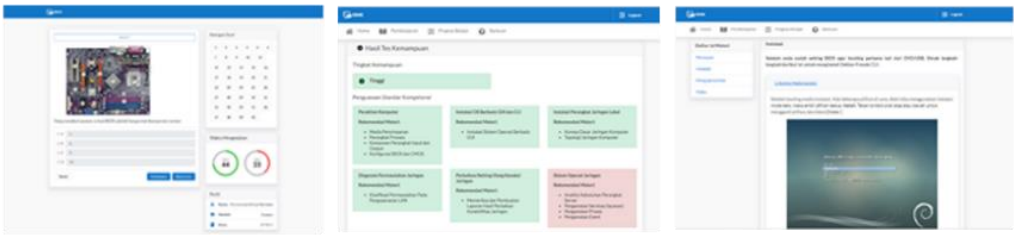

Figure 5. Implementation of Bayesian Intelligent Tutoring System

According to Figure 5 (A), the page Student Test will be displayed upon the initial login of students into the system. This assessment is utilized to ascertain the abilities of students. After students complete the exam, the page of the ability test will assess the student's ability level and offer recommendations for appropriate materials in Figure 5 (B). Figure 5 (C) illustrates the Learning Material page, which presents educational stuff in several formats, including textual information, visual graphics, and video presentations.

The experiment aimed to gather data that could be utilized to assess the efficacy or enhancement of learning outcomes through the implementation of the proposed ITS. The system underwent testing using a study sample including 69 students from SMK Negeri 4 Gowa, located in the South Sulawesi Province of Indonesia. The experiment spanned two weeks. The pretest was administered on September 1st, 2023, followed by implementing the proposed ITS for learning from September 1st to September 16th, 2023. The experiment concluded with administering the post-test on September 16th, 2023. The treatment outcome of the Bayesian Network on ITS is presented in Table 9.

Table 9. Bayesian Network result

Students	**P(CS-1)**	**P(CS-2)**	**P(CS-3)**	**P(CS-4)**	**P(CS-5)**	**P(CS-6)**	**Ability Level**
S-1	0.82	0.55	0.99	1	1	1	High
S-2	0.18	0.4	0.39	0.3	0.25	0.1	Low
S-3	0.73	0.3	0.23	0.6	0.25	0.65	Medium
S-4	0.71	0.5	0.46	0	0.5	0.45	Low
S-5	0.91	0.35	0.73	0.7	0.7	0.75	High
S-6	0.64	0.85	0.59	0.4	0.45	0.55	Medium
…	…	…	…	…	…	…	…
S-69	0.53	0.4	0.49	0.6	0.2	0.85	Medium

Based on the collected data on individual student learning outcomes using the Bayesian intelligent tutorial system, the distribution of student learning outcomes is shown in Table 10 below.

Table 10. Student learning outcomes distribution

Pretest		Posttest	
Value Range	Total (Students)	Value Range	Total (Students)
40 - 69	47	40 - 69	5
70 - 84	18	70 - 84	54
85 - 95	4	85 - 95	10

Based on Table 9 on the distribution of student learning outcomes, it can be observed that the distribution of learning outcomes (pre-test) with the highest frequency is found in the range of 40-69, totaling 47 students or 68%. The distribution of learning outcomes (posttest) with the highest frequency in the range of 70-84 amounted to 54 students or 78%. This means that the range of values with the highest frequency or number between the initial and final tests has increased, and it can be concluded that implementing the Bayesian Intelligent Tutoring System at SMKN 4 Gowa has improved average student learning outcomes.

Based on the Minimum Passing Criteria value set at 70, it is found that five students, or 7%, did n`ot pass the final exam, while the remaining 64 students, or 93%, were declared to have passed. This means that the learning outcomes have been achieved because the classical mastery has reached more than 85%.

3.4 Evaluation of Bayesian Network Model

The evaluation was undertaken to assess the Bayesian Network (BN) model's efficacy by utilizing K-fold cross-validation, employing parameter values of K = 10. This process yielded confusion matrix tables as outcomes. A total of 69 students were included in the analysis based on the data obtained from the experimental results. The test result is presented in Table 11.

Table 11. Confusion Matrix for K=10

Actual	**Prediction**		
	High	**Medium**	**Low**
High	14	6	0
Medium	0	31	0
Low	0	5	13
Accuracy		0.840	
Precision		0.807	
Recall		0.912	
F1 Score		0.855	

Based on the test results obtained for K = 10, the accuracy value is calculated to be 84%, the precision is determined to be 80.7%, the F1 score is measured at 85.5%, and the recall is 91.2%. The findings demonstrate that the constructed BN model exhibits notable accuracy and stability.

3.5 Evaluation of the Learning Outcomes

The researchers conducted a comparison between the pretest scores and the post-test scores based on the experimental results. In a general sense, the outcomes of the data comparison are presented in Table 12.

Table 12. Pretest and posttest score

	Pretest	Posttest
n	69	
Minimum	41	62
Maximum	87	90
Mean	62.68	78.54
Standard Deviation	12.46	5.81

According to the data presented in Table 12, the mean score for the pre-test results is 62.68. In the interim, there has been a notable increase of 15.86 in the average scores of the post-test, resulting in an average score of 78.54. The study was afterward performed to determine the degree to which the experimental results improved.

This task was achieved by evaluating the disparity between the scores obtained in the pretest and posttest, employing the N-Gain assessment. Before doing N-gain testing, a normality test is performed to determine whether a data distribution originates from a normally distributed population or not. The data analysis technique used in testing for normality is the Kolmogorov-Smirnov method, with a significance level of 5%. Data is assumed to follow a normal distribution when the significance (Sig.) is more than 0.05 (Sig > 0.05) (Rahmi Ramadhani & Nuraini Sri Bina, 2021). The normality test results indicate a significance value (sig.) of 0.072 for the pretest and 0.074 for the posttest. Therefore, it may be concluded that the data of the initial and final test scores are normally distributed. The outcomes of the N-Gain computation are presented in Table 13.

Table 13. N-Gain Result

n	Mean		Interpretation
	Improvement	N-Gain	
69	15.86	0.4	Medium

The data in Table 10 indicates a gain score, also called a 0.4 score change analysis. The value acquired is afterward regarded as the criterion for assessing the enhancement of the learning outcomes (Hake, 1998), with a score of 0.4 as a moderate change in score. Hence, it can be inferred that a notable enhancement in educational achievements exists after the implementation of the proposed ITS.

4. CONCLUSIONS

This study uses the Bayesian Network to present a proposed model for an Intelligent Tutoring System (ITS) in Vocational High Schools. The model aims to assess students' abilities and provide tailored instruction on skills competency materials, taking into account individual ability levels. The Bayesian Network is an inference for classifying students' proficiency levels and providing adaptive material recommendations. This demonstrates that the Bayesian Network in the developed intelligent tutorial system reflects a personalized tutoring approach between students and actual teachers. The ITS experiment intended for testing conducted on a sample of 69 students from SMKN 4 Gowa reveals that 29% of the students fall under the high ability category, 45% fall under the medium ability category, and the remaining 26% fall under the low ability. The evaluation results with K-fold cross-validation indicate that the constructed BN model exhibits a consistently high accuracy. Specifically, the test results K = 10 yields an accuracy rate of 84%. The experimental findings demonstrate that the proposed ITS was found to help enhance skill competencies. The analysis was performed in the N-Gain test to examine changes in scores. The obtained score changes of 0.4 falls within the medium range of score changes.

It should be noted that this study has certain limitations that need to be acknowledged. For instance, this research is limited by a small-scale trial conducted on only one vocational program in one vocational high school. However, despite these limitations, this study provides a solid foundation for developing Intelligent Tutoring Systems (ITS) to improve the vocational skills competence of vocational high school students. Future work may concentrate on validating the findings of research conducted on a larger scale through extensive experimentation in vocational schools and other specialized programs. Furthermore, it is crucial to conduct further research with the implementation of other artificial intelligence models as a means of comparison to the existing studies. ITS functions as an educational tool that emulates the role of a teacher by assisting students in their learning endeavors. While ITS is a highly effective learning system comparable to a human tutor, it is not intended to supplant traditional teaching and learning models. However, it can serve as a valuable tool to enhance the learning process.

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Multi-Criteria Analysis of Selection Waste Management Development Strategy for Lubuk Binjai Landfill in Lubuk Linggau City

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Keywords
Analytical Hierarchy Process; Waste Management Strategy; Landfill.

Abstract

Environmental sustainability is an urgent priority in dealing with waste management problems in Indonesian cities, one of which is Lubuk Linggau City. In the 2012-2032 Lubuk Linggau City RTRW, waste management standards have been set using the Controlled Landfill or Sanitary Landfill method, but in reality the Lubuk Binjai landfillstill adopts the Open Dumping method. This waste management not in accordance with environmentally sound waste management methods, so it is necessary to develop a waste management strategy for the Binjai Landfill. This research aims to identify priority strategies that can be applied in developing landfill waste management in Lubuk Linggau City using the Analytical Hierarchy Process (AHP) method. Data collection was carried out by conducting interviews with key informants who were managers of the Lubuk Binjai waste disposal site. Determination of criteria and sub-criteria based on previous literature studies and determination of alternative strategies based on the Lubuk Linggau City RTRW for 2021-2032. From the results of the analysis, it shows that the prioritized strategy is the Strategy for Improving Waste Management Methods & Technology, with alternatives such as recycling processing, compost, and more sophisticated waste management technology such as controlled burning or anaerobic management. This is appropriate and crucial in overcoming problems at the Lubuk Binjai waste disposal site, that the Open Dumping method is still applied. It is hoped that the implementation of this strategy can bring positive and sustainable changes in waste management in Lubuk Linggau City.

1. INTRODUCTION

The large amount of waste that cannot be handled will cause various problems to arise due to the lack of alternatives and perspectives for the community in managing and utilizing waste, both directly and indirectly. Environmental sustainability is an urgent priority in dealing with waste management problems in Indonesian cities. Waste management so far is still not in accordance with environmentally sound waste management methods, even though waste management has an influence and is the main source of environmental toxicity in soil, air, and water (Neo et al, 2021). Most of the landfill waste management in Indonesia uses the Open Dumping and Landfill method, as well as other methods such as composting, burning, sorting, and recycling, although they are not widely used (Winahyu et al, 2013). Open dumping is a disposal method that is often used for solid waste in cities throughout the world (Tun et al, 2018). According to Kardono (2007:631), waste management problems in Indonesia can be seen from several indicators, namely the high amount of waste produced, the level of waste management services is still low, the number of final disposal sites is limited, waste management institutions, and cost problems.

Lubuk Linggau City is one of the cities in South Sumatra Province. The population of Lubuk Linggau City in 2021 is 236,828 people with an area of 401.50 Km2 and is categorized as a medium city (BPS, 2022). Waste

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disposal in Lubuk Linggau City is accommodated by the Petanang waste disposal site. However, in 2015, there was an overload of waste so the Petanang landfill could no longer accommodate waste in Lubuk Linggau City.

Source: Documentation results researcher, 2021

Figure 1. Petanang Landfill is *Overload*

In response this, the city government diverted waste storage to the Lubuk Binjai landfill (Dinas Lingkungan Hidup Kota Lubuk Linggau, 2021). Lubuk Binjai Landfill has an area of 25.4 landfill with a capacity of 446.47 m^3/day. Waste Management at the Lubuk Binjai landfill is carried out using the open dumping method, which throwing away the waste on land without processing the waste. This contrasts with the government's plan stated in the Lubuk Linggau City Spatial Plans for 2012-2032. The spatial plans document states that waste management in Lubuk Linggau City must be carried out using the Controlled Landfill or Sanitary Landfill method, where waste already collected at the final disposal site is managed using the buried waste method. Waste must be compacted with heavy equipment and then covered with soil.

This study will identify strategies for developing optimal landfill waste management that the Lubuk Linggau City Government can implement. This study determines priority strategies in developing landfill waste management in Lubuk Linggau City through consideration assessment from related stakeholders by applying the principles of multi-criteria analysis using *analytical hierarchy process* (AHP) methods. This research is important to carry out because the recommended priorities can then be used to develop a waste management plan that is more environmentally friendly and can be optimal for the available landfill which will then accommodate domestic waste in Lubuk Linggau City.

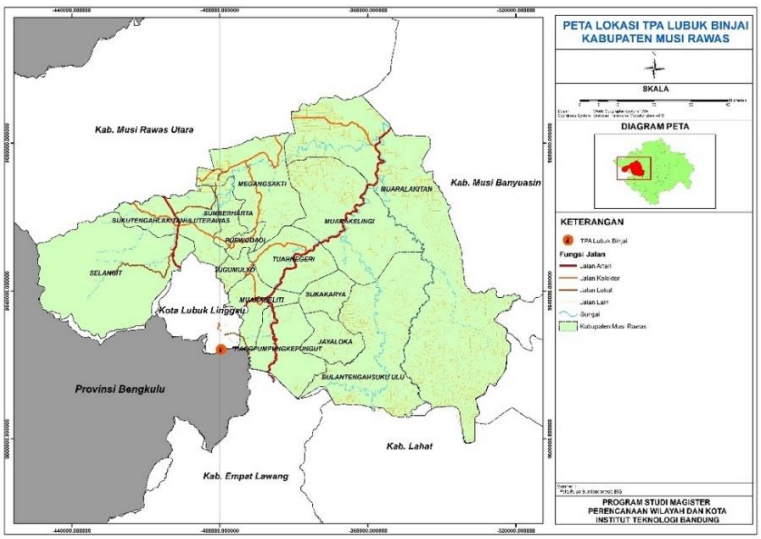

Figure 2. Lubuk Binjai landfill Location

2. LITERATURE REVIEW

2.1 *Open Dumping* Waste Management

Waste management using the open dumping method is considered less friendly because it can cause groundwater pollution. The open dumping method has a significant impact involving serious challenges to the environment and public health. In practice, discarded waste can pollute groundwater with dangerous substances, such as heavy metals, chemicals, and decomposing organic matter. Decomposing waste can produce a liquid called "leachate" which contains toxic and dangerous ingredients. This leachate can seep into the soil and pollute groundwater which is used as a source of drinking water and other groundwater (UNEP, 2015). Apart from that, this method also has the impact of causing air pollution. Garbage thrown away in open dumps can produce toxic gases such as methane (CH4) and sulfur dioxide (SO2). These gases can be released into the atmosphere and contribute to the greenhouse effect and air pollution (Bove, J., 2002). Not only does impact the environment, but open dumping waste management also poses risks to public health. Workers and local communities living around open waste dumps are at high risk of air and water pollution, as well as potential physical harm from piles of waste (WHO, 2018). Meanwhile, damage to natural habitats and local ecosystems is a direct consequence of this practice.

From the social and economic fields, people who are directly exposed can experience stigmatization and a decrease in quality of life due to odors, pollution, and other impacts. Open dumping systems tend to be unsustainable, accelerating necessary land improvements. This hampers local economic development (World Bank, 2018) and does not encourage the practice of recycling or reusing waste. By recognizing these impacts, transitioning to more sustainable and environmentally friendly waste management methods becomes imperative for future sustainability (Ongondo, Williams, & Cherrett, 2011).

2.2 *Sanitary Landfill* Waste Management

The sanitary landfill management method, although better than open dumping, also has several negative impacts on the environment. Sanitary landfills do not completely prevent groundwater pollution. Liquid waste (leachate) produced from decomposed waste can still seep through the soil layers and pollute the surrounding groundwater. This leachate contains dangerous ingredients such as heavy metals, pesticides, and other chemicals that can pollute groundwater sources. Sanitary landfills can also cause air pollution. The process of decomposing waste in landfills produces methane gas which is a strong greenhouse gas and contributes to climate change. Apart from that, there is also the release of other gases such as sulfur dioxide and ammonia which can cause air pollution (US Environmental Protection Agency, 2016).

3. METHOD

3.1 Method Data Analysis

This research was conducted using the AHP method. The existence of a hierarchical structure because of the selected criteria down to detailed sub-criteria in AHP can integrate subjectivity and objectivity in the decision-making process. AHP considers preferences hierarchically and seeks to integrate them, distinguishing them from other methods of resolving problems categorized as not too complex. This approach is based on the preferences of experienced experts in the field, particularly employees from the Environmental Service of Lubuk Linggau City. This method can also identify important factors in complex phenomena. The main tool of the Analytical Hierarchy Process (AHP) is a functional hierarchy with the main input being human perception. With hierarchy, a complex and unstructured problem is broken down into groups, and then arranged into a form of hierarchy. The hierarchy for selecting waste management strategies at the Lubuk Binjai landfill consists of alternative strategies, sub-criteria, criteria, and goals (achievements). The choice of hierarchy is based on previous research that has been synthesized.

Table 1. Previous Research to determine the Hierarchy

No	Researcher and Year	Title Study	Criteria	Sub Criteria
1	Dino Rimantho and Marlina Tamba (2021)	Proposed Solid Waste Management Strategy at the Burangkeng Bekasi landfill using the SWOT and AHP Approach	Human	Number of human resources
				HR expertise
			Technology	Innovation Management
				Mastery Technology Waste
			Finance	Capital
				Technology Prices In accordance
			Source Power	Raw material
				Facilities and infrastructure
				Materials and tools
			Institutions and Government	Support Management
				Requests and Cooperation
				Policy Government
				Suitability with RTRW
2	Alref BA and Tri Padmi (2015)	Multi Criteria Analysis of the Selection of Waste Management Concepts (Case Study: Village Areas in the Lake Sentani Region)	Technical Aspects	Initial waste handling patterns
				Management effectiveness
				Ease of operation
				Total processing time
			Social Aspect	Community desires in waste management
				Local community wisdom in waste management
				HR readiness in applying technology
				Employment
				Community participation
			Environment Aspect	Spread of disease vectors
				Potential air pollution
				Water and soil pollution due to leachate produced
				Aesthetic aspect/environmental beauty
			Institutional Aspect	Availability of institutions
				Availability of regulations
				Collaboration between stakeholders
			Economic Aspects	Low investment value
				Low operational and maintenance costs
				Increasing direct benefits to society
3	Mochammad Chaerul, Elprida Agustina, and I Made Wahyu Widyarsana (2019)	Multicriteria Analysis in Selection of Waste Processing Systems in Klungkung Regency, Bali Province	Environment	Prevent environmental pollution
				Aesthetics
				Disease vector
			Financial	Investment costs

In data management, Expert Choice software is used, which is an application based on the AHP method to determine criteria weights (Erdogan et al., 2017). Expert Choice can produce a level of inconsistency in respondents' answers. A CR value < 0.1 indicates that the respondent was consistent in providing assessments. The hierarchical structure of decision-making can be seen in the following figure.

