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PREFACE

The Journal of Emerging Supply Chain, Clean Energy and Process Engineering (JESCEE) is a journal of the Faculty of Industrial Technology, Universitas Pertamina that promotes communication between researchers, dissemination of research results, development of academic culture, and development of new ideas in the fields of mechanical, electrical, chemical, and logistics. This journal's volume 2, issue no. 1 has captivated the attention of numerous researchers interested in publishing their work.

On behalf of the Editor-in-Chief, I would like to thank the people who support this journal, especially the Dean of the Faculty of Industrial Technology Industrial for their direct and indirect assistance, the editors who work well and are dedicated, the reviewers who provide suggestions and constructive criticism for each paper collected, and the authors who entrust JESCEE with the publication of their research results.

We hope that this publication will continue to expand and present the most recent information in the fields of mechanical, electrical, chemical, and logistical. We also welcome collaboration from parties who are pleased with the existence of this journal and wish for its further growth.

Jakarta, April 2023
Editor-in-Chief

Dr. Eng. Muhammad Abdillah

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IMPLEMENTATION OF LEAN MANUFACTURING TO IDENTIFY AND MINIMIZE WASTE IN THE WELDING FRAMEBODY DEPARTMENT OF PT XYZ

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Abstract
PT XYZ is a transportation equipment manufacturing company that must always maintain that the products it produces can achieve sales targets. However, in carrying out the production process, PT XYZ often experiences shortages in the production process, one of which is due to problems in the welding frame body department. thus the objectives of this research are determine the flow of the production process in the welding frame body department, then analyze the waste that occurs in the body parts of the welding frame. This frame body welding department has a production process flow starting from St. Rear Frame 1 to St. Rear Frame 4, then St. Front Frame 1 to St. Front Frame 3, after that St. General Assy, Permanent Robot/Robot Handling, Fine Boring, Manual 1 and Manual 2, and ends in Tapping and Numbering. Based on the flow of the production process, it was found that St. Rear Frame 3 is the most problematic with a percentage of 21%. By using the DMAIC method, in the Define stage it was found that the most common problems occurred in St. Rear Frame 3 is a torn pipe lower jig B with a percentage of 6%. At the Define stage, it is also known that the root cause of the problem is the lack of accuracy from the operator who may be sleepy at work due to lack of rest, or even chatting which results in setting teaching too far because it is more dominant to the lower, not to the iron connection between the lower and the sub frame. Then at the Measure stage the target is to reduce 6% of the problems to 4%. Furthermore, at the Analyze stage, an analysis is carried out if the potential problem occurs then what next steps will be conducted which is useful for minimizing waste. At the Improve and Control stage, namely the steps taken to minimize the problem or waste (preventive actions) and what steps or ways to do if the problem or waste occurs again (contingent actions).

Keywords:
DMAIC; lean manufacturing; waste

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1. Introduction

Currently, many companies are competing to maintain the company in the development of the business world which is increasingly increasing rapidly. A manufacturing company is a company that must always increase its production results. This production must always be improved in terms of service to consumers and the quality of the product itself. Manufacturing companies must provide a guarantee of both service and quality to consumers so that companies can compete with other companies in taking the interest of their consumers. This can also prove that this company's product is in proper condition and of high quality.

Manufacturing is a series of production activities that transform a raw material into a new item with a higher value. Activities will be said to have added value if there are additions to several inputs to activities that will provide added value to the product according to consumer desires [1]. There are two types of flow in the manufacturing process, namely the flow of materials/semi-finished goods and the flow of information. The flow of materials/semi-finished goods occurs when moving materials from one work station another. As long as the material flow takes place, of course, there are several factors that affect production results. One factor that is quite influential is waste or waste. Waste or waste is a work activity that does not add value in the process of making, or producing goods [2].

Indonesia has contributed 20.27% to the largest manufacturing industry in ASEAN on a national scale economy. Indonesia has been able to shift the role from commodity-based to manufacture-based. The manufacturing industry is considered more productive so that the value of raw materials can be increased, the workforce is expanded, and it contributes a lot to taxes and customs. Manufacturing value added places the top position for the manufacturing industry among ASEAN countries with an achievement of 4.5%.

Indonesia is ranked 9th out of all countries in the world when viewed globally. The automotive manufacturing industry has made a major contribution to the national economy (as shown by Figure 1). Based on UN data, the transportation equipment industry contributes as much as 1.35% to the national GDP in 2020. It has been more than 50 years that the automotive industry in Indonesia has developed, with the issuance of a Joint Decree between the ministers of industry and the minister of trade in 1969 regarding how to import vehicles. motor vehicles that are Completely Built Up (CBU) and Completely Knock Down (CKD) imported by the Brand Holder Sole Agent (ATPM) and also require ATPM to build a domestic motor vehicle assembly industry. With this policy, the local industry began to grow in the field of motorized equipment and components such as making jigs & fixtures, welding, trimming, and others. The growth of the transportation equipment industry in 2016 increased by 4.52% but fell again until 2019 by 3.43% due to the Covid-19 pandemic. The problem faced by the company is due to the Covid-19 pandemic, namely the depleting supply of raw materials and parts. Apart from that, the performance of the company is also needed for the automotive industry which is very useful for the Indonesian economy [3]. In full, the contribution of each industry can be seen in Fig. 1 below.

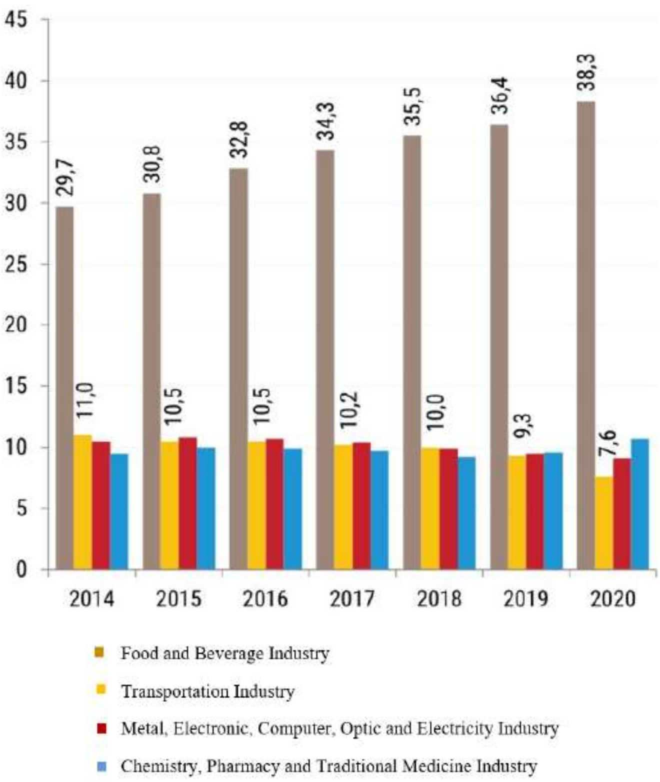

Figure 1. The biggest contribution of the industrial sector

PT XYZ is a transportation equipment manufacturing company that must always maintain that the products it produces can reach sales targets. However, in carrying out its production process, PT XYZ often experiences a shortage in the production process, one of which is due to a problem in the body frame welding. The production time continues and work station the assembly supply from the welding frame body department. This is a waste that if left unchecked will result in a product experiencing a shortage.

Good quality is very important so we need a method that can control problems and improve product quality in an effective and efficient manner. In the welding frame body, there is a logistics process namely moving parts from one work station to another work station. Therefore, by using Lean Manufacturing it is hoped that this will minimize the waste that occurs in the welding frame body and make the logistics process flow in the welding frame body run smoothly [4], [5]. Lean Manufacturing is a useful approach in identifying and minimizing waste through improvement activities, thus the objectives of this research are determine the flow of the production process in the welding frame body department, then analyze the waste that occurs in the body parts of the welding frame.

2. Experimental Method

A. Literature Study

A literature study is a series of research activities carried out to collect information from books, scientific journals, previous research, magazines, etc. in the future will assist researchers in compiling research reports. Therefore, this literature study is useful for researchers in solving problems in this practical work research. The problem will be solved because there are references from several sources related to the problem that the author raises.

B. Field Observations

Field observations are a series of research activities held directly at the location where the research takes place. This field observation is useful to make it easier for writers to retrieve actual data by looking at real conditions. The author made field observations at the welding frame body department in line 3.

C. Interviews

Interviews are a series of research activities conducted by researchers by asking questions to informants. Questions in the form of topics related to the research that the author raised. By asking questions to the informants, information will be obtained which will later be useful for the smooth running of research that has not been obtained from previous methods.

D. Processing Data

Processing Data is carried out using the DMAIC method (Define, Measure, Analyze, Improve, Control) [6]. The Define stage is the initial stage used to find the source of problems that exist at PT XYZ by using the SIPOC Diagram tools [7], the production process flow in the welding frame body department, Pie Charts, Pareto Diagrams, Fishbone Diagrams [8]. Furthermore, the Measure stage is the second stage which is carried out to measure the level of waste from the production process and the targets made to reduce this waste can be reduced. Then the third stage is *a*nalyze which is the stage in finding a solution that will be applied later and seeing whether the solution is valid or invalid so that improvement can be held. The next step is Improve and Control, this step is the implementation stage of the solutions conducted to deal with existing problems and make improvements if the impact of these problems cannot be overcome and how to prevent these problems from recurring, this stage can use KTPPA tools (Kepner Tregoe Potential Problem Analysis). In detail, the measurement methods in this study are presented in Fig. 2 below.