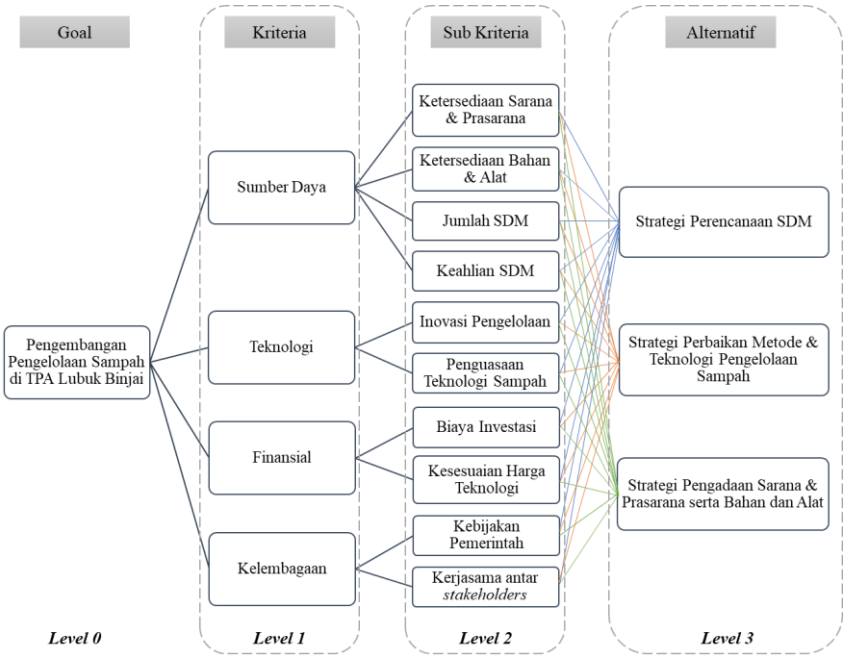

Figure 3. Hierarchy of Selection of Waste Management Development Strategies Lubuk Binjai Landfill

3.2 Method Data collection

Data collection was carried out by structured interviews using the questionnaire/questionnaire method. The questionnaire was structured based on a predetermined hierarchy and was discussed in advance with two respondents (Kepala Bagian Tata Usaha dan Kepala Bidang Pengelolaan Sampah dan RTH DLH Kota Lubuk Linggau) to adapt it to the case study at Lubuk Binjai Landfill.

Determining the number of respondents at this stage uses the purposive sampling method, namely a random sampling methodology. The researcher determines special criteria according to the research objectives. The criteria of respondents were carried out based on the consideration that the person or group selected acted as a decision maker, faced or was directly involved in determining waste management strategies at the Lubuk Binjai landfill.

Table 2. List of Respondent

No	Name	Position	Department
1	Erik Estrada	Head of the Administration Section of the Lubuk Linggau City Environmental Service	Office
2.	Rully Wijaya	Head of the Waste Management and Green Open Space Division of the Lubuk Linggau City Environmental Service	Office
3.	Anis Asril	Head of the Waste Management Section of the Lubuk Linggau City Environmental Service	Office
4.	Hartono	Lubuk Binjai landfill Coordinator Supervisor	Office/landfill

4. RESULT AND DISCUSSION

4.1 Analysis Criteria Development Management Lubuk landfill waste Binjai

The analysis in this section determines the criteria that respondents consider most important in selecting priority strategies for developing waste management at landfills (Dan & Ngo, 2018). The results of this analysis are a calculation of the combined weights of all respondents. Based on the results of data management with Expert Choice software, it can be seen that the respondents' assessment of the importance of the criteria prioritized in selecting a development strategy for landfill waste management is the technology criteria (aspect) with a priority weight of 38.1%, then the resource criteria 36.2%, financial criteria 14.7%, and institutional criteria 11%. In this analysis, the inconsistency level is 0.04, which is less than 0.1, meaning it is acceptable. Technology Criteria is a priority criterion because technology is considered to be something that must be improved in the waste management aspect at Lubuk Linggau landfill. This section discusses the results of the analysis which can be displayed in the form of diagrams, pictures, tables, or other forms of illustration that are easy to understand and communicate.

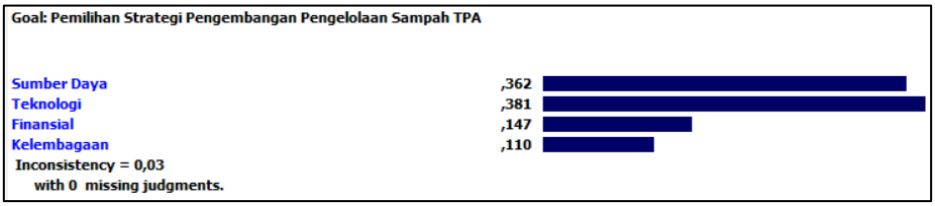

Figure 4. Expert Choice Results Priority Criteria for Lubuk Linggau Landfill Waste Management Development Criteria

In waste management, the technological aspect is important, because great technology can influence the efficiency, sustainability, and environmental impact of the waste processing process. Technology that is sophisticated and appropriate to local conditions can help reduce negative environmental impacts, increase efficiency in processing, and produce more valuable products from waste in Lubuk Linggau City. However, the technology operation certainly requires qualified resources, adequate financing for technology maintenance, and supporting institutions (World Bank, 2005).

4.2 Sub-Criteria Analysis and Alternative Development Strategies Management Lubuk Binjai Landfill

The analysis in this section is to find which sub-criteria are considered more important by respondents in each criterion in selecting priority strategies for developing waste management at landfills. The results of this analysis are a calculation of the combined weights of all respondents.

A. Resource Power

The priority sub-criteria for selecting strategies for developing waste management at landfills in the Resource criteria is HR Skills at 39.3% with an inconsistency of 0.03 < 0.1. HR expertise is prioritized compared to other criteria because Human Resources (HR) expertise shows the ability/skills in management needed to develop waste management at Final Processing Sites (Landfill).

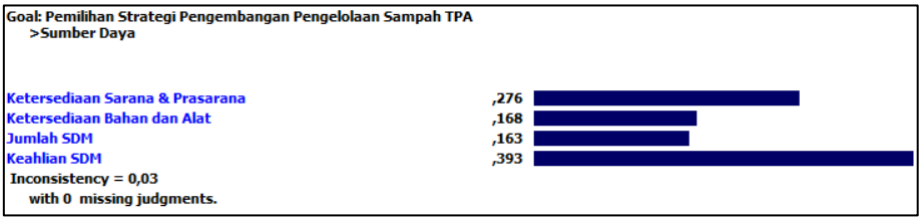

Figure 5. Expert Choice Results Priority Criteria for Resources for Lubuk Linggau Landfill Waste Management Development

In the resource aspect, human resource expertise has a high priority because the quality and effectiveness of the processing are very dependent on the knowledge, skills, and competence of the workers involved in the operation. Although facilities and infrastructure, availability of tools and materials, and quantity of human resources are also important, human resource expertise is a very determining factor in achieving optimal and sustainable waste processing results (World Bank, 2012). A skilled workforce can contribute to technological development and innovation in waste processing. Good HR skills can also increase efficiency in waste processing operations. In addition, trained human resources can help ensure that waste processing is carried out by applicable regulations and standards, avoiding negative impacts on the environment and health.

1. Availability of Facilities and Infrastructure Sub-Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the Availability of Facilities & Infrastructure sub-criteria is the Procurement Strategy for Facilities & Infrastructure and Materials & Tools at 37.6% with an inconsistency of 0.00008 < 0.1 which is acceptable.

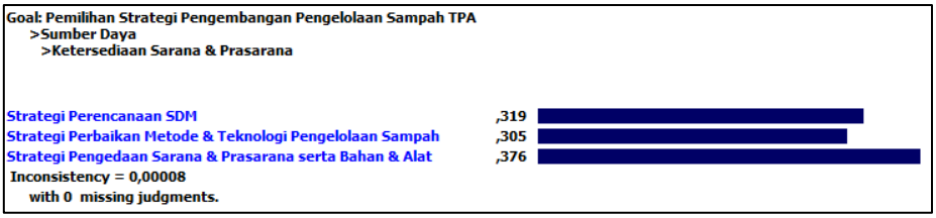

Figure 6. Results of Expert Choice Priority Sub-Criteria Infrastructure for Development of Lubuk Linggau Landfill Waste Management

2. Availability of Materials and Tools Sub Criteria

The alternative priority for selecting a waste management development strategy at the Landfill in the Availability of Materials & Tools sub-criteria is the Strategy for Procurement of Facilities & Infrastructure and Materials & Tools at 42% with an inconsistency of 0.00084 < 0.1 which is acceptable.

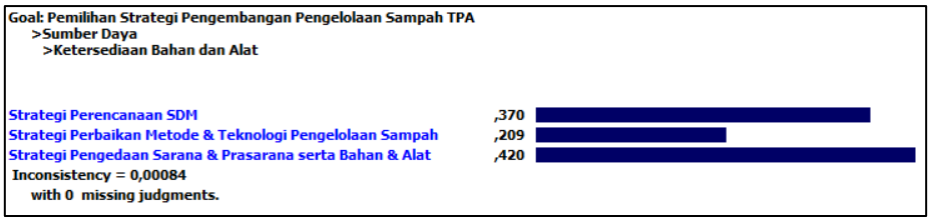

Figure 7. Results of Expert Choice Priority Sub Criteria for Tools and Materials for Development of Lubuk Linggau Landfill Waste Management

3. Human Resources Sub-Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the sub-criteria for Number of Human Resources is HR Planning Strategy at 62.6% with an inconsistency of 0.02 < 0.1 which is acceptable.

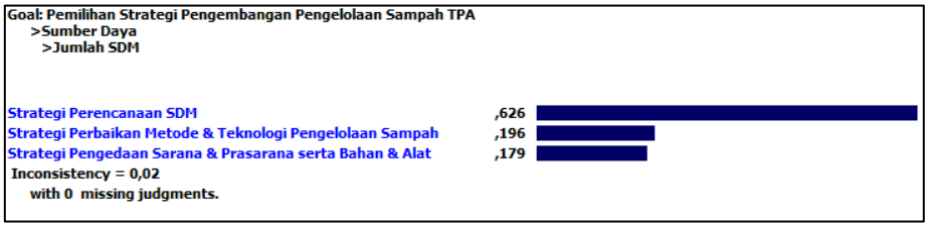

Figure 8. Expert Choice Results Priority Sub Criteria Number of Human Resources for Lubuk Linggau Landfill Waste Management Development

4. Human Resources Expertise Sub Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the HR Skills sub-criterion is HR Planning Strategy at 63.2% with an inconsistency of 0.00573 < 0.1 which is acceptable.

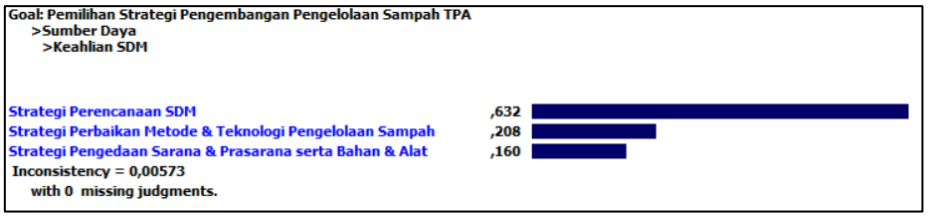

Figure 9. Expert Choice Results Priority Sub-Criteria Human Resource Expertise Development of Lubuk Linggau Landfill Waste Management

B. Technology Criteria

The priority of the sub-criteria for selecting waste management development strategies in landfills on the Technology criteria is Mastery of Waste Technology of 64.7% with an inconsistency of 0.02 < 0.1 which is more prioritized than the management innovation sub-criteria. The sub-criteria for mastering waste technology needed in developing landfill waste management is in line with the sub-criteria for human resource expertise which is prioritized in the resource criteria.

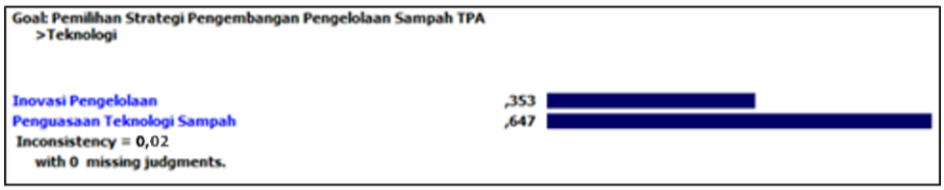

Figure 10. Expert Choice Results Priority Criteria for Lubuk Linggau Landfill Waste Management Technology

Mastery of waste technology is often prioritized over management innovation because technology that is already established and proven can be a strong basis for managing waste efficiently and effectively. Technology that has been tested and is sure to produce consistent and reliable results and reduce the risk of errors or failures in waste management (World Bank, 2012). It is important if Lubuk Linggau City prioritizes mastering waste technology because this is also a problem in the current management process. One of the strategies that can be developed is by providing HR training on using related technology.

1. Innovation Management Sub-Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the Management Innovation sub-criteria is the Strategy for Improving Waste Management Methods & Technology at 45.9% with an inconsistency of 0.0027 < 0.1 which is acceptable.

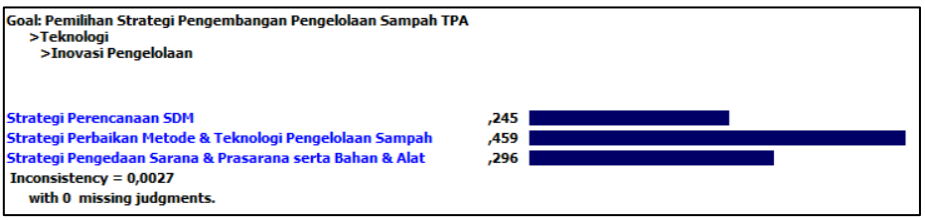

Figure 11. Expert Choice Results Priority Sub Criteria for Management Innovation and Development of Lubuk Linggau Landfill Waste Management

2. Mastery Technology Waste Sub-Criteria

The alternative priority for selecting strategies for developing waste management in landfills in the sub-criteria for Waste Technology Mastery is the Strategy for Improving Waste Management Methods & Technology at 48.1% with an inconsistency of 0.00133 < 0.1.

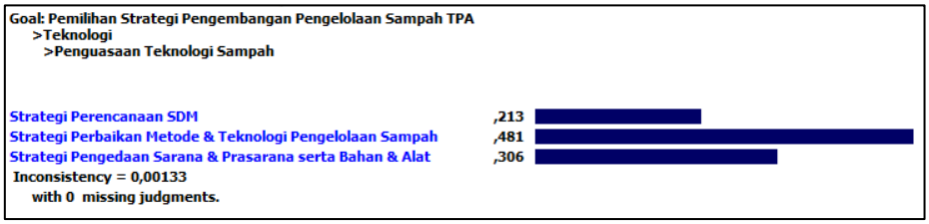

Figure 12. Expert Choice Results Priority Sub Criteria Mastery of Technology for Lubuk Linggau Landfill Waste Management Development

C. Financial Criteria

The priority of the sub-criteria for selecting waste management development strategies at landfills in the financial criteria is Investment Costs of 84.2% with an inconsistency of 0.031 < 0.1 which is more prioritized than the sub-criteria of technological price suitability. Sub-criteria for investment costs are needed in developing waste management at Landfill as funds that can be used.

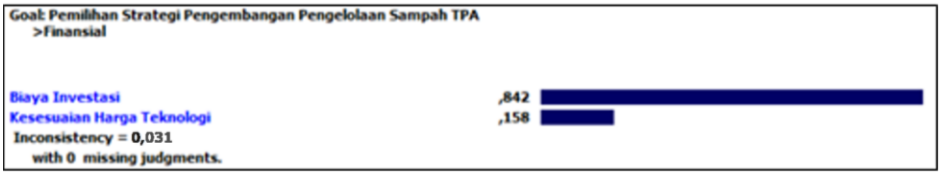

Figure 13. Expert Choice Results Priority Financial Criteria for Lubuk Linggau Landfill Waste Management Development

Investment costs are prioritized over technology price suitability because the initial investment costs required to adopt waste management technology can have a significant impact on an entity's budget and financial resources (Putra, 2021). Therefore, decision-making regarding waste management in Lubuk Linggau City focuses on the initial investment costs that must be incurred.

1. Investment Cost Sub-Criteria

The alternative priority for selecting a waste management development strategy at the Landfill in the Investment Cost sub-criteria is the Strategy for Improving Waste Management Methods & Technology at 51.5% with an inconsistency of 0.00378<0.1 which is acceptable.

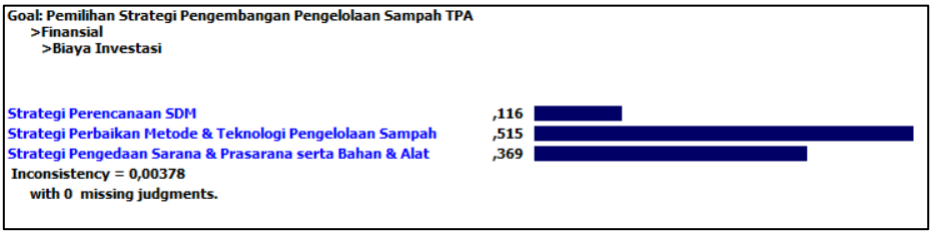

Figure 14. Expert Choice Results Priority Sub Criteria Investment Costs for Lubuk Linggau Landfill Waste Management

2. Sub-Criteria Technology Price Match

The alternative priority for selecting a strategy for developing waste management at the Landfill in the sub-criteria of Suitability of Technology Prices is the Strategy for Improving Waste Management Methods & Technology at 48.1% with an inconsistency of 0.00814 < 0.1 which is acceptable.

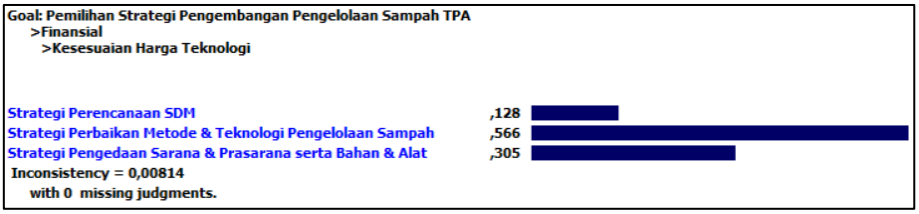

Figure 15. Expert Choice Results Priority Sub Criteria Price Suitability of Technology for Lubuk Linggau Landfill Waste Management Development

D. Criteria Institutional

The priority of the sub-criteria for selecting strategies for developing waste management in landfills in the Institutional criteria is Cooperation between stakeholders at 71.7% with an inconsistency of 0.02 < 0.1 which is more prioritized than the government policy sub-criteria. The priority selection for institutional criteria, namely the sub-criteria for collaboration between stakeholders, is in line with the priority selection for financial criteria.

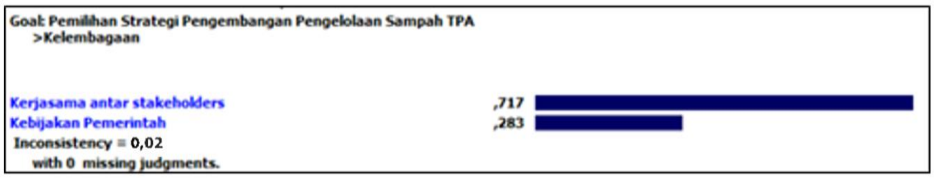

Figure 16. Expert Choice Results Priority Institutional Criteria for Lubuk Linggau Landfill Waste Management Development

Waste management in Lubuk Linggau City involves many parties who have different roles and responsibilities. Good cooperation between stakeholders can help overcome complex challenges in waste management, such as collection, transportation, processing, and recycling (Puspasari, 2016). Effective collaboration between stakeholders can also accelerate innovation, share knowledge and resources, and ensure broader support for sustainable waste management efforts (Qodriyatun, 2015). Government policy remains important as a framework for regulating and directing waste management, but institutions and collaboration between stakeholders can provide more effective and holistic implementation.

1. Stakeholders Collaboration Sub-Criteria

The alternative priority for selecting a strategy for developing waste management at the landfill in the sub-criteria for collaboration between stakeholders is HR Planning Strategy at 38.8% with an inconsistency of 0.03 < 0.1.