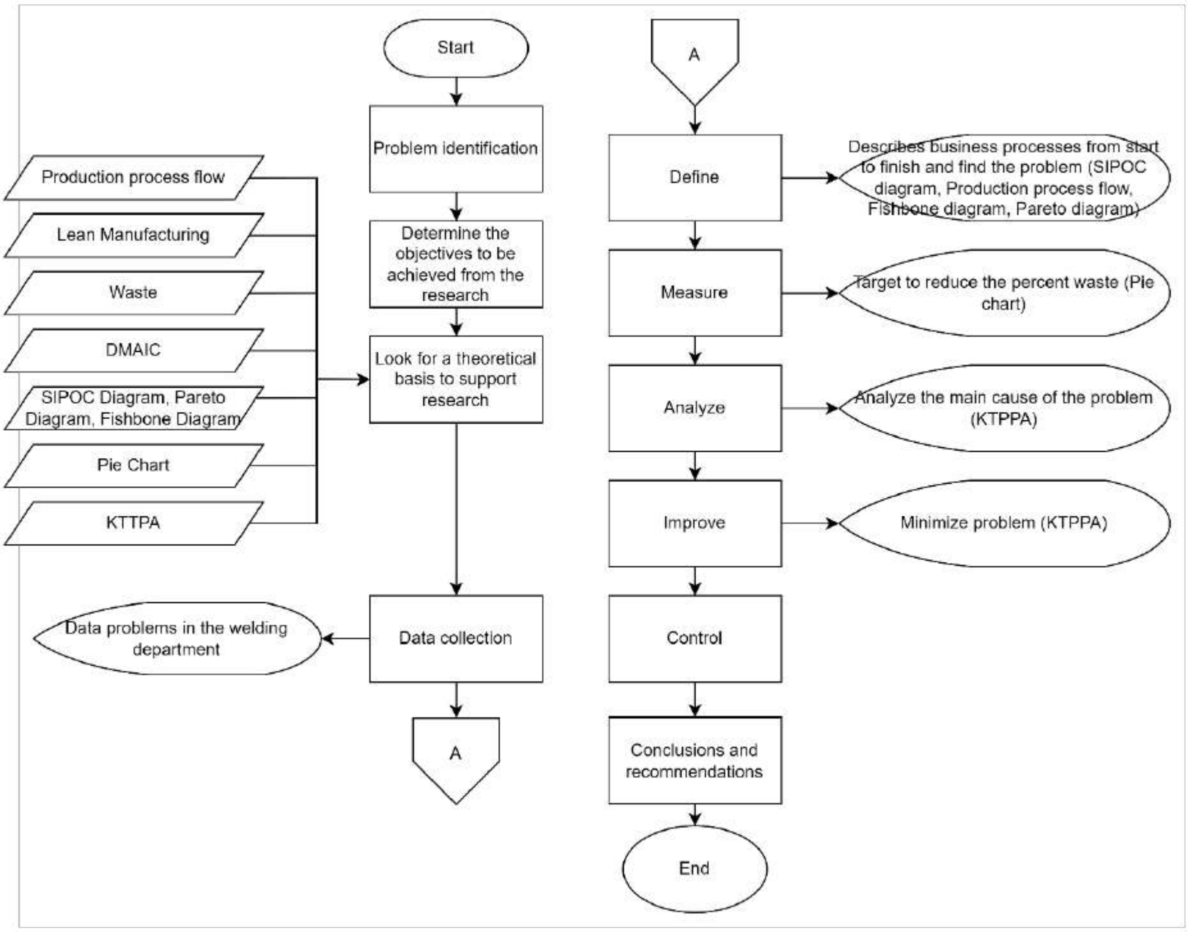

Figure 2. Research method flowchart

3. Result and Discussion

Results

Processing Data is conducted using the DMAIC method to overcome and solve problems that exist in the welding frame body department. The stages in DMAIC are started with the Define (Problem Identification) stage, Measure (Measurement), Analyze (Problem Analysis), Improve (Improvement) and the last is Control (Control).

A. Define

The Define is held to determine several factors that cause problems in the welding department starting from the goods coming from the supplier until the goods are sent to the assembly unit. By using the SIPOC diagram, you can see the business process from start to finish in the welding department. Fig. 3 is a SIPOC diagram in the welding department.

Supplier	*Input*	*Process*	*Output*	*Customer*
- WAHO 1 - LC - *Press*	- *Front dan Rear Frame* - *Pipe R & L* - *Sub Frame* - *Plate Pivot Unit* - *Engine Hanger R & L* - *Stay Upper Cover*	- *Welding*	- *Welding Frame Body*	- *Painting Steel*

Figure 3. Welding frame body SIPOC diagram

The process of automation in welding using a welding robot is used to make work more productive, effective, and efficient. Apart from that, this is an innovation made by the company in its production process. A welding section is a place for welding motor parts, one of which is the frame body.

The process that occurs is the process of welding or welding which is carried out at the Rear Frame, Front Frame, General Assy, Permanent Robot, Fine Boring, Manual, Tapping, and Numbering stations. For welding from the Rear Frame station to Fine Boring using a robot, but for Manual, Tapping, and Numbering still use manpower to complete the welding deficiencies caused by the previous robot. Fig. 4 is the flow of the production process from the welding frame body.

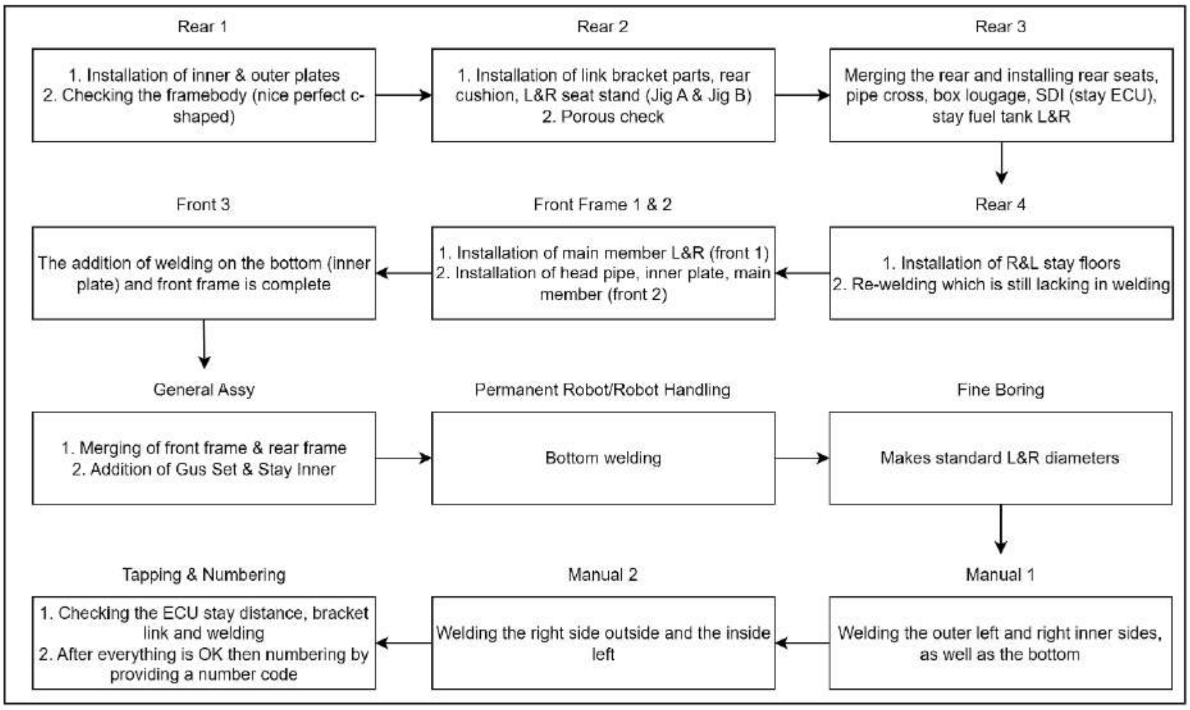

Figure 4. Production process flow of welding frame body

St. Rear Frame 3 is the work station that has the most frequent problems with a percentage of 21%. At this station the parts in separate conditions between L and R are then combined at the rear. In this process, Seat Rear, Pipe Cross, Box Laugage, Stay ECU, Stay Fuel Tank (L&R) are installed.

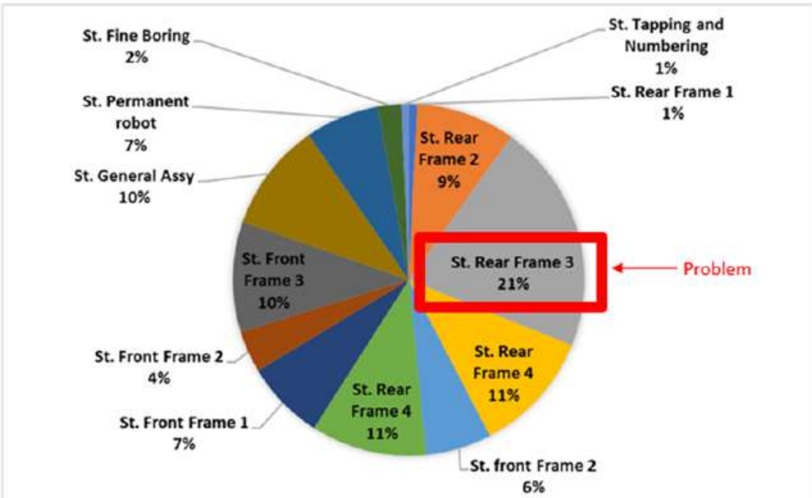

Figure 5. Problem diagram at each work station

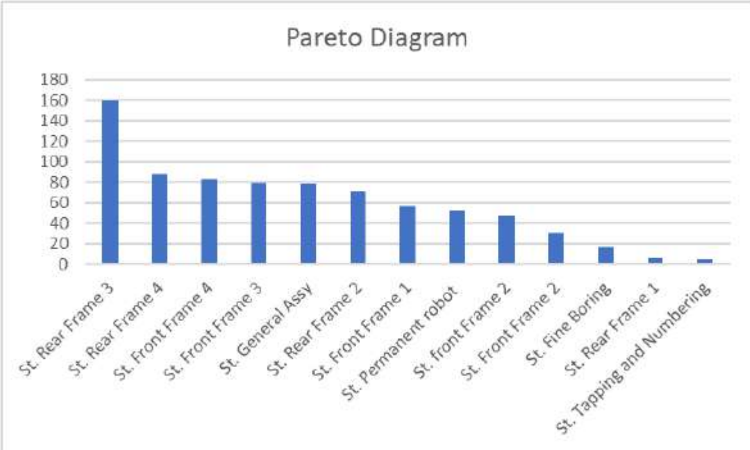

Figure 6. Pareto Diagram

After it became known that St. Rear Frame 3 is the work station that contributes the most problems as can be seen in Fig. 5 and Fig. 6. Rear Frame 3. The most common problem is the welding of the pipe lower jig B with the number of incidents being 10 times in the period January 2021- May 2022 and can be seen in Fig. 7.

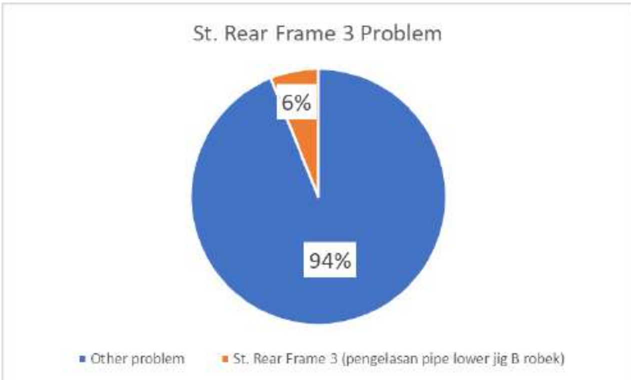

Figure 7. Percentage of Broken Pipe Lower Jig B Problems

Pipe lower jig B problems accounted for as much as 6% of the total problems that exist in St. Rear Frame 3 as shown in Fig. 8. This is a fairly big problem, and the root cause must be sought why this torn pipe lower jig B can occur.

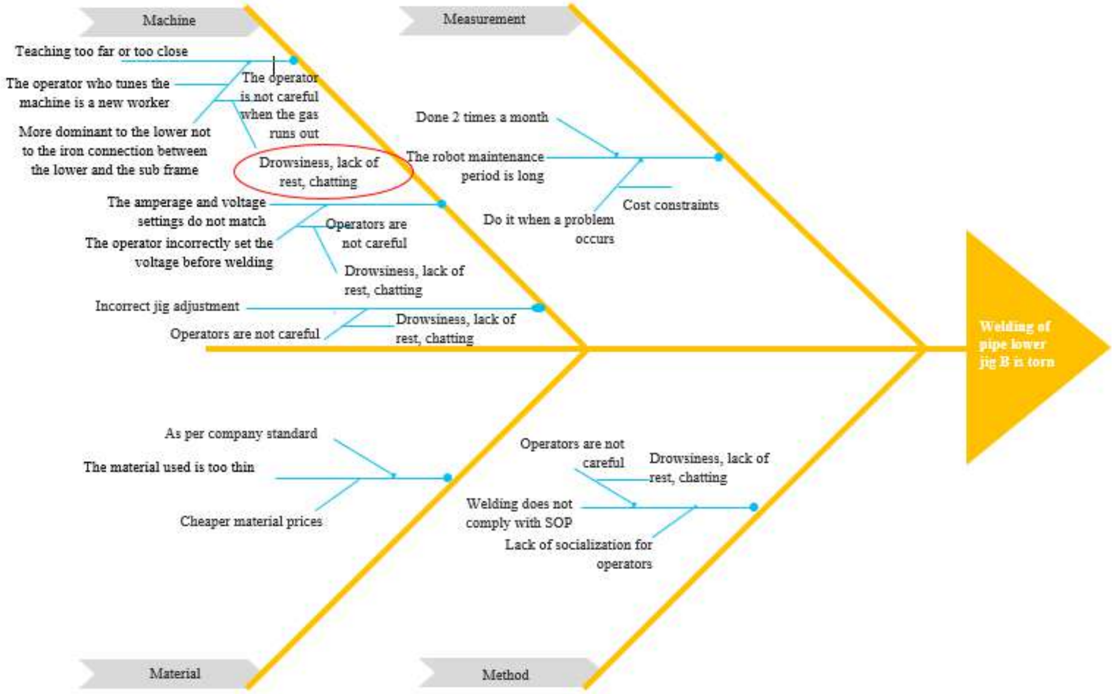

Figure 8. Fishbone Diagram

Once it is known that welding pipe lower jig B is a problem that often occurs, using the Fishbone Diagram it can be identified the root of the problem that occurs and can be seen in Fig. 9. Torn welding on the pipe lower is a waste type of defect because the frame body is torn due to teaching which is too far and is more dominant to the lower not to the iron connection between the lower and the sub-frame because the operator is not careful when the gas runs out due to drowsiness, lack of rest, chatting. This causes motion waste and has implications for time waste. Motion waste and time waste are some of the causes of waste referring to lean manufacturing [5], [9], [10].

B. Measure

From the known problems, the target is to minimize the problem in welding pipe lower jig B from 6% to 4%, which means minimizing the frequency of occurrence of 10 times to 6 times the maximum can occur as can be seen in Fig. 10.

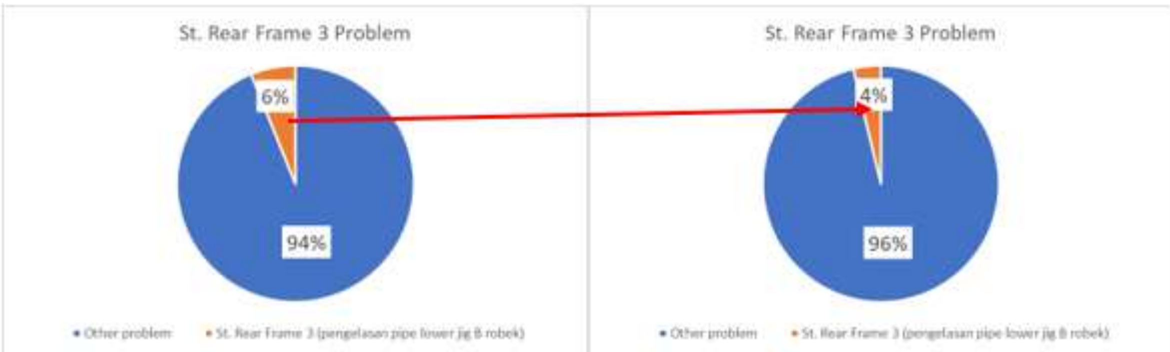

Figure 7. Improvement Targets

C. Analyze

Table 1. KTPPA table

Factor	Potential Problem	Possible Causes	Preventive Actions	Contingent Actions	Pros and Lack	Judge -ment
Machine	Teaching too far or too close	More dominant to the lower not to the iron connection between the lower and the sub frame	Re-teaching the robot in the lower section	Check the jig or repair the weld manually by inserting the used nozzle into the lower pipe hole	Pros: Welding will be perfect Lack: -	Valid
		The operator who tunes the machine is a new worker	Conduct training for the operator	Reprimand the operator for implementing and carrying out the SOP that has been set by the company	Pros: Operators will understand more about the SOPs set by the company Lack: -	Invalid
		The operator is not careful in checking the gas indicator because he is sleepy, lacks rest or talks	Reprimand the operator for implementing and carrying out the SOP that has been provided by the company and routinely checking the gas indicator and immediately filling the gas until it is full again if the gas runs out	The company provides SP for operators	Pros: Operators become more serious and concentrate on doing work Lack: -	Valid
	The amperage and voltage settings do not match	The operator incorrectly set the voltage before welding	Check the voltage and voltage before welding whether it is correct or not	Change the voltage and voltage until it is suitable	Pros: Welding will be perfect Lack: takes a little time to change the voltage to normal	Invalid

Factor	Potential Problem	Possible Causes	Preventive Actions	Contingent Actions	Pros and Lack	Judge -ment
Machine	The amperage and voltage settings do not match	Operators are not careful because they are sleepy, lack of rest or chatting	Reprimand operators for implementing and carrying out SOPs that have been provided by the company	The company provides SP for the operator and changes the voltage back to normal	Pros: Operators become more serious and concentrate on doing work Lack: wasting time to change the voltage to normal again	Invali d
	Incorrect jig adjustment	Operators are not careful because they are sleepy, lack of rest or chatting	Reprimand the operator for implementing and carrying out the SOP that has been provided by the company and always checking the jig on the machine before using the machine	Do a reset and the company can provide SP for the operator if it happens repeatedly	Pros: Operators become more serious and concentrate on doing work Lack: time consuming to do jig reset	Invali d
Measure-ment	The robot maintenance period is long	Done twice a month	Perform maintenance three times a month	Carry out maintenanc e as soon as possible for the robot so that the robot can return to its prime and the robot is not constrained by anything	Pros: Robots rarely experience errors Lack: Requires a higher cost	Invali d

Factor	Potential Problem	Possible Causes	Preventive Actions	Contingent Actions	Pros and Lack	Judge-ment
Measure-ment	The robot maintena nce period is long	Done only when a problem occurs due to cost constraints	Doing robot maintenance not only when there is a problem but also doing regular checks on the robot	Carry out maintenance as soon as possible for the robot so that the robot can return to its prime and the robot is not constrained by anything	Pros: Robots rarely experience errors Lack: Requires a higher cost	Invalid
Material	The material used is too thin	Follow company standards	Operators must be careful in welding because the material is too thin	Doing repairs to cover the torn welding results due to thin material	Pros: Welding is not torn Lack: -	Invalid
		Cheaper material prices	Replace it with a material that is thicker than the previous material at the same price	Make changes to new standards to change materials	Pros: The material used is stronger Lack: higher price	Invalid
Method	Welding is not in accordan ce with the SOP	Operators are not careful because they are sleepy, lack of rest or chatting	Reprimand the operator for implementing and carrying out the SOP that has been provided by the company and always checking the jig on the machine before using the machine	The company can provide SP for operators if it occurs repeatedly	Pros: Operators become more serious and concentrate on doing work Lack: -	Invalid

Factor	Potential Problem	Possible Causes	Preventive Actions	Contingent Actions	Pros and Lack	Judge-ment
Method	Welding is not in accordance with the SOP	Lack of socialization for operators	Conduct training for the operator	Re-socialize the SOP that the company has made for operators	Pros: Operators have been equipped with new SOPs so that welding work will be in accordance with SOPs Lack: The company will spend money, time and energy to re-socialize.	Invalid

Table 1 above is the analyze stage where this stage is the stage in finding a solution that will be applied later and seeing whether the solution is valid or invalid so that improvement can be conducted. Based on Table 1. above, the broken pipe lower jig B problem is caused because the teaching is too far or too close. Teaching that is too far or too close can be caused because it is more dominant to the lower not to the iron connection between the lower and the sub-frame. The operator who tunes the machine is a new worker and also the operator is not careful in checking the gas indicator due to sleepiness, lack of rest or chatting. With the handling that can be done, it is hoped that waste can be reduced and the company can apply the handling suggestions listed in Table 1.

D. Improve and Control

Improve and control stage the improve and control stage is the implementation stage of the solution held to deal with existing problems and make improvements if the impact of these problems cannot be resolved and how to prevent these problems from recurring, at this stage you can use KTPPA (Kepner Tregoe Potential Problem Analysis) tools.

Seeing that the operator's lack of accuracy in checking the gas indicator causes the teaching to change (too far or too close) is the root of the problem. Even though other potential problems that occur are not the main problem, they can also cause these problems to occur. With actions like Table 2. it can reduce waste from 6% to 4%. This is a very good thing because it can improve performance and maximize existing processes in the production process in the welding frame body department, especially at St. Rear Frame 3. The following is Table 2 which can be seen as follows.