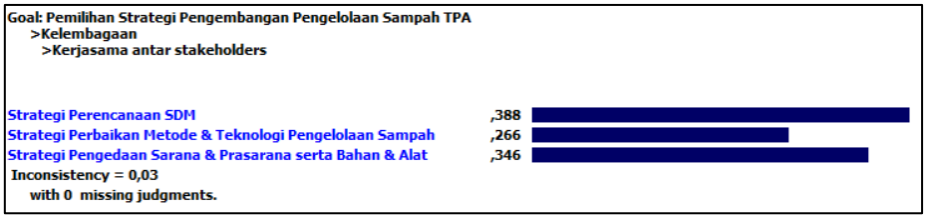

Figure 17. Expert Choice Results Priority Sub Criteria for Collaboration between Stakeholders for Development of Lubuk Linggau Landfill Waste Management

2. Policy Government Sub Criteria

The alternative priority for selecting a waste management development strategy at the landfill in the Government Policy sub-criteria is HR Planning Strategy at 50.2% with an inconsistency of 0.00204 < 0.1.

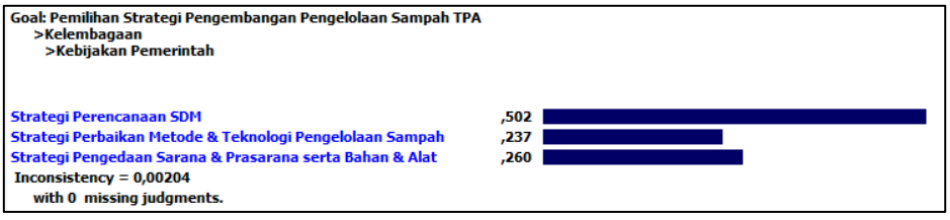

Figure 18. Expert Choice Results Priority Sub Criteria for Government Policy for Lubuk Linggau Landfill Waste Management

4.3 Analysis Priority Overall Strategy Alternatives

Based on the overall synthesis results, the alternative Strategy for Improving Waste Management Methods & Technology is a priority in selecting strategies for developing waste management in Landfills with a value of 37.1% compared to other alternatives. The results of this calculation are consistent enough or within the acceptance limits because the consistency ratio value obtained from this calculation is 0.02, which is below the specified standard (< 0.1). The alternative strategy for improving waste management methods & technology is assumed to be a priority because Lubuk Binjai Landfill still uses the Open Dumping system, so it is necessary to improve a better system to handle waste management at Lubuk Binjai Landfill.

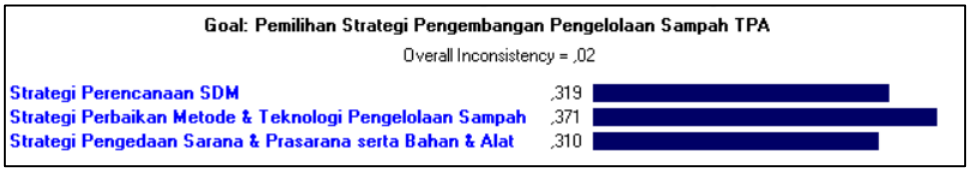

Figure 19. *Overall* Selection of Lubuk Linggau Landfill Waste Management Strategy

Based on four criteria that have been determined, the Technology criteria are prioritized by respondents compared to the Resource, Financial, and Institutional criteria. Based on the three alternatives assessed, the Waste Management Method & Technology Improvement Strategy alternative is prioritized compared to other alternatives. The results of the analysis, show that the prioritized strategy is the strategy for improving waste management methods & technology, which is needed by the problems at Lubuk Binjai TPA, namely still implementing the Open Dumping method. So that the prioritized alternative strategies can be applied in developing landfill waste management in Lubuklinggau City, apart from that, improving landfill waste management methods can be supported by the readiness and expertise of human resources.

Some alternatives can be implemented and are more environmentally friendly in waste management, namely recycling processing, composting, and more sophisticated waste management technologies such as controlled burning or anaerobic management. The use of technology in waste management must also be carried out optimally by procuring facilities and infrastructure as well as waste management materials and tools. There is also a need for an HR planning strategy. The city government needs to improve the quality of human resources by managing waste and landfills so that the benefits from technology management can also be optimal.

Another waste management innovation can be the construction of a Waste Power Plant (PLTSa). The construction of PLTSa is a good effort to reduce the amount of existing waste while utilizing it in other forms (Sucahyo, 2021). However, what needs to be noted is that a thorough evaluation of the existing waste management system must be carried out, identifying areas that can be optimized or adapted to support PLTSa. Selecting the right location for PLTSa also needs to consider the sustainability of the waste supply (Rajagukguk, 2020). Ultimately, waste management in PLTSa must be environmentally friendly and sustainable.

Application of further innovation in the Lubuk Binjai case study, increasing waste separation at source, ensuring that organic and non-organic waste is processed separately to increase the efficiency of PLTSa. PLTSa infrastructure can then be developed and integrated into existing systems by taking into account waste management capacity and local electricity needs. Sustainable funding and business models need to be considered, perhaps through partnerships with the private sector or the use of innovative financial schemes. Apart from that, educating the public about the benefits of PLTSa and their participation in waste separation is the key to the success of this integration.

5. CONCLUSION

In the context of waste management in Lubuk Linggau City, strategies for improving Waste Management Methods & Technology must be adopted by the City Government and Final Disposal Site (TPA) managers. This involves a change from open dumping waste management methods to more environmentally friendly

alternatives such as recycling, composting, and advanced waste management technologies. Increasing human resources for waste and landfill management and optimizing the use of technology are also emphasized. Apart from that, innovation in the form of a Waste Power Plant (PLTSa) is proposed as a solution to reduce the amount of waste and utilize it. However, it is necessary to carry out a thorough evaluation of the existing waste management system and select a sustainable location for PLTSa

Further research can be developed by considering other criteria and sub-criteria that are not in this study and adapting them to the conditions of the landfill. In addition, the respondents involved can be expanded by considering stakeholders outside government, for example, academics, NGOs, the community, and so on who can help in selecting priorities. This research is limited to determining waste management priorities in Lubuk Linggau City based on several important criteria for waste management in cities/regencies in Indonesia. As for recommendations for further studies that can be given, further research can discuss in detail the program plans based on the criteria that have been explained. Apart from that, further research can be carried out regarding effective waste management innovations in Lubuk Linggau City. This innovation can be in the form of an adaptation of a precedent or in the form of a study of the potential that Lubuk Linggau City has and can be utilized as a waste management development.

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Gamification: Strategy to Pull the Intention of DKI Jakarta Residents (Choice User) to Use Public Transportation

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Keywords

Gamification; Choice User; Pull Strategy; Theory of Planned Behaviour; PLS-SEM

Abstract

The higher practice of private car use in DKI Jakarta amid the implementation of the TDM strategy that continues to be developed leads to increased traffic congestion, which in turn causes economic losses, deteriorated air quality, and an increase in acute respiratory tract infection cases. Innovation is needed in the pull strategy of DKI Jakarta residents to suppress this behavior, especially those who have (access to) private vehicles to switch to public transportation. This study tries to analyze the effect of gamification on the behavioral intentions of DKI Jakarta residents (choice users) to use public transit for their daily activities (school/college/work). Modifications to the Theory of Planned Behavior (TPB) were carried out to investigate the influence of gamification through attitudes and behavioral control on behavioral intentions to use public transportation. The theory was tested using questionnaire data from 200 respondents with SEM-PLS analysis. The elements of points, levels, rewards, and games are used as indicators of gamification. This study shows that gamification positively and significantly affects attitudes and behavioral control. The study findings confirm the significant positive influence of attitudes on behavioral intentions to use public transportation. The results of this research can also be used as material for consideration in pull strategy (TDM) policy innovation in DKI Jakarta.

1. INTRODUCTION

The high usage of private vehicles by residents of DKI Jakarta post-COVID-19 pandemic has led to an increase in the congestion index of the capital from 34 percent to now reaching 53 percent (tomtom.com, 2023). Based on the population of DKI Jakarta in 2023, which is 10.6 million people, it is estimated that the number of motorized vehicle movements within DKI Jakarta itself reaches 22.4 million per day. The congestion that occurs results in a surge in air pollution, ultimately impacting the increase in cases of Acute Respiratory Tract Infection (ARI) in DKI Jakarta, reaching 200,000 cases, whereas, during the pandemic, ARI cases were only 50,000 (kompas.com, 2023). Data from the Ministry of Environment and Forestry (KLHK) shows that the transportation sector contributes 67.04 percent to the high air pollution in DKI Jakarta. In addition to air pollution, a study by the Jakarta-Bogor-Depok-Tangerang-Bekasi Transportation Management Agency (BPTJ) of the Ministry of Transportation in 2021 stated that the economic losses due to congestion in the Jabodetabek agglomeration reached IDR 71.4 trillion per year and the wastage of fuel amounted to 2.2 million liters.

To curb the use of private vehicles and their associated impacts, the government has implemented Transport Demand Management (TDM) policies. TDM involves applying strategies and policies to maximize the efficiency of urban transportation systems (pull strategy) by restricting the use of private vehicles (push strategy). One form of pull strategy implemented by the government and public transportation operators in DKI Jakarta is providing various public transportation options and improving their services. These public transportation options include road-based systems (Microtrans and TransJakarta), rail-based systems (MRT

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and LRT), as well as pedestrian and cyclist facilities. The KRL Commuter line also serves the DKI Jakarta area and its agglomeration. Improved services further support the variety of transportation options through the integration of modes (fare, routes, and stops/stations) and the availability of mobile applications (C-Access, MRTJ, TiJe, JakLingko, and LRTJ) to support the mobility of public transportation users.

Although TDM strategies have been implemented, private vehicle usage in DKI Jakarta is rising. Therefore, innovative approaches are needed to attract more residents of DKI Jakarta to use public transportation and mitigate the ongoing impacts of private vehicle usage. Yen et al. (2023b) state that a new concept is introduced in TDM, namely the use of gamification concepts in public transportation services to create more enjoyable, exciting, or addictive elements to enhance user engagement.

In the public transportation trip planner application in DKI Jakarta, some gamification elements, namely points and rewards, have already been implemented. However, the scheme for earning points and obtaining various rewards needs to be better explained, and many residents still need to be made aware of it. Given this situation, there is a thought about how the gamification scheme could be made more transparent and known to DKI Jakarta residents, especially those with preferences for modes of transportation (choice users). Will it attract residents to use public transportation? Therefore, this research aims to analyze the influence of implementing a gamification scheme on the intention of DKI Jakarta residents, specifically choice users, to use public transportation, using the theory of planned behavior framework.

2. LITERATURE REVIEW

2.1 Transport Demand Management (TDM)

The strategy of influencing public transportation preferences or travel behavior is referred to as transportation demand management (TDM) or mobility management in Europe. Tumlin (2012) defines TDM as a strategy to enhance the efficiency of the entire transportation system by shifting from private vehicles to public transportation or adjusting travel times outside of peak hours. TDM consists of various policies and programs that transform travel behavior to be more efficient, including changes in modes, destinations, routes, and travel times (Litman, 2008). TDM is crucial in developing long-term congestion avoidance strategies that focus on addressing the root causes of congestion to handle travel demand sustainably (Dinh Toan et al., 2023). There are two strategies to achieve the goal of transportation system efficiency in TDM: the "push" strategy by making the use of private vehicles less attractive and the "pull" strategy by making the use of other transportation modes more appealing; in this case, public transportation.

Wang et al. (2020) define the pull strategy as the positive attractiveness of using public transportation, while the push strategy is the negative attribute of using private vehicles. The push strategy aims to change individual behavior by explicitly making driving private vehicles more challenging. In contrast, the pull strategy seeks to change behavior by making alternative uses of private vehicles more appealing, namely by improving the quality of public transportation (Keizer et al., 2019). The improvement of public transportation quality is achieved through 1) integrated services, 2) the provision of dedicated bus lanes, 3) intersection priority, and 4) enhancing public transportation infrastructure for driving comfort and safety. Push and pull strategies should be implemented simultaneously to achieve maximum benefits and effectiveness in TDM. If fully implemented at an economically justified level, TDM would reduce the costs of motor vehicle congestion by 25-50 percent, although the exact impact is challenging to predict and varies depending on geographical, demographic, and economic conditions (Litman, 2008).

2.2 Gamification

Gamification is defined as incorporating video game elements into non-game systems to enhance user experience and engagement (Deterding et al., 2011). In gamification, core services are enhanced by adding rule-based services to provide a gaming experience that generates motivation and desired behaviors (Hamari et al., 2014; Huotari & Hamari, 2011, 2017). In gamification, promotional elements such as rewards, coupons, discounts, and loyalty programs are integrated into a unified strategy that encourages the desired behavior (Kaur et al., 2023). (Kaur et al., 2023) state that the enjoyment perceived from elements (story, aesthetics,

dynamics, and rewards) in gamification enhances consumers' or customers' intention to shop, thereby leading to behavioral intent. Setting goals (e.g., offering rewards) that encourage consumers to complete specific missions in gamification makes consumers enjoy the process and gain perceptions related to self-efficacy, ultimately enhancing purchasing behavior (Che et al., 2023).

The implementation of gamification strategies in the field of transportation, as one of the strategies in transport demand management (TDM), is generally done to reduce congestion during peak hours, promote the use of public transportation, and encourage safe driving behavior (Yen et al., 2023a). Gamification schemes, such as point systems, are applied to evaluate sustainable transportation usage, including public transportation and non-motorized transport such as cycling and walking. The accumulation of these points can later be redeemed for various rewards such as cashback or vouchers. Castellanos (2016), in their research, states that there is a shift in mode preferences that offer significant points in gamification schemes. The reward system through point accumulation in the study by (Koo et al., 2013) can also increase an individual's distance traveled using public transportation. Research results (Tsirimpa et al., 2019) conclude that the use of public transit can be influenced by materialistic motivations such as rewards through gamification schemes, where the level of rewards offered affects individual behavior changes (Yen et al., 2023b) state that in designing gamification schemes, policymakers must carefully consider the rewards offered. The implementation of gamification in the transportation sector in Indonesia was first carried out by online-based transportation, including Gojek through GoClub, where aspects of affordability in the program manifested in elements such as points, rewards, and missions have a high persuasive level that impacts the increased motivation of customers to continue transactions (Shahisa & Aprilianty, 2022).

2.3 Choice User

In understanding travel behavior, the approach commonly taken in the transportation sector involves identifying travelers into two groups: captive riders and choice riders. Captive riders are individuals who do not have mode choices and, therefore, must use public transportation (Jacques et al., 2013). Choice riders are defined as those who have mode choices but, for specific reasons, choose to use public transportation for their mobility (Jin et al. in (Krizek & El-Geneidy, 2007)). The terminology "choice riders" does not include travelers in the category of non-users of public transportation.

In this study, the term "Choice User" is used based on Sohn & Yun (2009), which refers to travelers who own private vehicles regardless of their choice to use private vehicles (car/motorcycle) or public transportation based on their respective utilities. (Guerra, 2022) also states that someone can be categorized as a choice user when they do not have a private vehicle but have access to or are transported by private vehicles owned by friends, family, or colleagues. (Krizek & El-Geneidy, 2007) The focus of choice users on public transportation is related to safety, the comfort of the provided service, service reliability, service type, and other supporting facilities. Therefore, choice users are more sensitive to negative potential changes in public transportation because they possess alternative mobility choices (Krizek & El-Geneidy, 2007).

2.4 Theory of Planned Behavior (TPB)

The theory of planned behavior (TPB) was initially proposed by Icek Ajzen and modified by subsequent scholars. It is used in this study to address how gamification can pull the intention of DKI Jakarta residents to use public transportation. Several studies on travel behavior, particularly mode choice, have also used extensions and modifications of TPB (Ali et al., 2023; Bandyopadhyaya & Bandyopadhyaya, 2022; Dirgahayani & Sutanto, 2020; Donald et al., 2014; Ishikawa et al., 2019; Zhao & Gao, 2022). TPB posits three variables that form intention: attitude, subjective norm, and perceived behavioral control. Attitude is an individual's evaluation of the benefits of the behavior, the subjective norm is the social pressure perceived by an individual to perform or not perform a behavior, and perceived behavioral control is an individual's perception of the ability or opportunity to perform a behavior (Ajzen, 1991).

Based on the explanation of gamification, it is assumed in this study that gamification elements such as points, levels, and rewards will make individuals perceive that public transportation behavior is advantageous (attitude). The enjoyment of playing games in gamification will influence an individual's perception of self-efficacy, anticipating barriers (behavioral control) to using public transportation, such as long waiting times and travel times. These attitudes and behavioral control will ultimately influence the intention to use public transportation. The modified TPB results are presented in Figure 1, with the following research hypotheses:

H1: Gamification positively influences attitude.

H2: Gamification positively influences behavioral control.

H3: Attitude positively influences intention.

H4: Behavioral control positively influences intention.

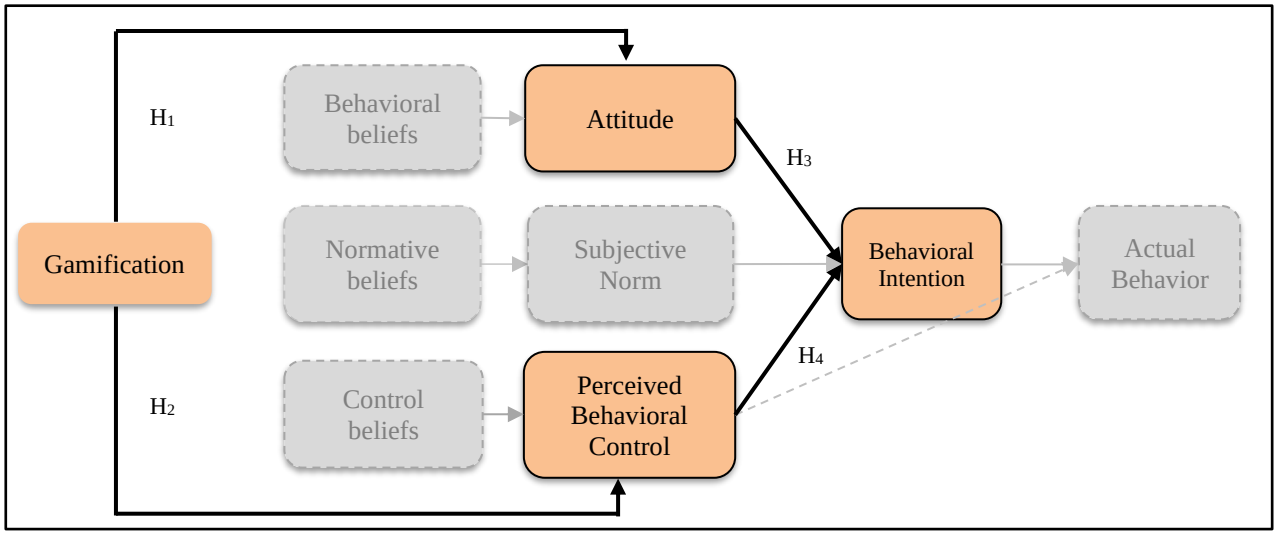

Figure 1. Proposed Constructs and Research Hypotheses. Source: Modification of Ajzen's Theory of Planned Behavior (1991).

3. METHODOLOGY

The method in this research is quantitative, utilizing primary data collected through a questionnaire instrument and distributed through social media platforms such as WhatsApp, Instagram, and Facebook stories.