Table 2. Improve and control KTPPA table

Factor	Potential Problem	Possible Causes	Preventive Actions	Contingent Actions	Pros and Lack
Machine	Teaching too far or too close	More dominant to the lower not to the iron connection between the lower and the sub frame	Re-teaching the robot in the lower section	Check the jig or repair the weld manually by inserting the used nozzle into the lower pipe hole	Pros: Welding will be perfect Lack: -
		The operator who tunes the machine is a new worker	Conduct training for the operator	Reprimand the operator for implementing and carrying out the SOP that has been set by the company	Pros: Operators will understand more about the SOPs set by the company Lack: -
		The operator is not careful in checking the gas indicator because he is sleepy, lacks rest or talks	Reprimand the operator for implementing and carrying out the SOP that has been provided by the company and routinely checking the gas indicator and immediately filling the gas until it is full again if the gas runs out	The company provides SP for operators	Pros: Operators become more serious and concentrate on doing work Lack: -
	The amperage and voltage settings do not match	The operator incorrectly set the voltage before welding	Check the voltage and voltage before welding whether it is correct or not	Change the voltage and voltage until it is suitable	Pros: Welding will be perfect Lack: takes a little time to change the voltage to normal

Factor	Potential Problem	Possible Causes	Preventive Actions	Contingent Actions	Pros and Lack
Measure-ment	The robot maintenance period is long	Done only when a problem occurs due to cost constraints	Doing robot maintenance not only when there is a problem but also doing regular checks on the robot	Carry out maintenance as soon as possible for the robot so that the robot can return to its prime and the robot is not constrained by anything	Pros: Robots rarely experience errors Lack: Requires a higher cost
Material	The material used is too thin	Follow company standards	Operators must be careful in welding because the material is too thin	Doing repairs to cover the torn welding results due to thin material	Pros: Welding is not torn Lack: -
		Cheaper material prices	Replace it with a material that is thicker than the previous material at the same price	Make changes to new standards to change materials	Pros: The material used is stronger Lack: higher price
Method	Welding is not in accordance with the SOP	Operators are not careful because they are sleepy, lack of rest or chatting	Reprimand the operator for implementing and carrying out the SOP that has been provided by the company and always checking the jig on the machine before using the machine	The company can provide SP for operators if it occurs repeatedly	Pros: Operators become more serious and concentrate on doing work Lack: -
		Lack of socialization for operators	Conduct training for the operator	Re-socialize the SOP that the company has made for operators	Pros: Operators have been equipped with new SOPs so that welding work will be in accordance with SOPs Lack: The company will spend money, time and energy to re-socialize.

Discussion

Based on the Fishbone Diagram it can be seen the root of the problem that occurs. Torn welding on the lower pipe is a type of defective waste because the frame body is torn due to teaching that is too far and is more dominant downward not to the steel joint between the lower and sub-frame because the operator was not careful when the gasoline ran out due to drowsiness, lack of rest, chatting, etc. The resulting waste can be in the form of off line production because part of the frame body is damaged so it cannot be sent to the production line and must be repaired again in the welding section which adds time. Lean manufacturing which is applied as an approach in this study is in accordance with lean principles, namely by applying lean philosophy and concepts through a series of steps, beginning with planning the change, defining the success elements, and concluding with implementation and progress monitoring [11]. The creation of a setting that makes the other process aspects possible is necessary for the adoption of lean manufacturing. This setting will guarantee that staff members feel empowered and have access to the resources they need to take responsibility for products and processes, work in focused teams, and have autonomy in developing solutions and process improvements [9].

The main focus of Lean is eliminating waste (waste) or anything that does not have added value in the process [12]–[14]. Not only is material wasted, but also a wide range of other resources, including time and energy. There are 7 types of waste in Lean, namely transportation, inventory, motion, waiting, overproduction, processing and defects [10]. In this study, the waste that occurs is waiting time and motion. Waiting is the term for lost time caused by sluggish or stopped production in one stage of the production chain while a stage before it is finished. For instance, in the manufacturing line, if one activity takes longer than another, whatever time the worker in charge of the subsequent task must wait is wasted. In order to make up for this lost time, the task that requires more time must be made more efficient, additional staff must be hired, or the workflow must be better organized or scheduled [4], [5], [15]. Whereas related to motion, all motion that could be decreased, whether it comes from a person or a machine, is considered wasteful motion. A margin of motion is squandered if it is used to add value that might have been added with less motion [10]. Motion can relate to anything from a worker stooping to pick up something on the production floor to more wear and tear on machines that necessitates replacement due to capital depreciation [11], [15].

4. Conclusion

Based on observations made in the welding frame body and the results of the analysis that the author has done in identifying waste in the production process flow in the welding frame body department, it can be concluded that the Welding Frame body has 12 work stations that are useful for converting several parts into frame bodies. Each work station has its own functions and duties. The production process flow in the frame body welding starts from St. Rear 1 to Rear 4, then St. Front 1 to St. Front 3, after that St. General Assy, Permanent Robot/Robot Handling, Fine Boring, Manual 1 and Manual 2, and ends in Tapping and Numbering. The tear in the welding on the lower pipe jig B is a waste type of defect because the frame body is torn due to the teaching being too far away and more dominant to the lower not to the iron connection between the lower and the sub-frame because the operator is not careful due to drowsiness, lack of rest, chatting.

By checking and resetting the jig or doing used manual weld repairs by inserting a nozzle into the pipe lower and reprimanding the operator for implementing and carrying out the SOP that has been provided by the company are the methods used to minimize waste. In minimizing waste, there are advantages, namely welding will be perfect and will not create minus in production. So the advice that the author can give is from the problem of welding the pipe lower jig B torn, so that the operator in the welding frame body always checks the machine first before using it so that the teaching is not far away and if this happens again because the operator is not thorough, the operator can be reprimanded and given SP so that they always focus on work and always apply the SOP that the company has set. In addition, the operator must also frequently check the gas indicator so that the gas does not run out and cause the teaching change.

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STUDY OF DISTRIBUTION TRANSFORMER VOLTAGE DROPS IN FEEDER 5 OUT GOING DISTRICTS 4 AND 6 AT PT. PLN (PERSERO) TARAKAN CITY, NORTH KALIMANTAN

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Abstract
This research aims to determine the low-voltage drop that occurs at the substation and customer side. The voltage drop is affected by many factors including line resistance, line current, power factor, and line length. The need for electric power is increasing every year, causing power losses and voltage drops in the network to be a major concern. This research was conducted at Feeder 5 out going villages 4 and 6, one of the areas of PT. PLN in Tarakan City. The research data is voltage measurement data. This research applies analytical calculations with a quantitative descriptive method compared to calculations based on ETAP software. The allowable voltage drop by SPLN is 5% of the nominal voltage. The results of the analysis show that the voltage drop that occurs on average is still within the limits permitted by the SPLN, namely below 5% of the nominal voltage.

Keywords:
Voltage drop; low voltage; distribution transformer; simulation

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1. Introduction

Electricity is an energy that is needed by society. This can be seen from the development of society, the need for electrical energy also increases. Therefore, the quality of electrical energy is very important in efforts to improve service to the community. However, the limited distribution of electrical energy where the generator is located far enough from the load center can cause a voltage drop. This problem can cause damage to household electrical equipment. Causes of voltage drop include line resistance, line current, power factor, and line length [1]. Previous researchers have studied this voltage drop a lot. one of them is influenced by the length of the conductor and the impedance value, where the value is affected by the value of the resistance and reactance of the line [2]. Analysis of the voltage drop in low voltage distribution networks has been carried out by researchers, such as Hamles L. Latupeirissa et al. This research analyzes the voltage loss in the 380/220 Volt low voltage network (JTR) at the Politeknik Negeri Ambon distribution substation. Where in this study aims: (i) to calculate how much voltage drop occurs in the secondary network; (ii) calculating the voltage drop correction on the secondary network. The types of data needed to carry out the calculation analysis: (i) standard data on cable types and sizes; (ii) the type and number of buses, as well as the length of the distribution channel; (iii) data of substations and distribution transformers; (iv) loading data. While the analysis of the calculation of the voltage drop in this study is focused on (i) determining the percentage of voltage drop; (ii) determining the ideal cable cross-sectional area and (iii) calculating the value of the voltage for each bus, the current in the inter-bus channel [1] and Kurniawati Naim et al., reconfigured the JTR between BTN Hamzy and BTN Antara to determine power losses and voltage drop [3]. Some researchers focus on examining the losses caused by voltage drops in the distribution network. Hontong et al., analyzed power losses caused by load imbalances that always occur in an electric power distribution network system [4]. Deni Mulyadi analyzes the effect of current on the neutral phase of the transformer [5]. Baqaruzi and Ali Muhtar analyzed the voltage drop and losses due to the influence of the use of distributed generation in the 20 kV primary distribution system, namely a small power generation system in the intermediate voltage distribution network [6].

This research will analyze the voltage drop in the low-voltage distribution network of PT. PLN (Persero) Tarakan City, outgoing Villages 4 and 6 which are one of the outputs from Feeder 5. This research is in collaboration with PT. PLN (Persero) Tarakan and Department of Electrical Engineering, Universitas Borneo Tarakan for 3 months, both through field studies and simulations conducted at the Power System Stability Laboratory.

2. Theory Foundation

A. Distribution System

The electric power distribution system covers all 20 kV intermediate voltage networks and all 380/220 V low-voltage networks up to the customer. The medium voltage network (JTM) is often referred to as the primary distribution network, while the low voltage network (JTR) is often referred to as the secondary distribution network.

The electric power distribution network can be classified into 2 parts of the system, namely:

Primary Distribution Network

Primary distribution is a distribution network of medium voltage electricity (20 kV). The primary distribution network is the feeder network. The primary distribution network starts from the secondary side of the power transformer that is installed at the substation to the primary side of the distribution transformer that is installed at the poles of the line.

Secondary Distribution Network

Secondary distribution is an electric power network that belongs to the low voltage category (380/220 Volt system). The secondary distribution network starts from the secondary side of the distribution transformer and ends at the customer's meter as shown in Fig. 1 below [7].

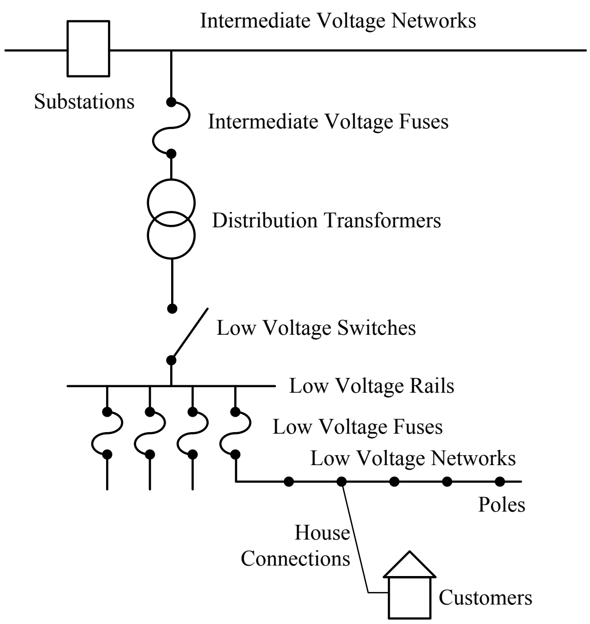

Figure 1. Secondary Distribution Network

B. Drop Voltage

Voltage drop is the amount of voltage lost in a conductor. The voltage drop on electric power lines is generally directly proportional to the length of the line and the load and inversely proportional to the cross-sectional area of the conductor. The magnitude of the voltage drop is expressed in percent or volts. The amount of the lower and upper limits is determined by the provisions regulated in the SPLN. Calculation of the voltage drop at certain limits by only calculating the magnitude of the resistance can still be considered. But in network systems, especially in intermediate voltage systems, inductance and capacitance issues are taken into account because their values are quite significant.