3.1 Population and Sample

The population in this study consists of residents of DKI Jakarta who engage in daily activities (school/college/work) within the Jakarta area and fall into the category of choice users. Therefore, the sampling technique employed in this study is nonprobability purposive sampling, which is a sampling technique that does not provide equal opportunities for every member of the population to be selected as a sample based on specific considerations. The sample criteria for this study are 1) residents of DKI Jakarta; 2) engaging in activities (school/college/work) in DKI Jakarta; 3) aged 17 to 49 years (the minimum age limit for having a driver's license, the largest age group in the current population composition of DKI Jakarta, and familiar with technology); and 4) owning (having access to) private vehicles. Due to the large population size and the limited time for collecting questionnaires (three weeks), the sample calculation uses the Slovin method with a margin of error of 7% (for large populations, the usual margin of error is 10%). Therefore, the sample size to be used is 204 samples. From the questionnaire distribution, 223 respondents were obtained, but after examination and data cleaning, valid data from 200 respondents were employed.

3.2 Questionnaire Design

The questionnaire in this study consists of 2 parts: (1) a section of questions regarding respondent characteristics (age, gender, type of activity, education, domicile, activity location, possession of driver's license, ownership of private vehicle, modes of activity, and travel chain), and (2) a section of statements related to the research constructs. At the beginning of the second part of the questionnaire, an explanation of the offered gamification scheme is provided, along with examples of applied gamification that respondents may have accessed (Figure 2).

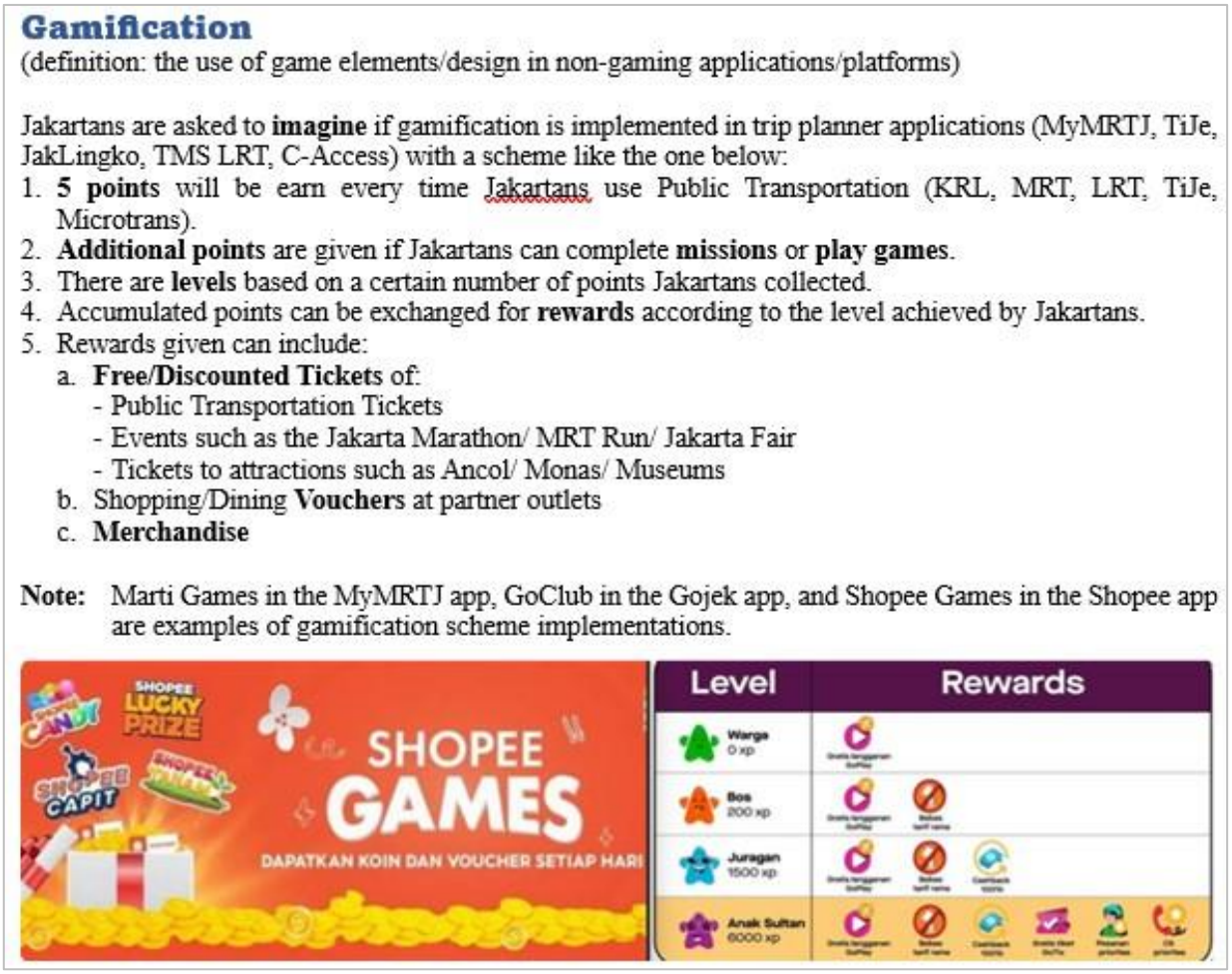

Figure 2. Explanation of the gamification scheme in the Likert scale questionnaire section.

After reading and understanding the offered gamification scheme, on the next page, respondents are asked to respond to statements regarding the influence of gamification on the intention to use public transportation (Table 1) in the form of a Likert scale with a range of 5 (strongly disagree, disagree, neutral, agree, and strongly agree).

Table 1. Constructs and Statement Items

No	Indicator	Item
Gamification		
1	G1	I am motivated to collect points to reach a certain level in the gamification scheme.
2	G2	I am motivated to collect points to obtain specific rewards (free/discounted tickets, vouchers, and merchandise) in the gamification scheme.
3	G3	I enjoy spending my leisure time playing games or completing missions in the gamification scheme.

No	Indicator	Item
4	G4	I can ward off boredom when playing games or completing missions in the gamification scheme.
5	G5	The rewards (free/discounted tickets, shopping vouchers, merchandise) offered motivate me to participate in the gamification scheme.
6	G6	I feel appreciated through rewards (free/discounted tickets, vouchers, and merchandise) that I can obtain by redeeming points/achieving certain levels in gamification.
Attitude		
1	SP1	I am appreciated or rewarded for using public transportation if rewards (free/discounted tickets, vouchers, and merchandise) through the gamification scheme are implemented.
2	SP2	If the gamification scheme is implemented in the trip planner application, I can obtain diverse rewards according to my preferences.
Perceived Behavioral Control		
1	KP1	I can alleviate boredom while waiting for public transportation by playing games and collecting points on the trip planner application.
2	KP2	My journey using public transportation would be more enjoyable if I could play games while collecting points on the trip planner application.
Intention		
1	NP1	I have/will reduce the use of private vehicles (motorcycle/car) in my daily activities (school/college/work).
2	NP2	I will continue/start using public transportation in my daily activities (school/college/work).
3	NP3	I will continue/start encouraging those around me to use public transportation more often in their daily activities (school/college/work).
4	NP4	I will use public transportation more often in my daily activities (school/college/work).

3.3 Analysis Method

The pilot survey was conducted by distributing questionnaires through WhatsApp groups at the office, among teacher colleagues, and to professors to gauge respondents' understanding from each category of workers, students, and university students regarding the questions and statements in the questionnaire. Validity and reliability tests were conducted on 60 pilot survey respondents' data to validate the questionnaire instrument in this study. Based on calculations using SPSS 2.6, it was found that all statement items were valid and reliable, as evidenced by the calculated value (r) > the table value and Cronbach's Alpha (α) > 0.7. An analysis was conducted on 200 respondent's data set to examine the influence of gamification on the intention to use public transportation using PLS-SEM with the following considerations (Hair et al., 2017):

1. Can be used to analyze the development of theoretical constructs.
2. Relationships between measurement indicators and variables can be reflective or formative indicator models.
3. Can be used in modeling analysis with relatively small and non-normally distributed samples.

4. DISCUSSION AND ANALYSIS

4.1 Analysis

The analysis section will explain the descriptive statistical analysis results of respondents' characteristics data and the results of PLS-SEM calculations to answer the hypotheses and research questions. The results of PLS-SEM are reviewed and evaluated using two systematic evaluation processes, namely the evaluation of the measurement model (outer model) to measure the reliability and validity of the research instrument and the evaluation of the structural model (inner model) to measure the predictive ability of the model.

4.1.1 Descriptive Statistics

Descriptive statistics were analyzed on the 200 data sets related to respondent characteristics (age, gender, type of activity, education, domicile, activity location, ownership of driver's license, ownership of private vehicle, mode of activity, and travel chain) (Table 2). It is found that the majority of respondents are aged between 24-39 years (54%), female (57.5%), engaged in daily work activities (72.5%), have a bachelor's degree or equivalent (44%), reside in East Jakarta (53%), carry out activities in East Jakarta (30.5%), have driver's licenses A & C (48.5%), own at least two private vehicles (38.5%), travel daily using private vehicles (73.5%), and do not have a trip chain (55%).

Table 2. Demographics and Travel Behavior of Respondents

	N	%		N	%
Age			**Activity Location**		
17-23	58	29%	Central Jakarta	73	36,5%
24-39	108	54%	North Jakarta	7	3,5%
40-49	34	17%	East Jakarta	61	30,5%
			South Jakarta	50	25%
Gender			West Jakarta	9	4,5%
Female	115	57,5%			
Male	85	42,5%	**Driver's License**		
			None	48	24%
Activity			SIM A	25	12,5%
School	39	19,5%	SIM C	30	15%
College	16	8%	SIM A + C	97	48,5%
Work	145	72,5%			
			Vehicles Ownership		
Education Degree			One vehicle	58	29%
Junior High	38	19%	Two vehicles	77	38,5%
Senior High	17	8,5%	Three vehicles	37	18,5%
Diploma 1/2/3	11	5,5%	>Three vehicles	28	14%
Bachelor	88	44%			
Master/Doctor	46	23%	**Activity Mode**		
			Private Vehicle	147	73,5%
Domicile			Public Transportation	53	26,5%
Central Jakarta	23	11,5%			
North Jakarta	13	6,5%	**Trip Chain**		
East Jakarta	106	53%	Yes	90	45%
South Jakarta	43	21,5%	No	110	55%
West Jakarta	15	7,5%			

4.1.2 Evaluation of Measurement Model (outer model)

The constructs of gamification, attitude, behavioral control, and intention in this study are reflective measurement models. Hair et al. (2017) state that the assessment of reflective measurement models includes composite reliability to evaluate internal consistency, outer loading, and average variance extracted (AVE) to assess convergent validity and discriminant validity.

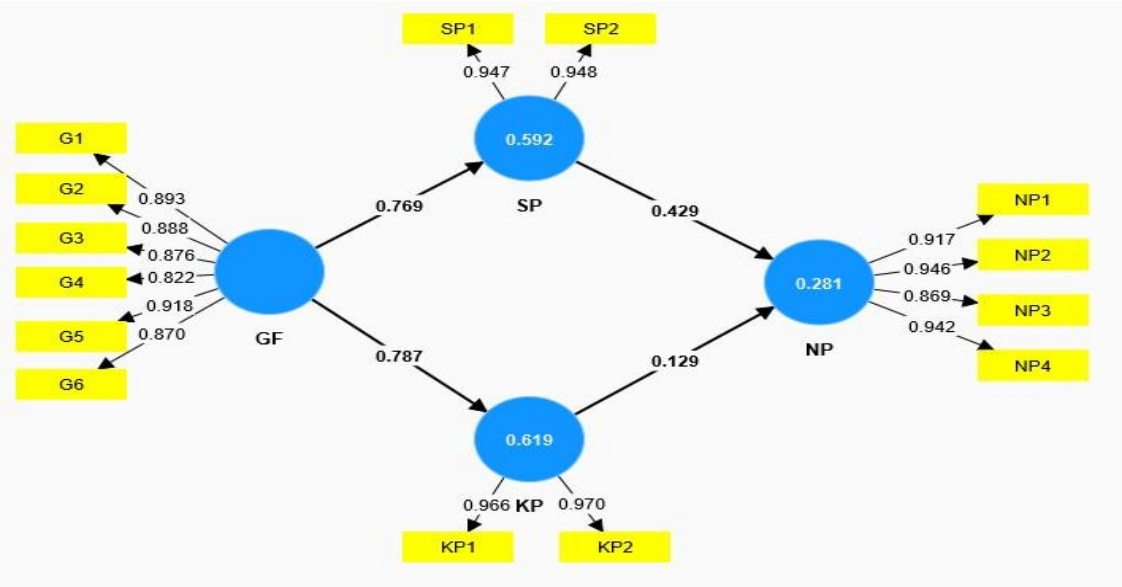

Figure 3. Results of PLS Algorithm Calculation

Internal Consistency Reliability

Two references were used to measure internal consistency reliability: Cronbach's alpha value >0.70 and composite reliability with the criteria that values from 0.6 to 0.7 are acceptable, values from 0.7 to 0.9 are reliable, and values >0.95 are unreliable. The following table shows the results of the PLS Algorithm measurement, indicating that all constructs in the model are reliable.

Table 3. Internal Consistency Reliability

Construct	Cronbach's Alpha (α)	*Composite Reliability*	Result
Gamification	0,940	0,941	Reliable
Attitude	0,885	0,885	Reliable
Perceived Behavioral Control	0,933	0,935	Reliable
Intention	0,938	0,943	Reliable

Convergent Validity

A convergent validity assessment was made based on the outer loading values of each statement item and the AVE (Average Variance Extracted) construct values. The construct is considered valid if the outer loading values and AVE values meet or exceed the threshold (OL > 0.7 and AVE > 0.5). From Figure 2 (PLS Algorithm calculation results), it can be observed that all items have outer loading values > 0.7, proving that the constructs in this study are valid. The AVE construct values are also > 0.5, indicating validity, as shown in the following table.

Table 4. Average Variance Extracted (AVE)

Construct	AVE	Result
Gamification	0,771	Valid
Attitude	0,897	Valid
Perceived Behavioral Control	0,937	Valid
Intention	0,845	Valid

Discriminant Validity

the HTMT (Heterotrait-Monotrait) values were used to measure discriminant validity in this study with a threshold below 0.9. Hair et al. (2017) recommended HTMT because it is more sensitive and accurate in detecting discriminant validity. Based on the PLS Algorithm calculation, all construct values were below 0.9, indicating that discriminant validity is fulfilled.

4.1.3 Structural Model Evaluation (inner model)

Once ensuring that the construct model is valid and reliable, the next step is to evaluate the structural model, which includes testing for collinearity and hypothesis testing (path coefficients, p-value, confidence interval, and f-square). The testing is performed using the bootstrapping method in PLS-SEM.

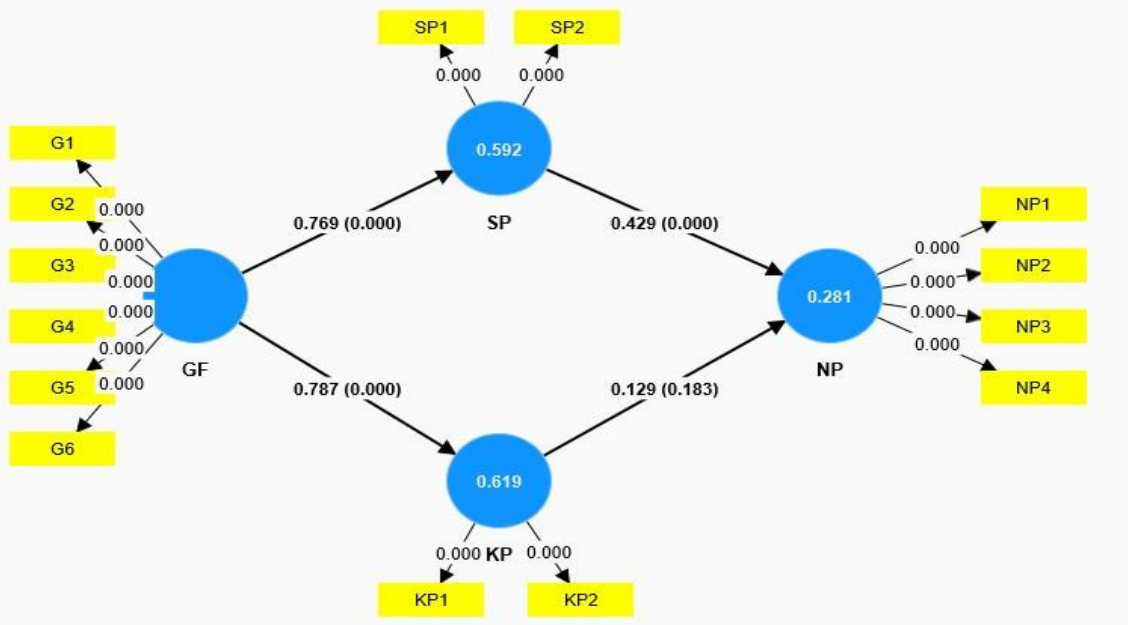

Figure 4. Results of PLS Bootstrapping Calculation

Collinearity assessment

The VIF values of all sets of predictor constructs were examined to assess the collinearity of the structural model, with values needing to be below 3, indicating no multicollinearity. Based on the calculations (Table 4), it is known that the estimated results show inner VIF values below 3, meaning there is no multicollinearity between variables, and these results reinforce that the parameter estimates in PLS-SEM are robust (unbiased).

Table 5. Variance Inflation Factor (VIF)

Hypothesis	VIF	Result
Gamification → Attitude	1,000	No Multicollinearity
Gamification → PBC	1,000	No Multicollinearity
Attitude → Intention	2,104	No Multicollinearity
PBC → Intention	2,104	No Multicollinearity

Hypothesis Testing

The constructs in this study involved three types of variables: exogenous variable (gamification), mediating variables, which are attitude and behavioral control, and endogenous variable (intention). Therefore, hypothesis testing is conducted by examining direct effects and indirect effects.

Direct Effect

The hypothesis testing for direct effects is assessed through three calculations: path coefficient, p-value with a criterion of less than 0.05 indicating a significant influence, and f-square indicating the magnitude of the effect (0.02 = low, 0.15 = moderate, and 0.35 = high). The following table shows the results of the direct hypothesis testing.

Table 6. Direct Effect Hypothesis Testing

Hypothesis	*path coefficient*	*p-value*	*Confidence interval*	*f-square*	Result
Gamification → Attitude	0,769	0,000	0,700 - 0,829	1,449	Significant
Gamification → PBC	0,787	0,000	0,718 - 0,845	1,627	Significant
Attitude → Intention	0,429	0,000	0,227 - 0,616	0,122	Significant
PBC → Intention	0,129	0,183	(0,061) - 0,319	0,011	Not Significant

Results of direct effect hypothesis testing:

H1: Accepted

A positive and significant influence exists between the gamification variable and attitude, as indicated by the p-value (0.000 or <0.05). Implementing gamification in public transportation platforms influences attitude formation by 76.9% (path coefficient). The upper threshold value of the confidence interval indicates that if gamification is applied with an attractive scheme (points, levels, and rewards), its influence on attitude formation can reach 82.9%. The f-square value of 1.449 indicates that gamification highly influences attitude formation.

H2: Accepted

There is a positive and significant influence between the gamification variable and behavioral control, as indicated by the p-value (0.000 or <0.05). Implementing gamification in public transportation platforms influences behavioral control formation by 78.7% (path coefficient). The upper threshold value of the confidence interval indicates that if gamification is applied by incorporating games, its influence on behavioral control formation can reach 84.5%. The f-square value of 1.627 indicates that gamification highly influences behavioral control formation.

H3: Accepted

There is a positive and significant influence between the attitude variable and intention, as indicated by the p-value (0.000 or <0.05). Positive attitudes resulting from the implementation of gamification on public transportation platforms influence the intention to use public transportation by 42.9% (path coefficient). The upper threshold value of the confidence interval indicates that if positive attitudes are enhanced, it can increase the intention of DKI Jakarta residents in the choice user category to 61.6%. However, the f-square value of 0.122 indicates that the significance of the influence of attitude on the intention to use public transportation is relatively moderate.

H4: Rejected

There is a positive but insignificant influence between the behavioral control variable and intention, as indicated by the p-value (0.183 or >0.05). Behavioral control formed through the presence of games in the gamification scheme only has an influence of 12.9% (path coefficient) on the intention to use public transportation. The f-square value of 0.011 also supports the low significance of behavioral control on the intention to use public transportation.

Indirect Effect

In assessing the indirect effects of gamification on intention, in addition to the path coefficient and p-value, the f-square value cannot be used to determine the magnitude of indirect influence through mediating variables. Instead, the statistic upsilon (v) is utilized. Lachowicz et al. (2018) state that the mediating effect of a mediating variable is calculated using the statistic upsilon (v), with the formula being the square of the path coefficients from each of its exogenous latent variables. Interpretation of the results of the statistic upsilon (v) follows the study by Ogbeibu et al. (2021), which is 0.075 (low mediating effect), 0.195 (moderate mediating effect), and 0.295 (high mediating effect).

Table 7. Indirect Effect Hypothesis Testing

Hypothesis	*path coefficient*	*p-value*	*Confidence interval*	*upsilon (v)*
Gamification → Attitude → Intention	0,333	0,000	0,172 - 0,482	0,109
Gamification → PBC → Intention	0,101	0,190	(0,048) - 0,257	0,010
Gamification → Intention	0,432	0,000	0,302 - 0,556	-

Results of testing indirect effects hypotheses:

1. Attitude plays a positive and significant role in mediating the gamification variable on the intention to use public transportation, as indicated by the p-value (0.000 or < 0.05). However, the mediating effect is relatively low, as shown by upsilon (v) = 0.109. Attitude mediates 33.3 percent of the intention to use public transportation.
2. Behavioral control has a positive but not significant role in mediating the gamification variable on the intention to use public transportation, as indicated by the p-value (0.190 or > 0.05), and its mediating effect is also very low, reflected in the upsilon (v) value = 0.010. Behavioral control can only mediate the intention to use public transportation by 10.1 percent.
3. Overall, the influence of implementing gamification on the intention to use public transportation is positive and significant (p-value = 0.000). The 95% confidence interval suggests that gamification (games, points, levels, rewards) will influence the intention by 30.2 percent. If gamification is made more attractive, it will affect the intention to use public transportation by 55.6 percent.

4.1.4 Theory Testing

PLS-SEM is a variance-based analysis that tests the theoretical model and focuses on predictive studies. Therefore, it is necessary to test whether the proposed model provides accurate and fitting predictions (good fit). Evaluations were conducted using the determinant coefficient (R2), predictive relevance (Q2), SRMR, and NFI to assess the constructs or the model built in this study.

R-Square

The coefficient of determination (R-square) measures the model's predictive power. The R2 criteria with values of 0.75 is considered strong, 0.50 is moderate, and 0.25 is weak. The following table shows the results of the PLS Algorithm calculations for the coefficient of determination.

Table 8. *R-Square*

Variable	*R-Square*	Result
Attitude	0,592	Moderate
Perceived Behavioral Control	0,619	Moderate
Intention	0,281	Weak

Based on the above R-square calculations, it is known that gamification is moderate in predicting the attitude variable, with 59.2 percent predicted by gamification and 40.8 percent by other variables. Gamification is also considered moderate in predicting the behavioral control variable, with 61.9 percent predicted by gamification and 38.1 percent by other variables. Attitude and behavioral control combined are weak in predicting the intention variable, with 28.1 percent predicted by attitude and 71.9 percent by other variables.

***Predictive Relevance* (Q^2)**

In evaluating the model's predictive power, besides using the R-square value, an assessment is also conducted on the Q-square, which indicates the predictive power or predictive relevance of the model beyond the sample. A Q2 value greater than 0 indicates accurate predictive relevance, while a 0 or below indicates a lack of predictive relevance. Using the PLSpredict/CVPAT method (Table 9), it can be stated that the proposed model has accurate predictive relevance.

Table 9. *Predictive Relevance*

Variabel	Q^2 *Predict*	Result
Attitude	0,587	Reliable
Perceived Behavioral Control	0,616	Reliable
Intention	0,240	Reliable

SRMR & NFI

A model is considered a good fit if it has an SRMR value less than 0.08 or 0.1 and an NFI above 0.9. Based on the PLSpredict calculations, the SRMR value obtained is 0.054, below 0.08, and the NFI value is 0.9 (rounded). Therefore, the model's constructs have a good fit.

4.2 Discussion

Based on the analysis using PLS-SEM, it is found that the reward element in gamification has the highest outer loading value; this indicates that the variety of rewards obtained through gamification schemes is the most influential factor in Jakarta residents' intention to use public transportation, categorized as choice users. Free/discounted tickets for returning to using public transportation, events like Jakarta Marathon/MRT Run/Jakarta Fair, shopping/dining vouchers, and merchandise can motivate Jakarta residents in the choice user category to use public transportation. This result aligns with a study by Tsirimpa et al. (2019), which found that the rewards obtained through gamification schemes influence individual behavior change, particularly in sustainable transportation use (public transportation, cycling, and walking).

Regarding direct effects, gamification has a positive and significant impact on shaping attitudes and behavioral control. The results show that collecting points to reach a certain level and obtaining rewards shapes a positive attitude by 78.7%, and the presence of games (gaming) on the platform shapes behavioral control by 76.9%. Furthermore, the positive and significant effect of attitude on the intention to use public transportation is observed. Based on the study findings, attitude has a 42.9% effect on the intention to use public transportation, although this effect is small. The two statements related to the variety of rewards in the

gamification scheme that respondents can obtain according to their preferences and validating the feeling of being appreciated for using public transportation significantly shape attitudes towards the additional benefits of using public transportation through gamification. Considering that most respondents in this study have at least two private vehicles and use them in their daily activities, the existence of rewards becomes an added value they can gain from switching to using public transportation. This result aligns with a study by Shahisa and Aprilianty (2022) regarding aspects such as rewards, points, and missions that have a high level of persuasion in motivating customers to continue transactions on online transportation platforms.

For the influence of the behavioral control variable on the intention of Jakarta residents to use public transportation, the results show a positive but insignificant effect, only 12.9%. The mediating effect of behavioral control also indicates a low influence because the indicators used to measure the behavioral control variable in this study are related to the enjoyment of playing games, while no simulation was conducted. Therefore, respondents do not directly perceive the enjoyment of playing games in warding off boredom while waiting or using public transportation. A study by Yen et al. (2023a) can also be referenced, stating that perceived enjoyment from gamification has no direct relationship with intention but is mediated by perceived ease of use, and the mediating effect is low. The difference in results between this study and the studies by Ali et al. (2023), Dirgahayani & Sutanto (2020), and Matubatuba & De Meyer-Heydenrych (2022) could be an alternative reason why behavioral control in this study is not significant. These studies stated that behavioral control has a positive and most significant influence (largest predictor) on the intention to use public transportation. In both studies, the main service attributes of public transportation (accessibility, fare, schedule information, travel time, frequency, comfort, and safety) were used to measure behavioral control. In other words, behavioral control is strongly influenced by primary services rather than complementary services like gamification. Considering that the respondents in this study are choice users, accessibility, frequency, travel time, comfort, and safety significantly impact their transportation mode choice decision.

In addition to direct effects, this study also analyses the indirect effects of gamification variables on the intention to use public transportation through the mediating variables of attitude and behavioral control. The attitude variable positively and significantly mediates the gamification variable with the intention to use public transportation by 33.3%, indicating that the assessment of the benefits obtained through attractive gamification motivates choice users' intentions to start or continue using public transportation. In other words, if choice users perceive that gamification provides more value benefits, it will increase the likelihood of them having the intention to start or continue using public transportation by 33.3%. The behavioral control variable in this study has not been able to become a mediator, with its influence only at 10.1%. The magnitude of the influence of the mediation variables is indeed low. Still, considering the limitations of using significant upsilon (v) in a simple model (parsimonious model), the mediating influence in this study is accepted (Lachowicz et al., 2018). Overall, the indirect influence of gamification on the intention to use public transportation using the TPB framework is positive and significant at 43.2%, indicating the potential of gamification to attract the intentions of Jakarta residents categorized as choice users to use public transportation.

5. CONCLUSION & RECOMMENDATION

5.1 Conclusion

Pulling more residents of DKI Jakarta, especially those in the choice user category, to use public transportation requires innovative pull strategies that align with the times. This research explores one strategy currently being widely applied in the context of Transportation Demand Management (TDM), namely gamification, to see the possibilities of it becoming an alternative innovation. By modifying the TPB constructs, it is assumed that if residents are aware of and understand the gamification scheme (points, levels, rewards, games) in the trip planner application, it will influence their attitudes and control over behavior and ultimately affect the intention to use public transportation.

Based on the analysis, gamification impacts the intention to use public transportation mediated by the attitude variable. Indicates that the appreciation of the behavior of choice user category residents using public

transportation through various rewards can motivate them to start/continue using public transportation. The result states that behavioral control has a positive but insignificant impact in mediating gamification, and the intention to use public transportation should not be seen as a failure of this research. Instead, it can serve as a foundation for further research to simulate games and observe the real impact of gaming elements in gamification in shaping behavioral control. It is also essential to understand that gamification is a form of development from the core services of public transportation. Therefore, gamification strategies must be integrated with improving the primary public transportation services to attract Jakarta residents, especially choice users, to use it.

5.2 Limitations

In this study, game simulations were not conducted within the offered gamification scheme (only asking respondents to imagine), so the respondents did not have an authentic experience related to gamification. This study also did not examine the influence of gamification on subjective norms as a mediating variable for the intention to use public transportation. More than 200 respondents are needed to strengthen the research findings further. Based on PLS-SEM calculations, the results of testing the theory and constructs used in this study show that the proposed model is appropriate and has accurate predictive relevance, even though its predictive power is still in the moderate and weak categories. Therefore, improvements are needed in the statement items to make them more accurate in predicting the model.

5.3 Recommendation

The research results can provide input for the government and public transportation operators to enhance their pull strategy innovations, especially regarding the variety of rewards that can be obtained from public transportation. Public transportation operators need to explain what rewards can be obtained from collected points or achieved levels in the trip planner application to attract more residents of DKI Jakarta, especially choice users, to use public transportation. These rewards must be tailored to the interests, habits, and conditions of DKI Jakarta residents. Rewards that incentivize participation in events or visits to tourist attractions organized by the Jakarta provincial government can ultimately serve as effective means of publicity.

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Integrated Planning of Thematic Green Open Spaces with Goals of Urban Detailed Spatial Planning

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Keywords

Thematic Urban Parks; Green Open Spaces; Livable Cities: Bandar Lampung

Abstract

This research aims to generate the theme of urban parks by developing urban areas towards livable cities. Qualitative and quantitative descriptive methods are operated to identify the availability of urban parks, discover the characteristics of urban development areas, and arrange the theme of a park. Eight themes could be adopted: history and culture, entertainment, hobbies, health, conservation, hazard mitigation, branding, and education. The objective of urban development areas, structure plan, land use, and specific characteristics of an area are considered when selecting the theme of the urban parks. As a primer area in development, WP I had more variety in urban park themes than the others.

1. INTRODUCTION

A liveable city can be defined as a sufficient urban environment to support the activities of its residents, both by providing infrastructure and socio-economic aspects (Castells, 2002; Makalalag et al., 2019; Sutriadi & Noviansyah, 2021). To achieve livability, cities must provide public spaces for socialising, interacting, recreation, and improving the quality of life (Abdi & Furqan, 2019; Lloyd & Auld, 2003; Southworth, 2016). In Indonesia, a city must have green open spaces (GOS) with a percentage of around 30% of the city; it can be divided between around 20% public ownership and 10% private ownership. Urban parks, as a part of public GOS, play an imperative role in improving the quality of life of the local community. Ultimately, it contributes to realising a city's liveability program (C.-L. Li, 2020; Neema et al., 2014)

The development of thematic city parks is an effort that can be made to increase the attractiveness of urban parks parks (Widyahantari & Rudiarto, 2018) by improving the park's image, theme attractions for visitors, and improving end-user experiences (Amin et al., 2014; Fujianti et al., 2021; F Sinatra, 2017). Thematic parks are expected to improve the lovability (Lindfield & Steinberg, 2012; Widyahantari & Rudiarto, 2018). Thematic parks are an alternative for people to have recreation that is cheap and useful, so in their provision, they need to pay attention to the needs of various community groups (Amin et al., 2014; Fujianti et al., 2021; F Sinatra, 2017). In addition, the development of park themes can be integrated with spatial plans by considering policy directions for developing planning areas (Elliott, 2012).

Various demands are faced to develop urban parks, not only related to the quantity of parks – the proportion of parks available – but also the quality of the parks. Moreover, the imperative consideration is the lack of integrated directions for developing public parks that can support the goals of urban detailed spatial planning or "wilayah perencanaan" (WP). Integrating the development of thematic parks with the proposed WP not only encourages the improvement of the quantity of green open spaces but also improves the quality of the park itself.

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Bandar Lampung is a metropolitan area in southern Sumatra experiencing a need for more quality and quantity of urban parks. In Bandar Lampung, the number of public green open spaces is still below 20% by statutory provisions (Fran Sinatra et al., 2022). If we look at the level of citizen satisfaction with aspects of the availability of urban facilities, it is still below the national rate in Indonesia IAP Indonesia, 2022). Therefore, providing public parks is the prioritised program that must be implemented to create a livable city.

Previous studies examined the development of thematic urban parks to improve park quality by increasing its attractiveness, enriching the visitor experience, improving place image, increasing the visitor wellbeing index, and providing environmental education (Liu et al., 2021; Praganingrum et al., 2017; Wolch et al., 2014; Xue et al., 2017). In Indonesia, theme park development is often carried out in several major cities such as Bandung, Surabaya, Jakarta and other cities. Its development is focused on increasing the attractiveness of urban parks, but it still needs to integrate it with regional development goals (Sinatra & Fitra, 2021).

It is significant to integrate the theme of urban parks and the goal of WP because it will improve the image, character, and unity of space function to generate liveable cities. Therefore, this research aims to develop a park theme based on the objectives of formulated WP as part of efforts to improve urban liveability in the case of Bandar Lampung City. The results of this research are expected to gain the approaches or methods for developing thematic urban parks. It is oriented towards aesthetic and social aspects and pays attention to the integration of urban spatial planning goals in each WP. Local governments can adopt this study to provide urban design guidelines, or master plans for green open spaces.

2. METHODS

2.1 Types and Data Collections

This research used secondary data on general urban spatial planning (RTRW) and literature studies. Data related to RTRW was collected through desk surveys, while data from literature reviews was carried out by collecting published journals and scientific articles. The selected information in the RTRW document is related to identifying spatial planning policies, goals of development areas (WP), structure plans, spatial pattern plans, and unique development characteristics in each WP. Moreover, the distribution and availability of parks at city and sub-district scales are referred to in the spatial pattern plan in Bandar Lampung City, RTRW, for 2021-2041. The literature reviews are also conducted to enrich information related to city characteristics and determine park themes that have been and will be developed.

2.2 Research Method

This research process was conducted in three stages, which include (Figure 1): The first step is to Identify the Urban Detailed Spatial Planning or Wilayah Perencanaan (WP) of Bandar Lampung City. At this stage, qualitative and quantitative descriptive analysis is used to identify the division of WPs, WP development objectives, structural plans, and spatial patterns, and unique local characteristics are used to obtain a full figure regarding the spatial planning policies of the City of Bandar Lampung for 2021-2041. the second step is to Identify the availability and distribution of GOS at the city and sub-district scale-operated spatial analysis, particularly ArcGis software. The third is to develop criteria, weigh them, and provide themes of GOS. There were several sub-stages carried out in this stage, namely: developing a theme GOS to support a livable city, Developing criteria and considerations for spatial planning policies related to determining GOS themes using descriptive analysis methods And arranging the GOS themes per sub-district in each WP operated quantitative descriptive by weighting (table 1). Following the weighting process, it selected the adequate theme of GOS for each WP, which the theme can be adopted in single or multiple themes. This decision depends on the output of the weighting process.

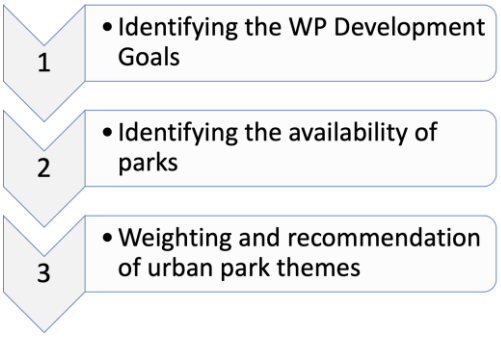

Figure 1. Research Process
Source: Authors, 2024

Table 1. The criteria of Theme Weighting

Weighting	Criteria
Very recommended (3)	The themes are very relevant to the objectives of WP, Structural, spatial plan, zoning plan, and specific site characteristics
Recommended (2)	The themes are relevant to the objectives of WP, Structural, spatial plan, zoning plan, and specific site characteristics
Not Recommended (1)	The themes need to be more relevant to the objectives of WP, Structural, spatial plan, zoning plan, and specific site characteristics

Source: Authors, 2024

3. DISCUSSIONS

3.1 Integrated Planning of Thematic Green Open Spaces

Bandar Lampung is a metropolitan area in southern Sumatra with a total area of around 197.22 km2 and 20 sub-districts. From general city spatial planning, RTRW, of Bandar Lampung, it can be identified that the aim is the dynamic, intelligent and sustainable Bandar Lampung City as a center for trade and services. There are 5 (five) detailed spatial urban planning areas (WP), which: WP I consists of South Telukbetung, Bumi Waras, North Telukbetung, Enggal, East Tanjungkarang, Central Tanjungkarang, Kecepatan, Kedaton and Way Halim district; WP II includes Sukarame, Tanjung Senang, Rajabasa, Langkapura and Labuhan Ratu Districts; WP III covers Panjang and Sukabumi Districts; WP IV covers East Telukbetung and West Telukbetung Districts; and WP V covers Kemiling and West Tanjungkarang Districts (Figure 1). The characteristics of WP development can be identified from the objectives of WP, the spatial structure plan and the spatial pattern plan.

In WP I, the spatial planning objective is aimed at a trade and services centre for the regional area, the government office centre, and additional functions as a transportation node, integrated sports facilities, health, and education. In the spatial structure plan, this area is planned as a significant urban service centre or "Pusat Pelayanan Kota" (PPK), which involves the Tanjungkarang Pusat; Subs-urban service centre or "Subs-Pusat Pelayanan Kota (SPPK) consist of Tanjungkarang Timur and Kedaton; and the local urban service centre or "pusat pelayanan lokal" (PPL) is in Enggal, Peace, Way Halim, Bumi Waras, North Telukbetung, and South Telukbetung district. Meanwhile, in the pattern or zoning spatial plan, the Kedamaian District is a preserved cultural heritage area of the Keratuan Dibalau and conservation and historical tourism areas. Telukbetung Selatan is a site to preserve the old city of the Grand Mosque of Al Munawar; Telukbetung Utara and Bumi Waras are allocated to the religious tourism centre; and the industrial area is in Bumi Waras, Kedamaian, dan Kedaton; the central business district for regional scale are allocated in Tanjungkarang Pusat dan Enggal. Central business districts for city scale are in Telukbetung Selatan dan Bumi Waras. The centre of urban culture is in Way Halim, and the protected urban forest for ecotourism is in Telukbetung Utara.