Voltage drop can be defined as [8]:

$$\Delta \boldsymbol{V} = \boldsymbol{V_s} - \boldsymbol{V_r} \quad (1)$$

where:

$\Delta \boldsymbol{V}$ = drop voltage (Volt)
$\boldsymbol{V_s}$ = the voltage on the sending side of the low-voltage distribution transformer (Volt)
$\boldsymbol{V_r}$ = load receiving voltage/consumer (Volt)

Due to the resistance in the conductor, the voltage received by the consumer ($\boldsymbol{V_r}$) will be less than the sending voltage ($\boldsymbol{V_s}$), so that the voltage drop ($\boldsymbol{V_{drop}}$) is the difference between the voltage at the sending end and the voltage at the receiving end.

The relative voltage drop is called voltage regulation ($\boldsymbol{V_R}$) and is expressed by the formula [8]:

$$\boldsymbol{V_R} = \frac{V_s - V_r}{V_r} \times \mathbf{100\%} \quad (2)$$

In the calculation, it is assumed that the loads are a balanced three-phase load and the power factor ($\cos \boldsymbol{\varphi}$) is between 0.6 to 0.85 points.

The voltage drop for a three-phase network system can be calculated based on the relationship approach formula as follows [6]:

$$\boldsymbol{V_{drop}} = \sqrt{\mathbf{3}} \times \boldsymbol{I} \times \boldsymbol{L}\,(\boldsymbol{R}\cos\boldsymbol{\varphi} + \boldsymbol{X}\sin\boldsymbol{\varphi}) \quad (3)$$

where:

$\boldsymbol{V_{drop}}$ = drop voltage (Volt)
$\boldsymbol{I}$ = load current (Ampere)
$\boldsymbol{L}$ = conductor length (meters)
$\boldsymbol{R}$ = resistance (Ohm/km)
$\boldsymbol{X}$ = reactance (Ohm/km)
$\boldsymbol{\varphi}$ = power factor angle

3. Methods

A. Research Framework

This research was conducted with the following stages:

1. Literature Study
   In this step, we will collect journals and articles related to the voltage drop in the distribution transformer on the low voltage side.
2. Collect data
   In this step, will collect data on PT. PLN (Persero) Tarakan City. The data taken is in the form of measurement data in the field, data single line diagram feeder 5 out going Villages 4 and 6.
3. Voltage Drop Analysis
   In this step, we will analyze the voltage drop on the distribution transformer on the low voltage side of feeder 5 out going Villages 4 and 6 using voltage measurement data from field measurements. The results of calculation data based on measurements and simulation data based on ETAP software will be compared using the mean absolute percentage error (MAPE) calculation [9].
4. Final
   The results of the voltage drop analysis on the low voltage side distribution transformer on feeder 5 out going Villages 4 and 6 are the recommendations given for voltage drop analysis to PT. PLN (Persero) Tarakan City.

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B. Data

The data needed in this study are primary and secondary data.

1. Primary data, form:
   - voltage
   - load current
   - power factor
   - the length and cross-sectional area of the conducting channel
2. Secondary data, form:
   - single line out going Villages 4 and 6.

C. Technique of Data Collection

Following are the stages in collecting primary and secondary data, namely:

1. Primary data
   - voltage measurements were carried out on the PHB TR and MCB at the consumer's house at the research location, using a digital ampere meter.
   - measurement of the load current on the MCB using a digital ampere meter.
2. Secondary data
   - single line out going chart of villages 4 and 6 obtained from PT. PLN (Persero) Tarakan City.

D. Data Analysis

As for how to analyze the data with the following stages:

1. The collected data will be analyzed with the help of Ms Excel.
2. Make a voltage drop simulation.
3. Comparing the analysis results with the simulation results using the MAPE equation.

4. Results and Discussion

A. Calculation of the Voltage Drop of Measurement Results Data

This research was conducted at PT. PLN (Persero) Tarakan City on Feeder 5 out going Villages 4 and 6. This voltage drop calculation is based on direct measurement data in the field, where researchers measure the voltage at PHB as the sending voltage and the voltage at the consumer as the voltage receiver. The calculation results consist of the calculation of the voltage drop and voltage regulation on each phase

1. Voltage Drop Calculation

The calculation of the voltage drop is calculated using equation (1). The calculation results are presented in Table 1 below.

Table 1. Voltage drop calculation

Substations	Sending voltage (V_s)			Receive voltage (V_r)			Drop voltage (ΔV)		
	R	S	T	R	S	T	R	S	T
KPE 155	222	223	221	220	222	219	2	1	2
KPE 92	223	222	224	222	220	223	1	2	1
KPE 42	215	216	214	213	214	212	2	2	2
KPE 62	211	210	210	209	208	208	2	2	2
KPE 228	224	223	225	222	221	223	2	2	2
KPE 399	222	226	224	220	224	222	2	2	2
KPE 36	221	221	223	219	219	221	2	2	2
KPE 52	223	223	222	221	221	220	2	2	2
KPE 388	227	226	226	225	224	223	2	2	3
KPE 165	223	225	224	221	223	222	2	2	2
KPE 53	222	223	223	220	221	221	2	2	2

KPE 352	223	225	224	221	223	222	2	2	2
MBR 37	222	223	221	220	221	219	2	2	2
KPE 166	229	224	223	221	222	220	8	2	3
MBR 324	224	225	226	222	223	224	2	2	2
MBR 72	219	219	220	217	217	219	2	2	1
MBR 133	222	220	221	221	219	219	1	1	2
MBR 112	223	223	224	222	220	221	1	3	3
KRN 267	224	226	225	221	224	223	3	2	2
MBR 423	226	225	226	224	223	224	2	2	2
MBR 229	220	223	221	219	222	220	1	1	1
MBR 314	223	222	223	220	221	221	3	1	2
KRN 78	222	223	223	220	221	220	2	2	3
KRN 130	223	224	223	220	221	220	3	3	3
KRN 150	220	222	220	219	220	219	1	2	1
KRN 387	223	224	224	221	222	221	2	2	3
KRN 209	223	221	223	221	220	221	2	1	2
TJP 129	225	224	223	223	221	222	2	3	1
TJP 361	220	221	221	219	220	220	1	1	1
JTP 126	222	222	222	219	220	219	3	2	3
TJP 167	223	224	222	220	221	220	3	3	2

From table 1, it can be seen how much the sending voltage is from PHB and the voltage received by consumers, and how much voltage drop or voltage difference occurs in Feeder 5 Out Going Villages 4 and 6.

2. Voltage Regulation Calculation

Calculation of voltage regulation based on equation (2). After the voltage drop value is analyzed then the voltage regulation is calculated. The calculation results are presented in Table 2 below.

Table 2. Voltage Regulation Calculation

Substations	Sending (V_s)			Receive voltage (V_r)			Regulation voltage (%)		
	R	S	T	R	S	T	R	S	T
KPE 155	222	223	221	220	222	219	0,009091	0,004505	0,009132
KPE 92	223	222	224	222	220	223	0,004505	0,009091	0,004484
KPE 42	215	216	214	213	214	212	0,00939	0,009346	0,009434
KPE 62	211	210	210	209	208	208	0,009569	0,009615	0,009615
KPE 228	224	223	225	222	221	223	0,009009	0,00905	0,008969
KPE 399	222	226	224	220	224	222	0,009091	0,008929	0,009009
KPE 36	221	221	223	219	219	221	0,009132	0,009132	0,00905
KPE 52	223	223	222	221	221	220	0,00905	0,00905	0,009091
KPE 388	227	226	226	225	224	223	0,008889	0,008929	0,013453
KPE 165	223	225	224	221	223	222	0,00905	0,008969	0,009009
KPE 53	222	223	223	220	221	221	0,009091	0,00905	0,00905
KPE 352	223	225	224	221	223	222	0,00905	0,008969	0,009009
MBR 37	222	223	221	220	221	219	0,009091	0,00905	0,009132

KPE 166	229	224	223	221	222	220	0,036199	0,009009	0,013636
MBR 324	224	225	226	222	223	224	0,009009	0,008969	0,008929
MBR 72	219	219	220	217	217	219	0,009217	0,009217	0,004566
MBR 133	222	220	221	221	219	219	0,004525	0,004566	0,009132
MBR 112	223	223	224	222	220	221	0,004505	0,013636	0,013575
KRN 267	224	226	225	221	224	223	0,013575	0,008929	0,008969
MBR 423	226	225	226	224	223	224	0,008929	0,008969	0,008929
MBR 229	220	223	221	219	222	220	0,004566	0,004505	0,004545
MBR 314	223	222	223	220	221	221	0,013636	0,004525	0,00905
KRN 78	222	223	223	220	221	220	0,009091	0,00905	0,013636
KRN 130	223	224	223	220	221	220	0,013636	0,013575	0,013636
KRN 150	220	222	220	219	220	219	0,004566	0,009091	0,004566
KRN 387	223	224	224	221	222	221	0,00905	0,009009	0,013575
KRN 209	223	221	223	221	220	221	0,00905	0,004545	0,00905
TJP 129	225	224	223	223	221	222	0,008969	0,013575	0,004505
TJP 361	220	221	221	219	220	220	0,004566	0,004545	0,004545
TJP 126	222	222	222	219	220	219	0,013699	0,009091	0,013699
TJP 167	223	224	222	220	221	220	0,013636	0,013575	0,009091

3. Calculation of 1 Phase Load Voltage Drop

Calculation of the 1-phase load voltage drop using equation (3). In this equation to test the magnitude of the voltage drop that occurs on low voltage lines using current data, circuit resistance, circuit reactance, cable length.

Table 3. Calculation of 1 phase load voltage drop

Substations	Current			Cos	Sin	Resistance			Reactance			Length	Cable length SR			Voltage drop		
	R	S	T	φ	φ	R	S	T	R	S	T	Cable JTR	R	S	T	R	S	T
KPE 155	6,11	4,04	4,03	0,85	0,526	0,311	0,302	0,300	0,075	0,074	0,074	500	20	13	12	1,857	1,192	1,184
KPE 92	5,09	4,91	6,11	0,85	0,526	0,247	0,247	0,246	0,060	0,060	0,060	400	15	15	14	1,231	1,188	1,471
KPE 42	6,18	4,02	4,04	0,85	0,526	0,304	0,300	0,302	0,074	0,074	0,074	500	15	12	13	1,840	1,181	1,192
KPE 62	6,04	4,11	3,26	0,85	0,526	0,364	0,358	0,361	0,089	0,088	0,088	600	17	13	15	2,150	1,442	1,152
KPE 228	4,24	3,09	4,05	0,85	0,526	0,387	0,385	0,385	0,095	0,095	0,095	650	13	12	12	1,606	1,167	1,529
KPE 399	5,21	3,47	4,17	0,85	0,526	0,323	0,326	0,324	0,079	0,080	0,079	540	12	14	13	1,647	1,106	1,324
KPE 36	5,78	5,01	4,58	0,85	0,526	0,302	0,302	0,304	0,074	0,074	0,074	500	13	13	15	1,706	1,479	1,363
KPE 52	5,25	4,06	4,01	0,85	0,526	0,331	0,333	0,331	0,081	0,081	0,081	550	14	15	14	1,703	1,322	1,300
KPE 388	4,54	4,21	3,71	0,85	0,526	0,300	0,300	0,302	0,074	0,074	0,074	500	12	12	13	1,334	1,237	1,095
KPE 165	6,07	4,48	4,18	0,85	0,526	0,338	0,336	0,337	0,083	0,082	0,083	560	15	13	14	2,010	1,472	1,379
KPE 53	5,76	4,93	4,65	0,85	0,526	0,327	0,324	0,323	0,080	0,079	0,079	540	15	13	12	1,843	1,565	1,470
KPE 352	4,12	4,78	3,22	0,85	0,526	0,317	0,321	0,320	0,078	0,078	0,078	530	12	15	14	1,280	1,503	1,008
MBR 37	4,28	3,11	3,74	0,85	0,526	0,414	0,418	0,414	0,102	0,103	0,102	700	12	15	12	1,735	1,273	1,516
KPE 166	4,93	3,15	3,06	0,85	0,526	0,347	0,349	0,345	0,085	0,085	0,085	576	15	16	13	1,676	1,075	1,033
MBR 324	3,57	3,52	4,55	0,85	0,526	0,324	0,321	0,324	0,079	0,079	0,079	534	15	13	15	1,130	1,106	1,441
MBR 72	4,12	4,49	3,41	0,85	0,526	0,314	0,312	0,312	0,077	0,076	0,076	520	14	12	12	1,267	1,370	1,040

MBR 133	5,22	5,02	4,88	0,85	0,526	0,303	0,310	0,307	0,074	0,075	0,075	505	12	17	15	1,549	1,521	1,466
MBR 112	5,51	6,01	5,98	0,85	0,526	0,335	0,340	0,339	0,082	0,083	0,083	556	14	18	17	1,805	1,999	1,982
KRN 267	4,01	5,72	5,63	0,85	0,526	0,347	0,351	0,351	0,085	0,086	0,086	583	12	15	15	1,364	1,967	1,936
MBR 423	4,07	3,77	4,32	0,85	0,526	0,365	0,367	0,360	0,089	0,090	0,089	606	15	17	12	1,452	1,355	1,525
MBR 229	4,89	4,93	3,87	0,85	0,526	0,305	0,309	0,307	0,074	0,075	0,075	503	14	17	16	1,458	1,488	1,163
MBR 314	3,14	3,56	3,91	0,85	0,526	0,377	0,379	0,383	0,093	0,093	0,094	636	12	13	16	1,161	1,321	1,465
KRN 78	5,04	4,11	3,89	0,85	0,526	0,350	0,346	0,346	0,086	0,085	0,085	578	16	13	13	1,726	1,392	1,317
KRN 130	4,97	3,83	4,01	0,85	0,526	0,403	0,403	0,402	0,099	0,099	0,099	679	13	13	12	1,963	1,513	1,579
KRN 150	4,18	3,24	3,24	0,85	0,526	0,348	0,346	0,350	0,085	0,085	0,086	580	14	12	15	1,425	1,097	1,109
KRN 387	3,68	4,89	2,62	0,85	0,526	0,392	0,392	0,393	0,096	0,096	0,096	654	15	15	16	1,411	1,876	1,008
KRN 209	4,52	4,56	4,94	0,85	0,526	0,351	0,353	0,353	0,086	0,087	0,087	590	12	13	13	1,555	1,575	1,706
TJP 129	4,02	4,23	3,88	0,85	0,526	0,311	0,313	0,309	0,076	0,076	0,076	515	14	15	12	1,225	1,295	1,173
TJP 361	4,37	6,11	5,29	0,85	0,526	0,307	0,312	0,308	0,075	0,076	0,075	512	12	16	13	1,314	1,867	1,597
TJP 126	4,12	4,63	2,45	0,85	0,526	0,453	0,455	0,454	0,112	0,112	0,112	766	13	15	14	1,827	2,065	1,090
TJP 167	3,67	4,07	3,82	0,85	0,526	0,335	0,332	0,336	0,082	0,082	0,082	556	14	12	15	1,202	1,323	1,256

Table 3 is the result of the calculation of the 1-phase load voltage drop, based on the distance from the PHB to the consumer.

B. Calculation of Voltage Drop from Simulation

This research uses ETAP software, to compare the value of the voltage drop that occurs in measurements and simulations. The data used in the ETAP software is in the form of measurement results and field data observations.

1. Convert The 3 Phase Voltage Value to 1 Phase

Before the researcher analyzes the voltage drop further by using the existing equation, the researcher previously converted the 3-phase voltage to 1-phase voltage with the following equation:

$$V_{3\Phi} = \sqrt{3} \times V_{1\Phi}$$

Where the conversion results will be displayed in Table 4 below.

Table 4. Convert the 3 phase voltage value to 1 phase

Substations	Voltage	Sending voltage 3Φ			$\sqrt{3}$	Voltage			Receice voltage 1Φ		
	Sending 3Φ	R	S	T		R	S	T	R	S	T
KPE 155	380	379	379	379	1,73	220	220	220	219	219	219
KPE 92	380	379	379	379	1,73	220	220	220	219	219	219
KPE 42	380	379	379	379	1,73	220	220	220	219	219	219
KPE 62	380	379	379	379	1,73	220	220	220	219	219	219
KPE 228	380	379	379	379	1,73	220	220	220	219	219	219
KPE 399	380	379	379	379	1,73	220	220	220	219	219	219
KPE 36	380	379	379	379	1,73	220	220	220	219	219	219
KPE 52	380	379	379	379	1,73	220	220	220	219	219	219
KPE 388	380	379	379	379	1,73	220	220	220	219	219	219
KPE 165	380	379	379	379	1,73	220	220	220	219	219	219
KPE 53	380	379	379	379	1,73	220	220	220	219	219	219
KPE 352	380	379	379	379	1,73	220	220	220	219	219	219

MBR 37	380	379	379	379	1,73	220	220	220	219	219	219
KPE 166	380	379	379	379	1,73	220	220	220	219	219	219
MBR 324	380	379	379	379	1,73	220	220	220	219	219	219
MBR 72	380	379	379	379	1,73	220	220	220	219	219	219
MBR 133	380	379	379	379	1,73	220	220	220	219	219	219
MBR 112	380	379	379	379	1,73	220	220	220	219	219	219
KRN 267	380	379	379	379	1,73	220	220	220	219	219	219
MBR 423	380	379	379	379	1,73	220	220	220	219	219	219
MBR 229	380	379	379	379	1,73	220	220	220	219	219	219
MBR 314	380	379	379	379	1,73	220	220	220	219	219	219
KRN 78	380	379	379	379	1,73	220	220	220	219	219	219
KRN 130	380	379	379	379	1,73	220	220	220	219	219	219
KRN 150	380	379	379	379	1,73	220	220	220	219	219	219
KRN 387	380	379	379	379	1,73	220	220	220	219	219	219
KRN 209	380	379	379	379	1,73	220	220	220	219	219	219
TJP 129	380	379	379	379	1,73	220	220	220	219	219	219
TJP 361	380	379	379	379	1,73	220	220	220	219	219	219
TJP 126	380	379	379	379	1,73	220	220	220	219	219	219
TJP 167	380	379	379	379	1,73	220	220	220	219	219	219

2. Drop Voltage Calculation

The calculation of the voltage drop is calculated using equation (1). After the 3-phase voltage is converted to 1-phase voltage, it will then be analyzed. The results of this equation will then be displayed in Table 5 below.

Table 5. Drop voltage calculation

Substation	Sending voltage			Receive voltage			Drop voltage		
	R	S	T	R	S	T	R	S	T
KPE 155	220	220	220	219	219	219	1	1	1
KPE 92	220	220	220	219	219	219	1	1	1
KPE 42	220	220	220	219	219	219	1	1	1
KPE 62	220	220	220	219	219	219	1	1	1
KPE 228	220	220	220	219	219	219	1	1	1
KPE 399	220	220	220	219	219	219	1	1	1
KPE 36	220	220	220	219	219	219	1	1	1
KPE 52	220	220	220	219	219	219	1	1	1
KPE 388	220	220	220	219	219	219	1	1	1
KPE 165	220	220	220	219	219	219	1	1	1
KPE 53	220	220	220	219	219	219	1	1	1
KPE 352	220	220	220	219	219	219	1	1	1
MBR 37	220	220	220	219	219	219	1	1	1
KPE 166	220	220	220	219	219	219	1	1	1
MBR 324	220	220	220	219	219	219	1	1	1
MBR 72	220	220	220	219	219	219	1	1	1

MBR 133	220	220	220	219	219	219	1	1	1
MBR 112	220	220	220	219	219	219	1	1	1
KRN 267	220	220	220	219	219	219	1	1	1
MBR 423	220	220	220	219	219	219	1	1	1
MBR 229	220	220	220	219	219	219	1	1	1
MBR 314	220	220	220	219	219	219	1	1	1
KRN 78	220	220	220	219	219	219	1	1	1
KRN 130	220	220	220	219	219	219	1	1	1
KRN 150	220	220	220	219	219	219	1	1	1
KRN 387	220	220	220	219	219	219	1	1	1
KRN 209	220	220	220	219	219	219	1	1	1
TJP 129	220	220	220	219	219	219	1	1	1
TJP 361	220	220	220	219	219	219	1	1	1
TJP 126	220	220	220	219	219	219	1	1	1
33TJP 167	220	220	220	219	219	219	1	1	1

3. Regulation Voltage Calculation
   Calculation of voltage regulation based on equation (2). Where the data used to analyze voltage regulation is the result of the voltage drop in Table 6 below.