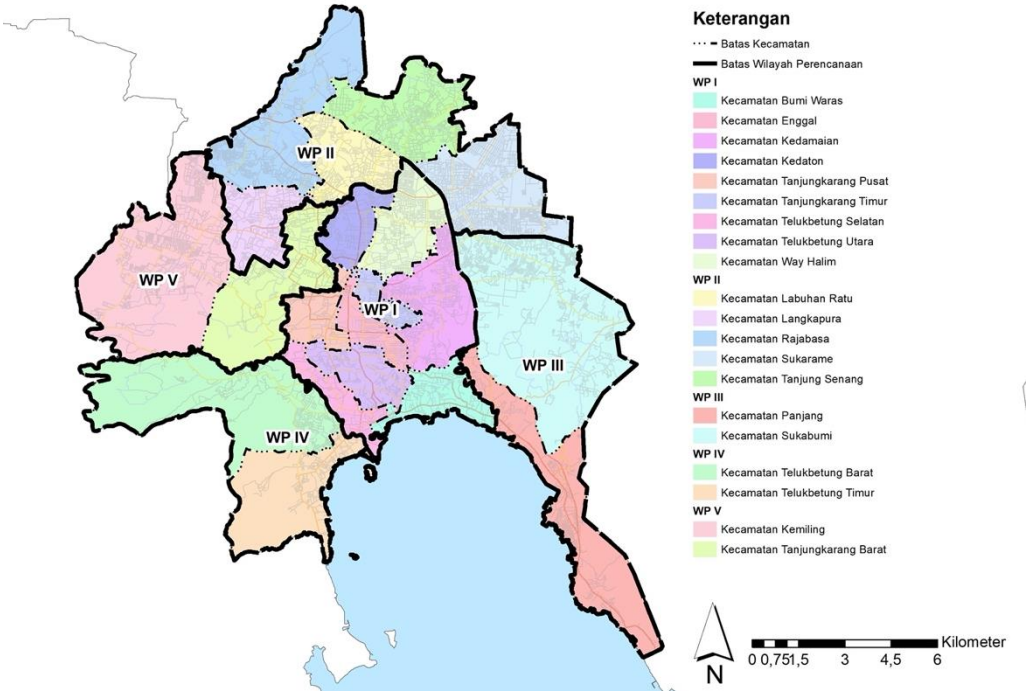

Figure 2. Wilah Perencanaan (WP) in Bandar Lampung

Source: RTRW Kota Bandar Lampung 2021-2041

WP II is allocated to a tertiary educational center in Bandar Lampung, the central transportation hub, urban residential areas, and CBD for local scale and additional function as a Micro, Small, and Medium Enterprise. According to the structural spatial plan, this WP is SPPK and PPL. The SPPK involves Sukarame district, and the PPL consists of Langkapura, Labuan Ratu, and Tanjung Senang district. Furthermore, the land use plan of this WP is intended for urban residential areas, agriculture, and Small industrial areas.

WP III is intended for the leading international harbor area, industrial area, and the additional function as a small urban residential area—in structural and spatial planning; this is a PPK located in Panjang District and PPL in Sukabumi. This WP's dominant land use planning is for the international harbour and industrial areas in Panjang District and small residential areas in Sukabumi.

WP IV is intended as a conservation area, and it has additional functions such as natural and marine tourism, a marine products processing industry, an integrated sanitary landfill area, and a local fishing harbor. In the structural, spatial plan, this WP is aimed as SPPK located in Telukbetung Barat and Telukbetung Timur District, and this WP has an essential infrastructure for sanitary, such as Bakung sanitary landfills area (TPA) on a city scale in Telukbetung Timur District. Meanwhile, the direction of the spatial pattern plan is to protect the Nature Conservation Area (KPA) located in Telukbetung Barat and Telukbetung Timur District; Telukbetung Barat District is purposed as a preservation area for traditional residential; Minapolitan, fishery-based urban development, is located in Telukbetung Timur District, Lempasing and Pasaran Island; industrial area in Telukbetung Timur; Telukbetung Timur and Telukbetung Barat as tourism areas; the traditional village of the Negeri Olok Gading is protected in Telukbetung Barat District; and the City Strategic Area for environmental preservation and a natural tourism area and conservation area are planned in Telukbetung Barat District.

WP V is dominantly allocated for urban green open spaces with additional functions as a center for special education, urban settlements, agritourism (agricultural tourism), ecotourism, and residential and higher education areas. In the spatial structure plan, this WP is directed as SPPK in Kemiling District and PPL in Tanjungkarang Barat District. Meanwhile, in the spatial pattern plan, this WP is intended as a Nature Conservation Area (KPA) in Kemiling District, the Tanjungkarang Barat as an industrial area, Tanjungkarang

Barat and Kemiling as a tourism area and conservation area in Batu Putu village in Kemiling District, Tanjungkarang Barat District as a natural tourism area and conservation area.

3.2 The Parks Availability in Bandar Lampung

The Bandar Lampung City and Regional Spatial Planning Plan (RTRW) for 2021-2041 explains that there are 2 (two) types of parks, namely city parks and sub-district parks, which are part of the urban green open space (GOS). The total urban parks are 295.82 ha, and sub-district parks are 20.56 ha. If you look at the distribution of parks, most of them are spread out in the suburban areas in WP II, III, IV, and V (see Figure 3).

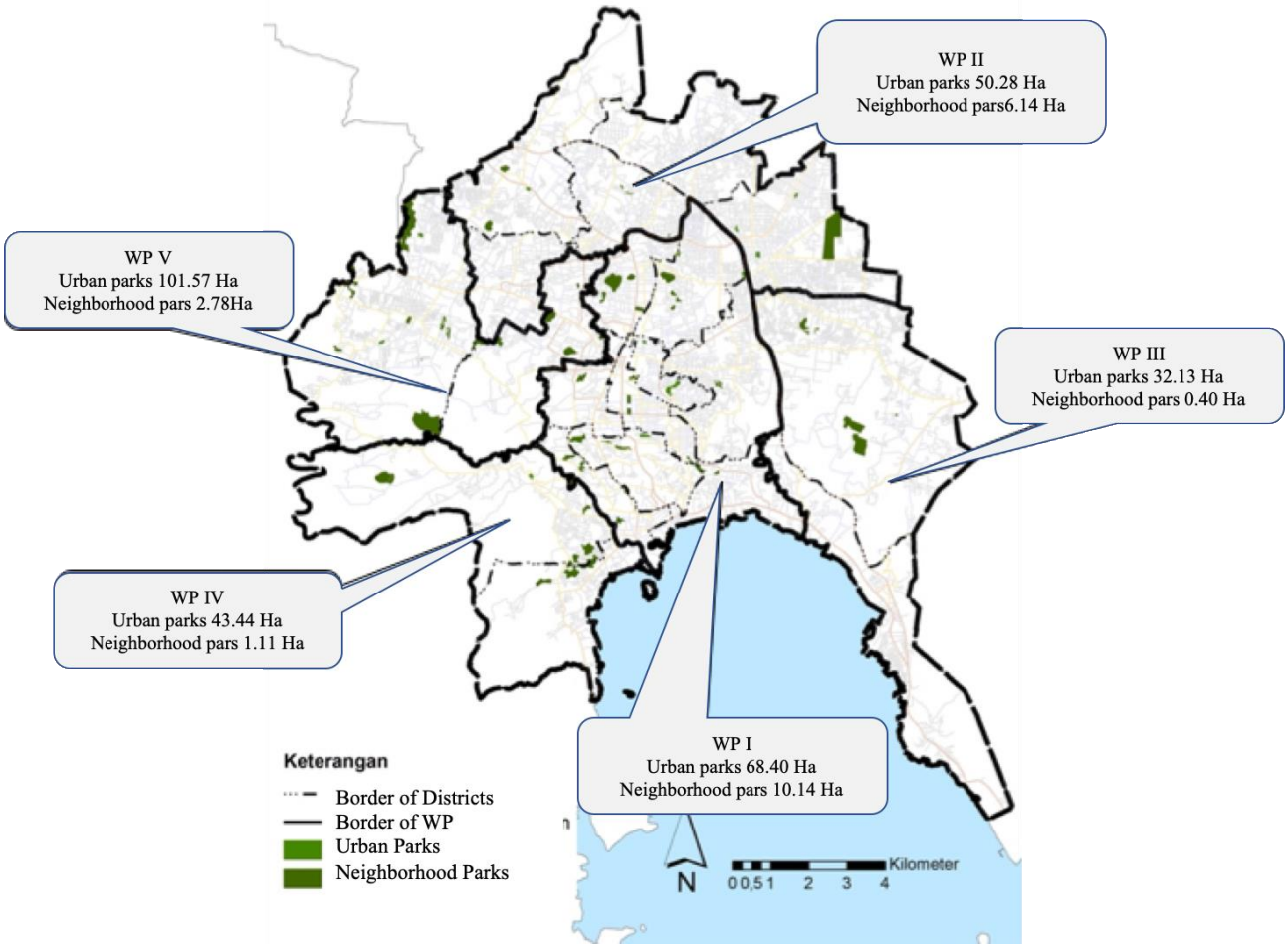

Figure 3 The Availability of Parks in Bandar Lampung

Sumber: RTRW Kota Bandar Lampung 2021-2041

In WP I, the total number of urban parks is approximately 68.40 ha, and neighbourhood parks are 10.14 ha. Tanjungkarang Timur is the only district in WP I that does not have an urban park, and several of the districts that do not have neighborhood parks are in Telukbetung Selatan, Bumi Waras, Enggal, Tanjungkarang Pusat, Kecepatan and Kedaton districts. The total number of urban and neighbourhood parks in WP II is 50.28 ha and 6.14 ha, respectively. The districts that do not have urban parks are Tanjung Senag and Langkapura districts. Meanwhile, the district that does not have a neighborhood park is Langkapura Sub-district. The total number of urban and neighbourhood parks in WP III is 32.13 ha and 0.40 ha, respectively. Panjang District is an area that does not have parks at either the city scale or neighborhood scale. In WP IV, the total area of urban parks and neighbourhood parks is 43.44 ha and 1.11 ha, respectively, whereas East Telukbetung District still needs to be provided with a neighbourhood park. WP IV is an area that has the largest urban park area in Bandar Lampung, with a total area of 101.57 ha. Meanwhile, the neighbourhood park is 20.56 ha. (see table 2).

Tabel 2. The Total Number of Urban Parks and Neighbourhood Parks in Each Wilayah Perencanaan (WP)

Wilayah Perencanaan (WP)	Districts	Urban Park for City or Districts Scale (Ha)	Urban Parks for Neighbourhood scale(Ha)
WP I	Telukbetung Selatan	9,01	0,00
	Bumi Waras	2,48	0,00
	Telukbetung Utara	10,04	2,06
	Enggal	7,12	0,00
	Tanjungkarang Timur	0,00	5,72
	Tanjungkarang Pusat	4,17	0,00
	Kedamaian	2,18	0,00
	Kedaton	22,91	0,10
	Way Halim	10,50	2,25
	Total di WP I	**68,40**	**10,14**
WP II	Sukarame	42,90	3,45
	Tanjung Senang	0,00	0,55
	Rajabasa	6,95	0,79
	Langkapura	0,00	0,00
	Labuhan Ratu	0,42	1,36
	Total di WP II	**50,28**	**6,14**
WP III	Panjang	0,00	0,00
	Sukabumi	32,13	0,40
	Total di WP III	**32,13**	**0,40**
WP IV	Telukbetung Timur	16,84	0,00
	Telukbetung Barat	26,60	1,11
	Total di WP IV	**43,44**	**1,11**
WP V	Kemiling	77,80	2,78
	Tanjungkarang Barat	23,77	0,00
	Total di WP V	**101,57**	**2,78**
Total Semua WP		**295,82**	**20,56**

Source: Modified RTRW, Kota Bandar Lampung 2021-2041

3.3 The Recommended Parks Themes by Goals of Wilayah Perencanaan (WP_ in Bandar Lampung

Developing parks with specific themes, as part of the natural environment and urban facilities, can be integrated with specific urban spatial planning objectives to support realising the planned area development objectives (Wynn, 2008). One of nature's urban parks development gives them themes to obtain maximum benefits in improving the quality of life (Koramaz & Türkoğlu, 2018; Fran Sinatra & Fitra, 2021). Several themes can be applied to increase the livability of a city, such as historical and cultural themes, entertainment, special interests, health, conservation, disaster mitigation, branding, and education.

Historical and cultural themes can be applied to areas with historical events. It can be seen in the provision of historical monuments (Ellis & Schwartz, 2016; Putra, 2016). On the other hand, it can also be applied to integrate people's lifestyles in public spaces (C. Li, 2014)to represent the community's identity and local wisdom (Henderson, 2013). There are several criteria, namely: a. The objectives of WP development are related to the preservation of cultural heritage areas and sites; b. Infrastructure, facilities, and utilities support preserving historical and cultural values; c. Land use includes cultural heritage areas, traditional settlements, and historical sites; and D. Areas can have specific characteristics in the form of strategic regions from social and cultural aspects that preserve local historical and cultural values.

The entertainment theme aims to create public spaces as recreational places (Putra, 2016) and provide various attractions. The criteria: a. The purpose of the WP is to serve as a retail and services area, as well as recreation and tourism; b. Activity centres (PPK/SPPK/PPL) and areas are supported by remarkable infrastructure, facilities, and recreational utilities; c. Dominant land use for retail and service areas and tourism; and D. The area can have specific characteristics in the form of a strategic location from an economic aspect, especially the city centre.

Special interest themes are intended as space and suggestions for exploring people's creativity and hobbies (Putra, 2016). The criteria that can be applied are as follows: a. The objectives of WP development are related to developing people's interests and talents; b. Supported by adequate facilities and infrastructure for developing hobbies and talents; c. Land use can accommodate special interest activities; d. Supported by the existence of strategic areas related to developing hobbies such as sports and arts.

The health theme is associated with a healthy lifestyle (Thompson, 2011) and can be used as a space for physical activity or sports (Yan, 2016) or as a space for meditation (Chiesura, 2004). The criteria include: a. The objectives of WP development are directed at sports activities, health, and nature conservation areas; b. The area is supported by facilities and infrastructure supporting health and sports improvements; c. Land use is aimed at conservation areas that provide an excellent environment to support meditation and healing of certain diseases and are located in residential areas.

The conservation theme can be applied to parks to maintain biodiversity, reduce pollution, and manage water (Sadeghian & Vardanyan, 2013). Park criteria that can be used for the theme of conservation and preservation are: a. WP development's objectives are related to conservation activities; b. Land use is designated as an area that supports conservation activities, especially those directed as protected areas; c. Adequate facilities and infrastructure for conservation; and D. Has a strategic location from the aspect of preserving the natural environment.

The theme of disaster mitigation can be directed at parks that support efforts to reduce the impact of natural disasters. The park can be used as an evacuation route or area (Jeong et al., 2021; Masuda, 2014; Perwira et al., 2019); criteria: a. WP development objectives aim to develop resilient regions to natural disasters; b. Land use can be applied to all areas, especially cultivation areas; c. The area is supported by regional infrastructure, facilities, and utilities in disaster mitigation, such as disaster evacuation sites, evacuation areas, and routes; and D. Located in an area prone to natural disasters.

The theme of disaster mitigation can be directed at parks that support efforts to reduce the impact of natural disasters. The park can be used as an evacuation route or area area (Jeong et al., 2021; Masuda, 2014; Perwira et al., 2019); criteria: a. WP development objectives aim to develop resilient regions to natural disasters; b. Land use can be applied to all areas, especially cultivation areas; c. The area is supported by regional infrastructure, facilities, and utilities in disaster mitigation, such as disaster evacuation sites, evacuation areas, and routes; and D. Located in an area prone to natural disasters.

Urban parks can also create place branding (Braiterman, 2011; F Sinatra, 2017). Branding is closely related to promoting the desired image in a city: a. The aim of developing WP activities related to trade and services, tourism, and industry; b. Land use can be in the form of cultivation areas related to trade and services, tourism, and other land uses associated with promoting the image of a particular place; and D. Located in a strategic location from social and economic aspects, it can have production centers for certain products, tourism areas, and can be in the city center.

Urban parks can also create place branding (Braiterman, 2011; F Sinatra, 2017). Branding is closely related to promoting the desired image in a city: a. The aim of developing WP activities related to trade and services, tourism, and industry; b. Land use can be in the form of cultivation areas related to trade and services, tourism, and other land uses associated with promoting the image of a particular place; and D. Located in a

strategic location from social and economic aspects, it can have production centres for certain products, tourism areas, and can be in the city centre.

The educational theme aims to educate visitors and the surrounding community regarding specific fields (Praganingrum et al., 2017). There are several sub-theme parks related to education, such as technology development and innovation theme parks, education parks related to agriculture, environmental sustainability education themes, and other themes: a. WP development objectives related to educational development in the technology and innovation sector, agriculture, environmental sustainability, and other related activities; b. The area is supported by regional infrastructure, facilities, and utilities that can support the educational theme; c. Academic areas and other land dominate land use uses related to the sub-theme of educational parks; and D. Located in a strategic location for education, technology development, and other areas related to the educational theme that will be developed.

Weighting is used to determine the theme that will be used in a park, with the number 3 (three) indicating a strong relationship between a park and the WP's objectives, spatial structure, land use, and unique characteristics by the theme criteria, weighting 2 (two) is correlated moderate, and 1 (one) is not correlated (see Table 1). A park can have a single or multiple themes depending on the area's characteristics. WP I has more varied theme park recommendations than other WPs due to the complexity and diversity of objectives, infrastructure, facilities and utilities, land use, and regional characteristics. WP II, the themes used focus more on education, health, and entertainment. WP III is more directed towards health and improving services in residential areas as a means of exercise and meditation. WP IV was further developed by adopting the themes of conservation, history and culture, disaster mitigation, and branding. WP V was directed to use the Minapolitan - marine-based urban development - product branding theme to support tourism activities. The table below shows the garden theme instructions that can be used in a WP garden.

Table 3. Recommendation of Park Themes

WP dan Districts	Availability of Urban Parks	Availability of Neighbourhood Parks	Themes								Recommended Themes
			History and culture	Entertainments	Special Interests	Healthy	Conservation	Disaster Mitigation	*Branding*	Education	
WP I											
Telukbetung Selatan	√	-	3	2	1	1	1	3	1	1	Historical and cultural urban parks and tsunami mitigation
Bumi Waras	√	-	3	2	1	1	2	3	1	2	Historical and cultural urban parks and tsunami mitigation
Telukbetung Utara	√	√	3	1	1	1	3	3	1	1	Historical and cultural urban parks and tsunami mitigation
Enggal	√	-	1	3	1	1	1	2	3	1	Branding and entertainment themes it is caused by location in the CBD
Tanjungkarang Timur	-	√	1	1	1	3	1	3	1	1	Tsunami Mitigation Themes and Landslides Evacuation
Tanjungkarang Pusat	√	-	1	3	1	1	1	1	3	1	Branding and entertainment themes it is caused by location in the CBD
Kedamaian	√	-	3	1	1	1	2	1	1	2	Cultural and historical parks are recommended at this location because it is the traditional site of Keratuan Dibalau.
Kedaton	√	√	1	2	1	1	3	1	3	3	Educational theme, conservation, and urban branding
Way Halim	√	√	3	1	3	3	1	2	1	1	Cultural and particular interests such as sports and health

WP dan Districts	Availability of Urban Parks	Availability of Neighbourhood Parks	Themes								Recommended Themes
			History and culture	Entertainments	Special Interests	Healthy	Conservation	Disaster Mitigation	*Branding*	Education	
WP II											
Sukarame	√	√	1	2	1	3	1	1	1	3	Education in technology due to this location close to a technical university. Also, a health theme for the local community
Tanjung Senang	-	√	1	1	1	3	1	1	1	1	The healthy theme is intended for workout and meditation spaces
Rajabasa	√	√	1	3	1	1	1	1	1	3	Entertainment themes are recommended to support the CBD
Langkapura	-	-									
Labuhan Ratu	√	√	1	1	1	3	1	1	1	1	The healthy theme is intended for workout and meditation spaces
WP III											
Panjang	-	-									
Sukabumi	√	√	1	2	1	3	1	1	1	1	The healthy theme is intended for workout and meditation spaces
WP IV											
Telukbetung Timur	√	-					3		3	3	Conservation, a product brand of Minapolitan (marine-based urban development)
Telukbetung Barat	√	√	3					3			Cultural and historical parks are recommended in this location because it has a traditional Negeri Olok Gading settlement. An additional theme is disaster mitigation for evacuation routes and areas.
WP V											
Kemiling	√	√		3				3	3		This is recommended for entertainment themes for SPPK, conservation, and tourism branding for agritourism and ecotourism.
Tanjungkarang Barat	√	-				3		3			The healthy theme is intended for workout and meditation spaces, and the conservation theme supports the conservation zones.