Table 6. Regulation voltage calculation

Substations	Sending voltage			Receice voltage			Regulation voltage		
	R	S	T	R	S	T	R	S	T
KPE 155	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 92	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 42	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 62	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 228	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 399	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 36	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 52	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 388	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 165	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 53	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 352	220	220	220	219	219	219	0,004566	0,004566	0,004566
MBR 37	220	220	220	219	219	219	0,004566	0,004566	0,004566
KPE 166	220	220	220	219	219	219	0,004566	0,004566	0,004566
MBR 324	220	220	220	219	219	219	0,004566	0,004566	0,004566
MBR 72	220	220	220	219	219	219	0,004566	0,004566	0,004566
MBR 133	220	220	220	219	219	219	0,004566	0,004566	0,004566
MBR 112	220	220	220	219	219	219	0,004566	0,004566	0,004566
KRN 267	220	220	220	219	219	219	0,004566	0,004566	0,004566
MBR 423	220	220	220	219	219	219	0,004566	0,004566	0,004566
MBR 229	220	220	220	219	219	219	0,004566	0,004566	0,004566

MBR 314	220	220	220	219	219	219	0,004566	0,004566	0,004566
KRN 78	220	220	220	219	219	219	0,004566	0,004566	0,004566
KRN 130	220	220	220	219	219	219	0,004566	0,004566	0,004566
KRN 150	220	220	220	219	219	219	0,004566	0,004566	0,004566
KRN 387	220	220	220	219	219	219	0,004566	0,004566	0,004566
KRN 209	220	220	220	219	219	219	0,004566	0,004566	0,004566
TJP 129	220	220	220	219	219	219	0,004566	0,004566	0,004566
TJP 361	220	220	220	219	219	219	0,004566	0,004566	0,004566
TJP 126	220	220	220	219	219	219	0,004566	0,004566	0,004566
TJP 167	220	220	220	219	219	219	0,004566	0,004566	0,004566

4. Calculation of 1 Phase Load Voltage Drop

The calculation of the voltage drop on a 1-phase load based on equation (3) is shown in Table 7. This equation is used to test the voltage drop that occurs on low-voltage lines using current, resistance, reactance, and cable length data.

Table 7. Calculation of 1 phase load voltage drop

Substations	Current			Cos	Sin	Resistance			Reactance			Length	Length cable SR			Drop voltage		
	R	S	T	φ	φ	R	S	T	R	S	T	Cable JTR	R	S	T	R	S	T
KPE 155	3,3	3,3	3,3	0,85	0,526	0,311	0,302	0,300	0,075	0,074	0,074	500	20	13	12	1,003	0,974	0,970
KPE 92	3,3	3,3	3,3	0,85	0,526	0,247	0,247	0,246	0,060	0,060	0,060	400	15	15	14	0,798	0,798	0,794
KPE 42	3,3	3,3	3,3	0,85	0,526	0,304	0,300	0,302	0,074	0,074	0,074	500	15	12	13	0,982	0,970	0,974
KPE 62	3,3	3,3	3,3	0,85	0,526	0,364	0,358	0,361	0,089	0,088	0,088	600	17	13	15	1,175	1,158	1,166
KPE 228	3,3	3,3	3,3	0,85	0,526	0,387	0,385	0,385	0,095	0,095	0,095	650	13	12	12	1,250	1,246	1,246
KPE 399	3,3	3,3	3,3	0,85	0,526	0,323	0,326	0,324	0,079	0,080	0,079	540	12	14	13	1,043	1,052	1,048
KPE 36	3,3	3,3	3,3	0,85	0,526	0,302	0,302	0,304	0,074	0,074	0,074	500	13	13	15	0,974	0,974	0,982
KPE 52	3,3	3,3	3,3	0,85	0,526	0,331	0,333	0,331	0,081	0,081	0,081	550	14	15	14	1,070	1,074	1,070
KPE 388	3,3	3,3	3,3	0,85	0,526	0,300	0,300	0,302	0,074	0,074	0,074	500	12	12	13	0,970	0,970	0,974
KPE 165	3,3	3,3	3,3	0,85	0,526	0,338	0,336	0,337	0,083	0,082	0,083	560	15	13	14	1,093	1,084	1,089
KPE 53	3,3	3,3	3,3	0,85	0,526	0,327	0,324	0,323	0,080	0,079	0,079	540	15	13	12	1,056	1,048	1,043
KPE 352	3,3	3,3	3,3	0,85	0,526	0,317	0,321	0,320	0,078	0,078	0,078	530	12	15	14	1,025	1,038	1,033
MBR 37	3,3	3,3	3,3	0,85	0,526	0,414	0,418	0,414	0,102	0,103	0,102	700	12	15	12	1,338	1,350	1,338
KPE 166	3,3	3,3	3,3	0,85	0,526	0,347	0,349	0,345	0,085	0,085	0,085	576	15	16	13	1,122	1,126	1,114
MBR 324	3,3	3,3	3,3	0,85	0,526	0,324	0,321	0,324	0,079	0,079	0,079	534	15	13	15	1,045	1,037	1,045
MBR 72	3,3	3,3	3,3	0,85	0,526	0,314	0,312	0,312	0,077	0,076	0,076	520	14	12	12	1,015	1,007	1,007
MBR 133	3,3	3,3	3,3	0,85	0,526	0,303	0,310	0,307	0,074	0,075	0,075	505	12	17	15	0,979	1,000	0,992
MBR 112	3,3	3,3	3,3	0,85	0,526	0,335	0,340	0,339	0,082	0,083	0,083	556	14	18	17	1,081	1,098	1,094
KRN 267	3,3	3,3	3,3	0,85	0,526	0,347	0,351	0,351	0,085	0,086	0,086	583	12	15	15	1,123	1,135	1,135
MBR 423	3,3	3,3	3,3	0,85	0,526	0,365	0,367	0,360	0,089	0,090	0,089	606	15	17	12	1,177	1,186	1,165
MBR 229	3,3	3,3	3,3	0,85	0,526	0,305	0,309	0,307	0,074	0,075	0,075	503	14	17	16	0,984	0,996	0,992
MBR 314	3,3	3,3	3,3	0,85	0,526	0,377	0,379	0,383	0,093	0,093	0,094	636	12	13	16	1,220	1,224	1,237
KRN 78	3,3	3,3	3,3	0,85	0,526	0,350	0,346	0,346	0,086	0,085	0,085	578	16	13	13	1,130	1,118	1,118
KRN 130	3,3	3,3	3,3	0,85	0,526	0,403	0,403	0,402	0,099	0,099	0,099	679	13	13	12	1,303	1,303	1,299

KRN 150	3,3	3,3	3,3	0,85	0,526	0,348	0,346	0,350	0,085	0,085	0,086	580	14	12	15	1,125	1,117	1,130
KRN 387	3,3	3,3	3,3	0,85	0,526	0,392	0,392	0,393	0,096	0,096	0,096	654	15	15	16	1,266	1,266	1,270
KRN 209	3,3	3,3	3,3	0,85	0,526	0,351	0,353	0,353	0,086	0,087	0,087	590	12	13	13	1,135	1,140	1,140
TJP 129	3,3	3,3	3,3	0,85	0,526	0,311	0,313	0,309	0,076	0,076	0,076	515	14	15	12	1,006	1,010	0,997
TJP 361	3,3	3,3	3,3	0,85	0,526	0,307	0,312	0,308	0,075	0,076	0,075	512	12	16	13	0,992	1,009	0,996
TJP 126	3,3	3,3	3,3	0,85	0,526	0,453	0,455	0,454	0,112	0,112	0,112	766	13	15	14	1,463	1,472	1,468
TJP 167	3,3	3,3	3,3	0,85	0,526	0,335	0,332	0,336	0,082	0,082	0,082	556	14	12	15	1,081	1,073	1,085

From the table above the load values for 1 phase are the same but because of the values of cos φ, sin φ, resistance, reactance, the length of the low voltage network cable along with the size and type of resistance, the voltage drop value for each house is different but almost close.

C. Voltage Drop Tolerance allowed by PLN

According to SPLN Number 72 of 1987, the allowable voltage drop for each type of connection is as follows:

1. The voltage drop on the intermediate voltage network is allowed [10]:
   - 2% of the working voltage as specified in paragraph 22 for systems that do not utilize STB (i.e. Spindle and Cluster systems).
   - 5% of the working stress for systems that utilize STB, namely radial systems on the ground and node systems.
2. The voltage drop on the distribution transformer is allowed 3% of the working voltage.
3. The voltage drop at low voltage connections is allowed up to 4% of the working voltage depending on the load density.
4. The voltage drop at the house connection is allowed 1% of the nominal voltage.

Based on field measurements and simulations, one of the case studies was on the KPE 155 transformer located in Village 6. The calculations below are intended to control the voltage drop tolerance allowed by SPLN.

1. Measurement Voltage Drop Data

   The data used to test the tolerance limit for the voltage drop allowed by the SPLN is the measurement data in Table 1 above.

Table 8. Calculation of Voltage Drop Tolerance

Substation	Sending voltage (V_r)			Drop voltage (ΔV)			Tolerance limit		
	R	S	T	R	S	T	R	S	T
KPE 155	220	222	219	2	1	2	0,91	0,45	0,91
KPE 92	222	220	223	1	2	1	0,45	0,91	0,45
KPE 42	213	214	212	2	2	2	0,94	0,93	0,94
KPE 62	209	208	208	2	2	2	0,96	0,96	0,96
KPE 228	222	221	223	2	2	2	0,90	0,90	0,90
KPE 399	220	224	222	2	2	2	0,91	0,89	0,90
KPE 36	219	219	221	2	2	2	0,91	0,91	0,90
KPE 52	221	221	220	2	2	2	0,90	0,90	0,91
KPE 388	225	224	223	2	2	3	0,89	0,89	1,35
KPE 165	221	223	222	2	2	2	0,90	0,90	0,90
KPE 53	220	221	221	2	2	2	0,91	0,90	0,90
KPE 352	221	223	222	2	2	2	0,90	0,90	0,90
MBR 37	220	221	219	2	2	2	0,91	0,90	0,91
KPE 166	221	222	220	8	2	3	3,62	0,90	1,36

MBR 324	222	223	224	2	2	2	0,90	0,90	0,89
MBR 72	217	217	219	2	2	1	0,92	0,92	0,46
MBR 133	221	219	219	1	1	2	0,45	0,46	0,91
MBR 112	222	220	221	1	3	3	0,45	1,36	1,36
KRN 267	221	224	223	3	2	2	1,36	0,89	0,90
MBR 423	224	223	224	2	2	2	0,89	0,90	0,89
MBR 229	219	222	220	1	1	1	0,46	0,45	0,45
MBR 314	220	221	221	3	1	2	1,36	0,45	0,90
KRN 78	220	221	220	2	2	3	0,91	0,90	1,36
KRN 130	220	221	220	3	3	3	1,36	1,36	1,36
KRN 150	219	220	219	1	2	1	0,46	0,91	0,46
KRN 387	221	222	221	2	2	3	0,90	0,90	1,36
KRN 209	221	220	221	2	1	2	0,90	0,45	0,90
TJP 129	223	221	222	2	3	1	0,90	1,36	0,45
TJP 361	219	220	220	1	1	1	0,46	0,45	0,45
TJP 126	219	220	219	3	2	3	1,37	0,91	1,37
TJP 167	220	221	220	3	3	2	1,36	1,36	0,91

Based on Table 8 above, it can be seen the calculation results of each transformer in each phase shows the tolerance limit for the voltage drop allowed by the SPLN. The highest value of the tolerance limit is found in the KPE 166 transformer in phase R at 3.62%, while the lowest value of the tolerance limit is 0.45%. The tolerance limit allowed by SPLN is 5%, so the voltage drop that occurs in Feeder 5 outgoing Villages 4 and 6 is still within the tolerance limit allowed by SPLN.