4. CONCLUSION

Several park themes can be applied to create a livable city, such as historical and cultural themes, entertainment, special interests or hobbies, health, conservation, disaster mitigation, branding, and education. The theme is determined based on the WP's objectives, structural plans, patterns, and unique characteristics of the area. From the five WPs in Bandar Lampung City, WP I is recommended to have more diverse themes such as history and culture, entertainment, special interests or hobbies, health, conservation, disaster mitigation, branding, and education. This is because this WP has diversity in spatial planning plans. The theme

of education dominates WP II because this area is a higher education area in Bandar Lampung. As a residential area, WP III is directed towards a health theme to support residents' physical activity and meditation. WP IV is required on history and culture, conservation, disaster mitigation, branding, and education. WP V is directed to adopt the themes of entertainment, health, disaster mitigation, and branding.

This research has yet to comprehensively examine the actual conditions related to WP in Bandar Lampung and involve the existing community. Therefore, further studies are needed to determine park themes that consider the existence of communities as park users. This is aimed at obtaining a more representative theme by community needs to be more sustainable and help improve the community's quality of life. Furthermore, a more in-depth study is needed on the effectiveness, implementation techniques in the design, and evaluation of the directed themes.

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Assessing the Performance of Off-Grid Solar Photovoltaic Power Plants in Supporting Aquaponics Systems

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Keywords

Off-grid; Photovoltaic Solar Power (PLTS); Performance Test; IEC 61724 Standard; Aquaponics.

Abstract

In an aquaponics system, the electricity produced by photovoltaic solar power (PLTS) is stored in batteries and used to power the water pumps. Using natural microorganisms to transform fish waste into plant nutrients, aquaponics is a cultivation method that blends fish and plant cultivation. The aquaponics system helps reduce the amount of trash released into the environment and is beneficial to the environment. The main goal of this study is to evaluate an off-grid PLTS system's functionality as a DC water pump power source in an aquaponics setting. This study's goal is to evaluate how well the PLTS operates when powering the DC water pump that circulates water in the aquaponics system. According to performance tests, the off-grid PLTS generates an average energy of 503.8 Wh, which is enough to power the DC pump for 20 hours a day of water circulation. The water pump uses only 382.6 Wh of electricity each day. With an average solar panel efficiency of 4.97%, an average solar charge controller (SCC) efficiency of 60.51%, and an average pump efficiency of 79.91%, the Off-grid PLTS demonstrates efficiency. With a daily solar irradiation of 7.8 kWh/m2, the average energy loss in the solar panel is 5.29 kWh/kWp, whereas the average energy loss in the system is 0.10 kWh/kWp. All things consider, these results provide insight into how well the Off-grid PLTS functions as a power source for the DC water pump in an aquaponics system.

1. INTRODUCTION

The demand for electricity in Indonesia is continuously rising alongside population growth and technological advancements. Ministry of Energy and Mineral Resources Number 143K/20/MEM/2019 revealed that the ratio of increase in national electricity demand reached 6.9% per year. In September 2022, the growth in electricity demand in Indonesia will be around 7.46% and total sales will reach 201.78 (TWh), compared to September 2021 which reached 187.8 TWh (Prasodjo, 2022). The new renewable energy mix in 2021 has met national electricity needs of 11.5%, while the Ministry of Energy and Mineral Resources (KESDM) estimates that the target can reach 23% of the renewable energy mix in 2025 (KESDM, 2021). Geographically, Indonesia's location on the equator provides various advantages and immense potential for harnessing solar energy (Rachmi et al., 2020),One of the applications of renewable energy is the utilization of solar energy as a power source, known as Solar Photovoltaic Power Plants (PLTS). A Solar Photovoltaic Power Plant (PLTS) is an electricity generation system that converts sunlight into electrical energy through solar cells (Wahyudi et al., 2021). Data from the Ministry of Energy and Mineral Resources states that Indonesia's potential for solar energy is very large, estimated at 4.8 kWh/m2 or the equivalent of 112,000 GWp. However, currently only around 0.05% of this potential has been utilized, with a total capacity of 103,949 megawatts (MW) (Budiyanto *et al*, 2021).

In the context of aquaponics, PLTS is often used as a source of electrical energy to fulfill the system's requirements or as an alternative energy solution. Several studies have successfully implemented Polycrystalline Solar Photovoltaic Power Plants (PLTS) (Hindarti, 2018), and integrated them as power sources to drive water pumps in aquaponic systems. Other research has also focused on designing solar panels

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and water flow control systems that supply nutrients to plants in aquaponic setups (Andansari et al., 2022). Aquaponics is a cultivation system that combines aquaculture (fish cultivation) and hydroponics (plant cultivation using water) by utilizing natural bacteria. In this system, the bacteria are responsible for converting waste and remaining fish food into nutrients that can be absorbed by plants. Thus, aquaponics can be explained as a system where plants and fish grow simultaneously and mutually support each other, as proposed by (Burlian et al., 2021). Utilization of renewable energy is the right solution to replace the use of conventional electricity. Apart from being able to reduce electricity costs, renewable energy also contributes to creating green energy (environmentally friendly energy) and reducing dependence on fossil energy which is increasingly scarce. Good potential in this case is the use of sunlight which lasts for around 7 to 8 hours per day (Krisnandar, 2020).

In general, PLTS (Solar Power Plants) are used as a renewable energy source to meet household electricity needs or as an alternative to other energy sources. In research conducted by (Andansari et al., 2022). Successfully built a PLTS using the polycrystalline type. The PLTS is operated as a power source to drive the air pump. Another research conducted by (Setiawan et al., 2020). Successfully designed a solar power generation system (solar panels) and an air flow control system aimed at supplying nutrients to plants in an aquaponic system. Research conducted by (Andansari et al., 2022) used an AC motor water pump where the circuit used an inverter, whereas in the research I conducted using a DC motor water pump, it was hoped that it would produce a more stable voltage and current. DC motors are direct current motors, as the name suggests, use direct current, used in special applications for high torque ignition or constant acceleration over a wide speed range (Amanda, 2019). Tther research on the use of Plts as an aquaponic energy source in Leuwi Karet Village, Guha Kulon Village, Klapa Nunggal, Bogor Regency (Monika et al., 2022).

In the framework of aquaponics, this study focuses on assessing the effectiveness of an off-grid solar photovoltaic power plant (PLTS) system used as a power source for DC water pumps. Analyzing the PLTS's ability to meet the energy requirements of the aquaponic system's water circulation pumps is the goal of this study. The IEC 61724 standard technique is used to test the PLTS's performance (Setiawan et al., 2020). Since every interested National Committee is represented on each technical committee, the formal decisions or agreements of the IEC on technical matters reflect, as far as practicable, an international consensus of view on the pertinent subjects.

2. METHODS

This test was conducted on the rooftop of the engineering building at Politeknik Negeri Jember using the Standard IEC 61724 Performance Test Method for Photovoltaic Systems. The guidelines for measurement, data exchange, and analysis for photovoltaic (PV) system performance monitoring are outlined in the Photovoltaic System Performance Monitoring - Guidelines for Measurement standard. This standard provides guidelines related to measurement, data exchange, and result analysis within PV systems. It helps ensure that PV systems function as intended and deliver the expected performance during their operational lifespan (El Hacen Jed et al., 2020)

This study was conducted over 10 working days, from June 14, 2023, to June 27, 2023, with data collection taking place for 6 hours at 5-minute intervals. The efficacy of an off-grid photovoltaic system as a power source for the water pump—which circulates water in an aquaponic system—was the main focus of the study. The water pump operated continuously for 24 hours, with a timer setting of 5 hours ON and 1 hour OFF, repeated throughout the 24-hour period.

2.1 Test Design

The deasign is off-grid solar photovoltaic system is oriented northward and consists of components such as a 200 Wp solar panel, a 30 A solar charge controller (SCC), a 12 V 100 Ah battery, a 12V water pump, and an aquaponic setup with dimensions of 100 cm x 52 cm x 102 cm. The aquaponic system features 4 levels of 1.5" pipes and a total of 20 netpots trays. Solar panel meter use to measure solar irradiation, Tang meter, Avometer, Multimeter use to measure voltage and current

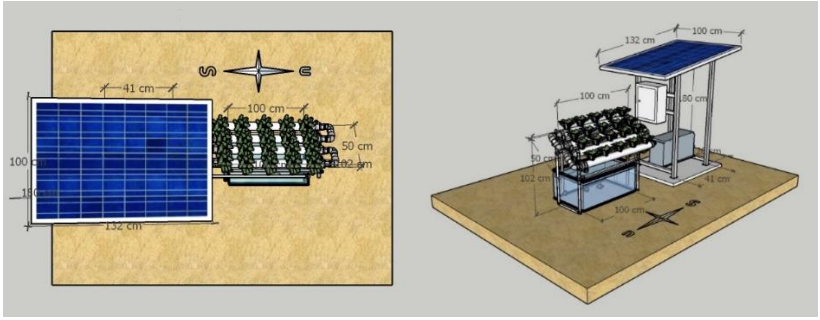
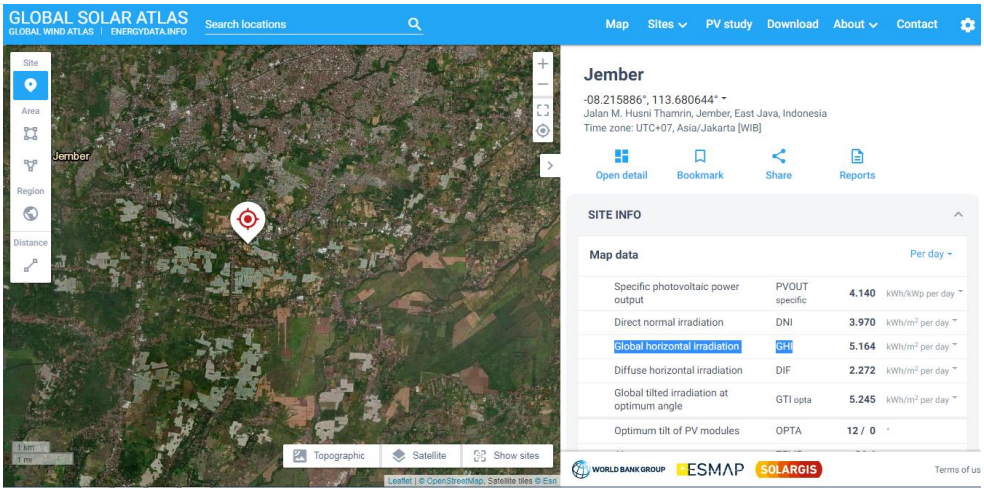


Figure 1. Solar system Design



Fugire 2. Image of GHI Data Site Location on the page https://globalsolaratlas.info/

The location of the research site is in the Politeknik Negeri Jember, Engineering Department Building which is located at coordinates –8.1580697 South Latitude and 113.7228278 East Longitude. The site location is located in a building with a height of 22 m with a frame as shown in Figure 4.1. Based on the image, only 1 off-grid solar module is used. The site location which is at a height of 22 m above a 5-story building allows the solar module to avoid the risk of shading. The solar panels installed in the Jember State Polytechnic Engineering Department Building are oriented north with a tilt angle of 9˚ facing north. In fact, the tilt angle of solar modules in Indonesia generally ranges between 6 – 11˚ according to Indonesia's geographical location, namely at 6˚ N – 11˚ S. This mismatch in tilt angle can cause less than optimal sunlight reception so that the energy produced is also less than optimal.

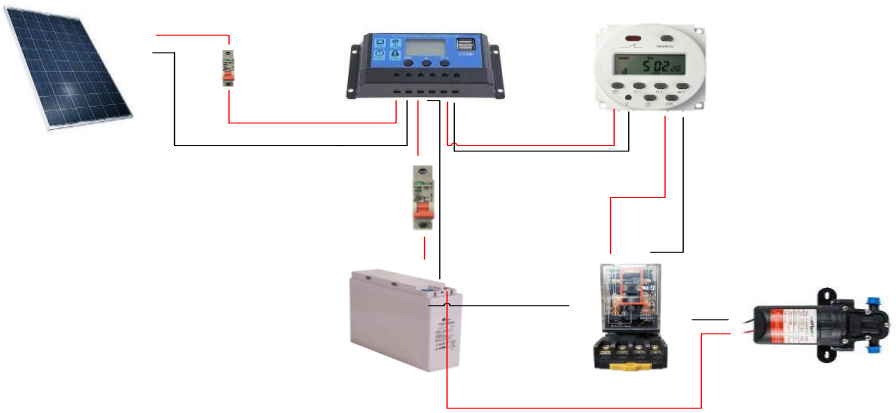


Figure 1.3. Wiring Solar system

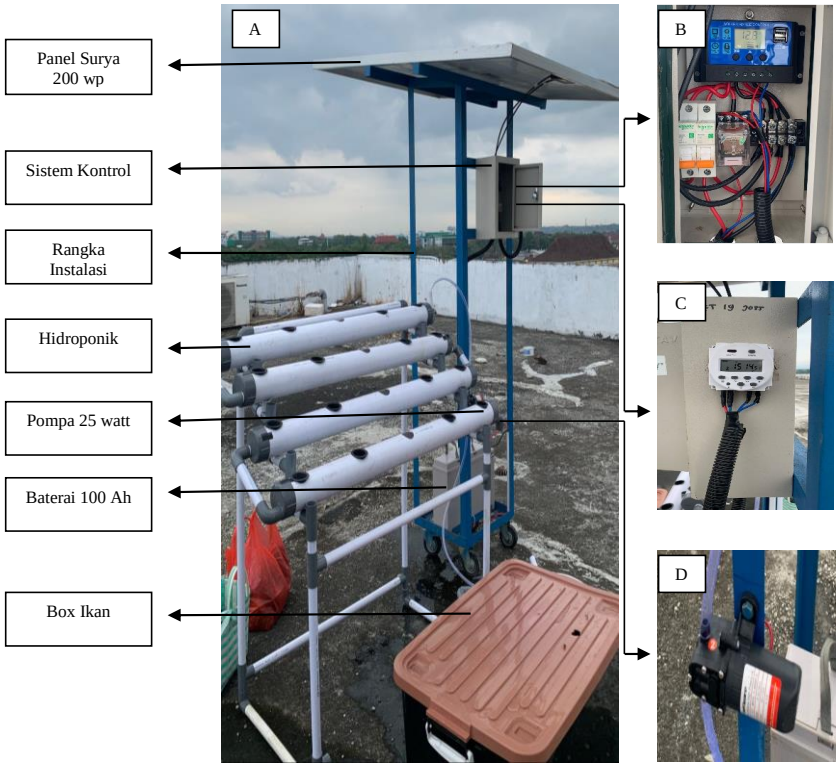


Figure 4. Test Equipment Design

2.2 Performance Evaluation of PV Array

Performance parameters of PV array are established by the international energy agency. They are described in IEC standard 611724. the normalized indicators gather energy output, array yield, final yield, reference yield, module efficiency, inverter efficiency, system efficiency, performance ratio, capacity factor, and energy loss (array capture loss and system loss).

2.2.1. Energy generated by the PV array system (Edc)

The total daily recorded value of DC power output (Edc,d) is given by the following equation:

$$Edc = Pdc\ x\ T \qquad (1)$$

Where :
T is Recording time interval
Pdc is the DC power (result of the current times the voltage). It is given as follows:

$$Pdc = Vdc\ x\ Idc \qquad (2)$$

2.2.2. Reference Yield (Yr)

The ratio of the total solar radiation Ht (kWh/m2) that is absorbed by the PV solar panels' surface to the quantity of reference radiation G0 (1 kW/m2) is known as the reference efficiency (Yr). It shows how many hours there are when the lighting is the same as the reference. The PV system's solar resource is defined by Yr. It is provided by:

$$Yr = \frac{Ht}{Go} \qquad (3)$$

Where :
Yr is Reference yield
Ht is Total irradiance on the array
Go is Reference irradiance

2.2.3. Array Yield (Ya)

The ratio of the total energy generated by the PV rows Edc (kWh) over a specified time period (day, month, or year) to the nominal power P0 (kWc) of the rows under standard conditions (STC: irradiation = 1000 W/m2, ambient temperature = 25 C, and AM 1.5-G reference spectrum) is known as the PV field's efficiency (Ya). The following formula yields the PV field's daily efficiency (Ya,d):

$$Ya = \frac{Edc}{Ppv(rated)} \qquad (4)$$

Where :
*Y*a is Array yield
Edc is Energy output generated by a Solar Panel
Ppv (rated) is total installed module capacity.

2.2.4. Final yield of the PV system or system yield (Yf)

The total energy generated by the PV system Eac (kWh) divided by the installed nominal power P0 (kWp) is the final efficiency (Yf). The number of hours that the PV field should run at its rated power is represented by this value. The following equations yield the daily final efficiency (Yf,d) and the monthly final efficiency (Yf,m):

$$Yf = \frac{Edc}{Ppv(rated)} \qquad (5)$$

Where :
*Y*a is Array yield
Edc is Energy output generated by a Solar Charge Controller
Ppv (rated) is total installed module capacity.

2.2.5. Pv module efficiency (hpv)

The effective energy produced by the module in relation to the available radiation is shown by the module efficiency, also known as energy efficiency (hpv). The following formula yields the daily PV array efficiency:

$$\eta PV = \frac{Edc}{G\ x\ Am}\ x\ 100 \qquad (6)$$

Where :
Edc is daily output energy of the PV array
G is Solar radiation
Am is total solar panel area

2.2.6. Solar Charge Controller Efficiency (ηSCC)

The efficiency of the Solar Charge Controller (SCC) is the ratio of battery power to solar power. The more efficient an SCC is, the better it can regulate the electric current and voltage flowing to or from the battery according to the installed PV system. SCC efficiency can be calculated using the equation

$$\eta SCC = \frac{PAh}{Ppv}\ x\ 100 \qquad (7)$$

Where :
PAh is Battery Output Power
Ppv is Solar Panel Output Power

2.2.7. System Efficiency (ηSys)

The PV generator and inverter module balance of the system affects the efficiency of the photovoltaic system. The following formula can be used to determine the monthly system efficiency:

$$\eta Sys = \eta PV\ x\ \eta SCC \qquad (8)$$

Where :
ηPV is Efficiency of Solar PV
ηSCC is Efficiency of Solar Charge Controller

2.2.8. Standardized performance index (PR)

The entire impact of losses in the energy production of a PV system's rows is shown by the performance ratio, or PR. The PR values show how close a photovoltaic system is to achieving optimal performance in practical operating circumstances. The ratio of the final yield to the reference yield is known as PR. It is a dimensionless number that looks like this:

$$PR = \frac{Yf}{Yr}\ x\ 100 \qquad (9)$$

2.2.9. System losses by conversion (Ls)

The losses of the system by conversion (LS) are due to the SCC conversion losses are defined by the difference between the yield of the PV field Ya and the final yield Yf. The system losses are given as follows:

$$Ls = Yf - Ya \qquad (10)$$

2.2.10. Array capture loss (Lc)

PV array energy loss is the difference between the reference yield (Yr) and the array yield (Ya). Array energy loss is assumed to represent losses due to factors such as solar module temperature, cables, shading, dust, and other factors that can impact the PV array's performance (El Hacen Jed et al., 2020). To calculate PV array energy loss, the equation :

$$Ls = Yr - Ya \qquad (11)$$

2.2.11. Offgrid Solar system Component Specifications

a. Solar Panel

No	Solar Panel	specifications
1	Brand	SUNASIA
2	Model	SP200-36P
3	*Peak Power (Pmax)*	200W
4	*Cell Efficiency*	16.93%
5	*Max. Power volt (Vmp)*	35.6V
6	*Max power current (Imp)*	5.62A
7	*Open Circuit volt (VOC)*	43.6V
8	*Short Circuit Current*	6.05A

b. Solar Charge Controller

No	***Solar Charge Controller***	specifications
1	brand	Mediatech
2	*Rated Voltage*	12V/24V
3	*Rated Current*	30A
4	*Max PV Voltage*	50V
5	*Max PV input POWER*	390W (12V) 780W (24V)

c. Battery

No	Battery	specifications
1	Brand	SHOTO
2	Model	6-XFMJ-100B
3	*Nominal Voltage*	12V
4	*Capacity*	100 Ah @ 10hr to 1.80 V per cell @ 25˚C (77˚F)
5	*Weight*	37.5 kg(82.7 Ibs)
6	*Dimensions*	Length: 520 mm (20.47 in) Width: 110 mm (4.33 in) Height: 254 mm (10.00 in)
7	*Internal Resistance (full charged)*	5.00 mΩ
8	*Short- circuit Current*	2526 A
9	*Recommended Charging Current*	15 A
10	*Capacity Affected by Temperature(C10)*	105% @ 40˚C(104˚F) 85% @ 0˚C(32˚F) 60% @ -20˚C(-4˚F)

d. Aquaponic

No	Aquaponic	Keterangan
1	Dimensions	1,15M x 0,567M x 1,24 M
2	capacity	4
3	Ø Netpot	15 cm
4	Ø Pipa	2 inch
5	Distance between holes	18 cm
6	Dimensions *Container Box*	72,4cm x 46,8cm x 47,3cm
7	capacity	160L

e. Pump

No	Pump	specifications
1	Brands	TaffWare
2	Model	DP-521
3	*Max discharge*	3,5L/Min
4	*Rated Voltage*	12V
5	*Max Current*	2A

f. Rellay

No	*Rellay*	specifications
1	Brand	OMRON
2	Model	MK2P-I
3	*Rate Voltage*	12V
4	*Rated Curent*	10 A
5	*Rated Load*	10 A at 28 VDC

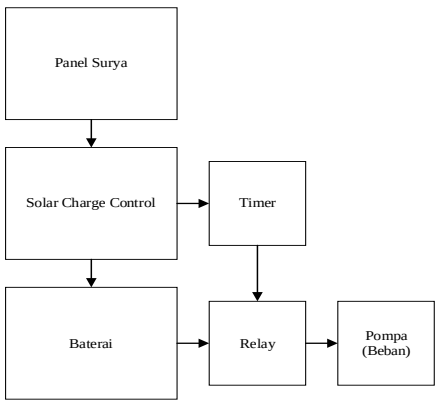


Figure 5. Solar system the circuit schematic in the system starts from the solar panel then goes to the solar charge controller to check the battery then the battery to the relay then turns on the pump.

Calibration of Measuring Instruments and Test Equipment

Calibration of measuring instruments and test equipment is carried out to ensure they are ready to be used for testing and to detect damage. Test equipment or measuring instruments that do not function normally will be repaired by identifying problems or errors with the equipment.

Repair/Settings

Repair/Set Ups are carried out due to problems or malfunctions of either the test equipment or measuring instruments. Repairs carried out can be in the form of replacing spare parts or adjusting and calibrating test equipment and measuring instruments. Repairs require replacement parts such as bolts, nuts, paralon, pipe covers and cables. Tools for repairs that require a screwdriver, pliers, wrench, soldering iron, cable.

Tool Testing

Tool testing is carried out to avoid using tools that do not suit your needs so that the tool can function optimally. It should be noted that the average sun exposure in Indonesia is optimal for 4-5 hours (Huda, 2022). So, to run the pump within 24 hours, several calculations need to be done to meet the electricity needs of the water pump for aquaponics.

Data retrieval

Data collection for testing is required as support for analyzing the specified data. Data collection on system performance is carried out for 10 days starting from 09.00 WIB to 15.00 WIB with a data collection interval of 5 minutes. This is done according to how aquuaponics works and how the equipment works. Determination of collection time is carried out based on the location's Peak Sun Hour which can be measured using the equation

PSH =(Solar Energy on the surface in 1 Day)/(1kW/m^2)

= 5.16 Hours

The average solar irradiation energy on the surface of a location in 1 day is obtained through GHI data via the globalsolaratlas. The data required for the test is solar irradiation, current and output voltage of the solar panel, solar charge controller, battery and pump.

3. RESULTS AND DISCUSSION

3.1 Result Generated by Solar Panel

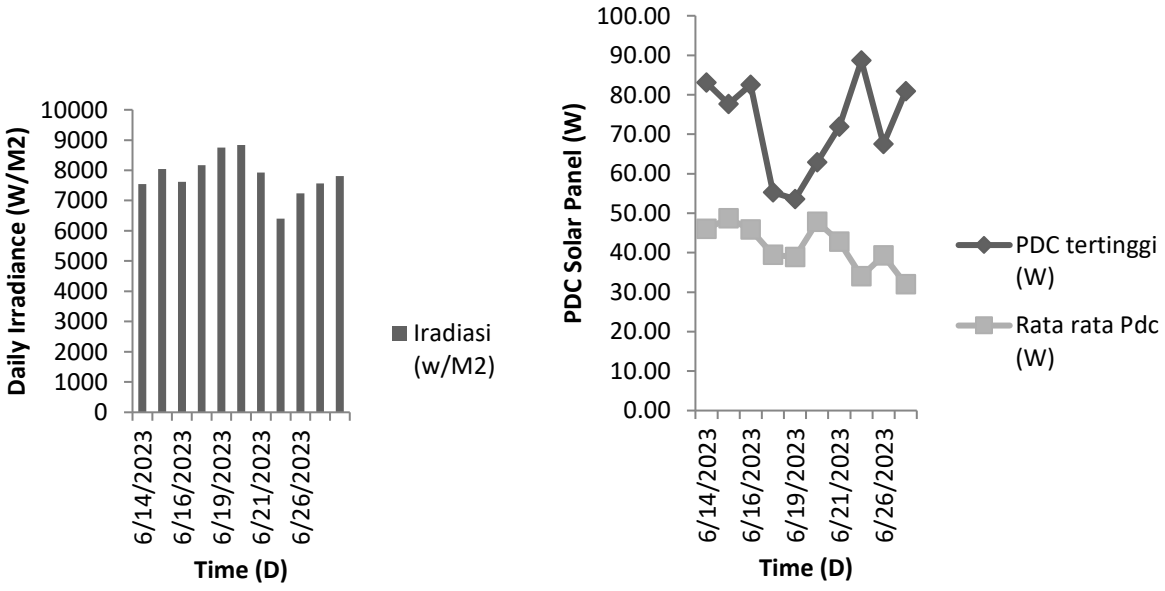
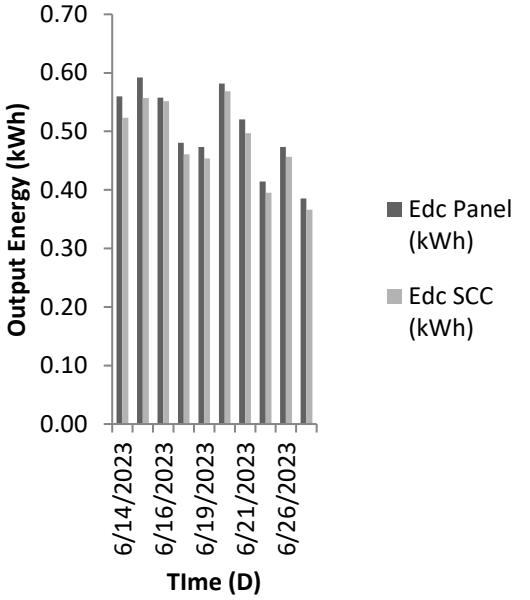


Figure 6. Daily Iradiance

Figure 7. Daily Output Solar PV



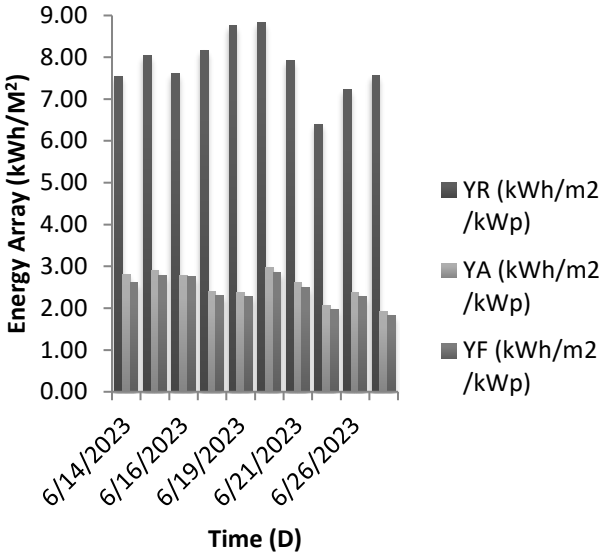
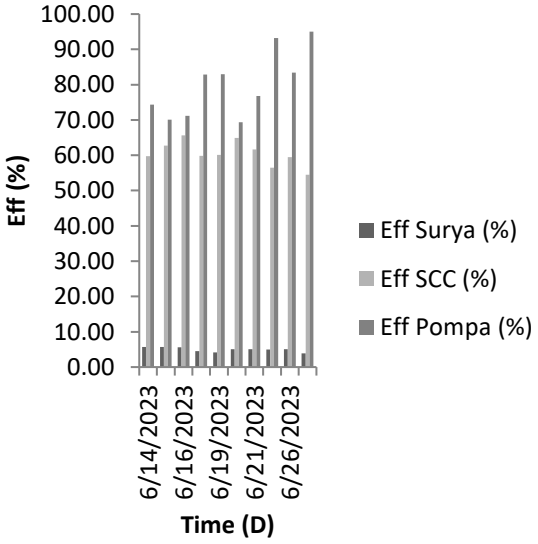


Figure 8. Daily Output Energy of PV and SCC

Figure 9. Daily Output Array Enegy



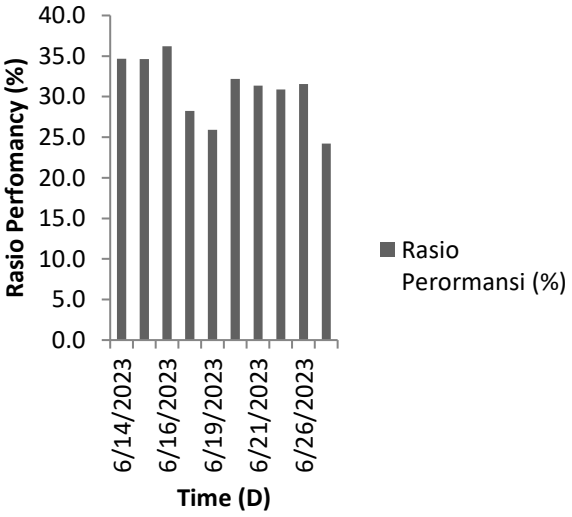


Figure 10. Daily Efficiency

Figure 11. Daily Rasio Performacy

The research was conducted over a period of 10 working days from June 14, 2023, to June 27, 2023, resulting in data on daily irradiance, daily DC power (PDC), daily energy (Edc), component efficiency (Eff), Performance Ratio (PR), array energy loss, and system energy loss. As shown in Figure 2, the highest daily irradiance recorded was 8.4 kW, with an average of 7.8 kW. Daily irradiance is influenced by weather conditions, which in turn affects the variability of daily irradiance levels. (Budiyanto et al., 2021) Figure 3 illustrates Pdc as the daily output from the solar PV, with the highest value recorded at 88.6 W and an average of 46.0 W. The Pdc values are correlated with solar irradiance, where higher solar irradiance results in higher output from the solar PV, indicating a direct proportionality between solar irradiance and solar PV output.

Figure 8. shows the output data generated by solar PV and SCC during the study. The highest value of Edc PV is 0.59 kWh with an average of 0.50 kWh, and the highest value of Edc SCC is 0.57 kWh with an average of 0.48 kWh. The value of Edc PV is influenced by the solar panel's ability to convert irradiance into electrical energy, while the value of Edc SCC is influenced by the SCC's ability to distribute battery charging and supply water pump ignition for circulation, supported by weather conditions that have a high and low impact on Edc values. Figure 5. The value of Yr is the reference yield, which represents the total daily irradiance received in the study. Ya represents the energy obtained from the array field (energy from solar PV), and Yf represents the energy usage from the array field. The highest Yr value is 8.83 kWh/m2/kWp with an average of 7.8 kWh/m2/kWp, the highest Ya value is 2.96 kWh/m2/kWp with an average of 2.52 kWh/m2/kWp, and the highest Yf value is 2.84 kWh/m2/kWp with an average of 2.41 kWh/m2/kWp. This data is influenced by solar irradiance intensity and the output of the solar PV, where the data will increase as the solar PV output increases, indicating a direct correlation.

Figure 9. The data includes three efficiencies: solar PV efficiency, SCC (Solar Charge Controller) efficiency, and pump efficiency. The solar PV efficiency value is 4.97%, which indicates that the ability of the solar PV to convert irradiance into electrical energy is very low compared to the specified value of 16.71%. This is due to several factors where the solar PV cannot reach its peak output, such as irradiance, surface temperature of the solar PV, and air mass (Muna, 2022). The SCC efficiency is 60.51%, indicating that the SCC's ability in battery charging and power supply for the water pump is quite good since the power coming from the solar PV is effectively supplied by the SCC. The pump efficiency of 79.91% indicates that the pump's efficiency in managing the input power and the power output for water circulation is quite optimal. The flow rate of the pump matches the specified value of 3.5 liters per minute, contributing to this high efficiency. This suggests that the pump is performing well in terms of energy conversion and water circulation, making it an effective component in the system

Figure 11. The Off-Grid PV System Performance Ratio is 30.98%, which falls significantly below the standard set by IEC 61724. According to this standard, a PV system is considered viable if the performance ratio is between 70% - 90%. In the study conducted, the PV system has a very low performance ratio, indicating that it does not meet the IEC 61724 standard. This could be attributed to the solar PV's low ability to harvest energy from the reference yield, thereby affecting the performance ratio value.However, it's noteworthy to mention that the SCC and water pump in the circulation system are deemed to be satisfactory and meet the standards, indicating that these components are performing adequately despite the PV system's shortcomings.

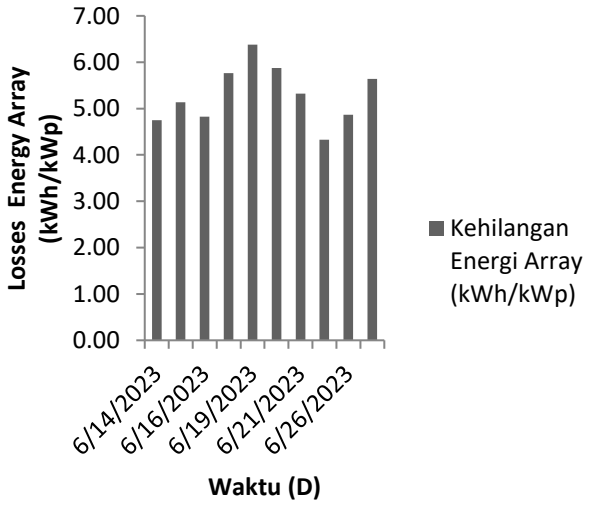


Figure 12. Losses Energy Array

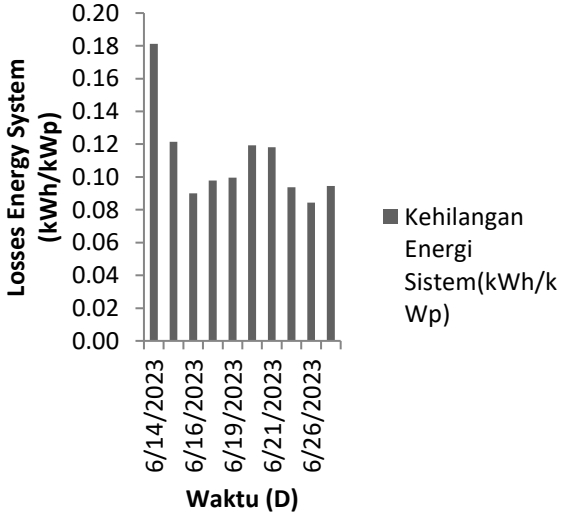


Figure 13. Losses Energy System

Figure 12. The value of energy loss in the array is 5.29 kWhkWp, which represents the energy that is wasted or not utilized by the solar PV due to its limited capacity or capability. This value is influenced by the

efficiency of the solar PV. The value of "Losses energy array" refers to the potential of the solar PV, thus affecting the performance ratio value since the low capability of the solar PV results in a low performance ratio value. Figure 13. The system's energy loss value is 0.10 kWh/kWp, and this value is likely influenced by losses in the cables, leading to a decrease in the energy obtained by the solar PV. The greater the resistance in the cables, the larger the losses.

4. CONCLUSION

4.1. Conclusion

The average energy generated by the Off-Grid PV system is 503.8 Wh, which is sufficient to support the operation of the DC water pump for 20 hours a day, with a total energy requirement of only 382.6 Wh. The Off-Grid PV system has an average efficiency value for the 200Wp Polycrystalline PV panel of 4.97%, an SCC efficiency of 60.51%, and an output power efficiency of the pump at 79.91%. The performance of the SCC and pump in terms of efficiency is good, but the efficiency of the solar PV panel remains low. The efficiency of the PV panel is highly influenced by its ability to convert irradiance.The Performance Ratio (PR) is 30.98%, which is very low due to the limited ability of the PV panel to convert solar irradiance. The Off-Grid PV system, based on this PR value, is considered not viable in terms of the solar panel's ability to convert solar irradiance. However, the system's viability is successful in supporting the water pump for aquaponic circulation.

4.2. Recomendation

Solar panels, utilizing more efficient solar panels, is recommended due to the SUNASIA 200Wp solar panel's efficiency being only 4.97%. The daily energy surplus of 97.1 Wh can be utilized by adding 4 units of 10 Watt ultraviolet lamps to enhance the growth of water spinach plants. An alternative recommendation is to reduce battery capacity by using a 12v 65Ah battery to support cost savings during component replacements. Creating a water reservoir tank for aquaponic circulation when the solar panel and battery are unable to supply power to the pump is necessary because aquaponic growing media must remain moist or have water circulation.

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