2. Voltage Drop Data Based on Simulation Results

The data used to test the allowable voltage drop tolerance limit by SPLN is the simulation data in Table 5. After the 3-phase voltage is converted to 1-phase voltage, it will then be analyzed and produce a voltage drop from the simulation data. Simulation data of the voltage drop tolerance limit can be seen in Table 9 below.

Table 9. Calculation of Simulation Voltage Drop Tolerance

Nama Gardu	Tegangan Terima			Jatuh Tegangan			Batas Toleransi		
	R	S	T	R	S	T	R	S	T
KPE 155	219	219	219	1	1	1	0,46	0,46	0,46
KPE 92	219	219	219	1	1	1	0,46	0,46	0,46
KPE 42	219	219	219	1	1	1	0,46	0,46	0,46
KPE 62	219	219	219	1	1	1	0,46	0,46	0,46
KPE 228	219	219	219	1	1	1	0,46	0,46	0,46
KPE 399	219	219	219	1	1	1	0,46	0,46	0,46
KPE 36	219	219	219	1	1	1	0,46	0,46	0,46
KPE 52	219	219	219	1	1	1	0,46	0,46	0,46
KPE 388	219	219	219	1	1	1	0,46	0,46	0,46
KPE 165	219	219	219	1	1	1	0,46	0,46	0,46
KPE 53	219	219	219	1	1	1	0,46	0,46	0,46
KPE 352	219	219	219	1	1	1	0,46	0,46	0,46

MBR 37	219	219	219	1	1	1	0,46	0,46	0,46
KPE 166	219	219	219	1	1	1	0,46	0,46	0,46
MBR 324	219	219	219	1	1	1	0,46	0,46	0,46
MBR 72	219	219	219	1	1	1	0,46	0,46	0,46
MBR 133	219	219	219	1	1	1	0,46	0,46	0,46
MBR 112	219	219	219	1	1	1	0,46	0,46	0,46
KRN 267	219	219	219	1	1	1	0,46	0,46	0,46
MBR 423	219	219	219	1	1	1	0,46	0,46	0,46
MBR 229	219	219	219	1	1	1	0,46	0,46	0,46
MBR 314	219	219	219	1	1	1	0,46	0,46	0,46
KRN 78	219	219	219	1	1	1	0,46	0,46	0,46
KRN 130	219	219	219	1	1	1	0,46	0,46	0,46
KRN 150	219	219	219	1	1	1	0,46	0,46	0,46
KRN 387	219	219	219	1	1	1	0,46	0,46	0,46
KRN 209	219	219	219	1	1	1	0,46	0,46	0,46
TJP 129	219	219	219	1	1	1	0,46	0,46	0,46
TJP 361	219	219	219	1	1	1	0,46	0,46	0,46
TJP 126	219	219	219	1	1	1	0,46	0,46	0,46
TJP 167	219	219	219	1	1	1	0,46	0,46	0,46

Based on Table 9, it can be seen that the results of the simulation data calculations show that the voltage drop is still within the tolerance limit allowed by the SPLN, which is 5%.

5. Conclusion

Based on the results of the analysis of calculations between measurement data and simulation data carried out on feeder 5 outgoing villages 4 and 6 it can be concluded, as follows:

A. For data from measurements and simulations, there is a voltage drop. For measurements, the largest voltage drop is found in the KPE 166 transformer at phase R of 8 Volts, phase S of 2 Volts, and phase T of 3 Volts, but it is still within the SPLN tolerance limit. Then for the KPE 62 transformer, there was a voltage drop of 2 Volts for phases R, S, and T but it had exceeded the SPLN tolerance limit of 5%. As for the simulation, the KPE 166 transformer only has a voltage drop of 1 volt for phases R, S, and T.
B. In the calculation of the voltage drop on a 1-phase load, there is a voltage drop. For measurement data, the largest voltage drop occurred in the KPE 62 transformer in the R phase at 2.150 Volts, in the TJP 126 transformer in the S phase at 2.065 Volts, and in the KPE 165 transformer in the R phase at 2.010 Volts. Whereas for the simulation data, the largest voltage drop occurs in the TJP 126 transformer at phase S of 1.472 Volts, phase T of 1.468 Volts, and phase R of 1.463 Volts.
C. In this research to compare the voltage drop that occurs in analytical calculations and simulation results is to use the MAPE equation. Based on the MAPE calculation results, namely: MAPE phase R of 44.22043 percent, MAPE phase S of 42.47312 percent and MAPE phase T of 44.08602 percent. However, overall the results of the MAPE calculations are respectable.

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REVERSE LOGISTICS IN THE FAST-MOVING CONSUMER GOODS INDUSTRY: A BIBLIOMETRIC ANALYSIS

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Abstract
The city's growing population is causing an increase in traffic demand for supply, mobility, and reverse logistics areas. These are the challenges that participants in the logistics sector are facing, together with rising commodity demand for fundamental requirements. As a result, many scientists are driven to design logistics solutions to mitigate the impact of a growing population, which increases demand for logistics and supply chains, which also has an influence on the community's environment. However, thorough literature survey studies targeted at finding potential treatments for the management of supply chain disorders using bibliometric, network, and theme analyses are still few and limited. According to the findings of the investigation, the primary supply chain themes are provider logistics and reverse logistics. This research has various implications for reverse logistics in the FMCG industry. According to the research, suppliers must understand that implementing environmental activities with their clients may improve their ability to compete in the market, and the "last mile" of distribution may thus be completed by electric cars because the distances are so short that they do not present any difficulties or require elaborate human planning. Therefore, we find that employing logistics providers to manage the FMCG industry or looking at the strategies of logistics providers for renewable energy might be an intriguing future study area.

Keywords:
Bibliometric; environmental; fast-moving consumer goods; logistics providers; reverse logistics

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1. Introduction

Currently, metropolitan regions house 55% of the world's population, and by 2050, this figure is expected to rise to 68% [1]; as more people live in cities, their population density increases. One-third of urban traffic is thought to be driven by commercial interests [4]. Furthermore, an increase in population will raise traffic demand in city centers for supply, mobility, and reverse logistics. As a result of the world's continually rising population and their consumption of commodities for basic needs, such as fast-moving consumer items, distribution planning research faces new challenges [1]. Fast-moving consumer goods (FMCG) sales outlets have been growing quickly in recent years because of the continual growth of FMCG sales, the integration of FMCG sales channels, and the acceleration of innovation [5]. The FMCG industry is known for being one of the most unpredictable and difficult to thrive in owing to fierce rivalry, the adoption of new rules, and the rapid improvement of technology, which causes buyers to not readily forgive any tiny flaws or issues with goods.

Because of a low unit volume of FMCG distribution, these commodities are frequently produced in batches [2]. The creation of optimal distribution strategies for batch items across many sites is necessary to satisfy the demands for a high consumption rate. Additionally, the amount of greenhouse gases (GHG) released into the atmosphere is increased by the expansion in road traffic and the usage of road freight transport. All facets of an organization's logistics must be green because it is one of the top market concerns today [6]. Therefore, it is essential to decouple an increase in transport-related emissions from an expansion in the supply of commodities, mobility, and reverse logistics. Many businesses measure their carbon footprint to assess their global environmental effect. The GHG emissions for which an organization, a product, an event, or a person is directly or indirectly responsible are referred to as their "carbon footprint." [3]. Carbon dioxide is the most common greenhouse gas produced by human activity, and it is mostly produced when fossil fuels are utilized for transportation, heating, and electricity generation [7].

Over the last two decades, the environmental implications of logistics have received significant economic awareness, particularly in Europe and Asia [8]. Green logistics is concerned with environmental logistics and supply chain management challenges. Hazardous material transportation and disposal are regularly monitored and restricted. Packaging and its materials, and associated objects used in the activities of manufacturing, storing, or transporting a product are increasingly being removed and neglected by organizations. If not addressed properly, these concerns burden forward and reverse logistics activities by possibly raising prices and having a negative impact on customer service.

World well-known logistics services providers like DHL, UPS, and FedEx tested the best way to integrate electric cars into their distribution networks to be ready for any future law changes and limitations while still trying to meet consumer expectations [9]. However, there are not many examples of electric cars being used for commercial transport and delivery, and more real-world trials and experiments will help us better understand the conditions and options for using electric vehicles for deliveries in cities [1]. By analyzing findings from industrial pilot projects, this research aims to contribute to the debate about whether switching to electric vehicles for urban deliveries for the emerging market, even in part, will help to meet urban transportation needs while also helping to reduce emissions from commercial transportation in cities. To this end, this research aims to address the following research questions:

RQ1. Which environmental measures are most prevalent in the FMCG sector?

RQ2. In what situations should logistics suppliers switch to electric vehicles?

Therefore, this study is the first to conduct a bibliometric and network analysis to identify the primary literature topics with a focus on reverse logistics in the FMCG business and logistics provider change. The remainder of this work is structured as follows: Section 2 describes how we conduct the literature search, choose the relevant studies, evaluate the research streams, and gather the data. Section 3 then undertakes bibliometric, citation, and network studies to efficiently meet the study objectives. Section 4 addresses the primary research streams and methods derived from the analysis. Section 5 presents the important results and future research needs based on the revealed findings.

2. Research Methodology

A. Main Research Steps

In management science, there is no formal study approach to conducting a comprehensive literature review. We incorporate and refine the methodology used in previous research that managed a comprehensive literature review on logistics and SCM. This is based on various steps we took in putting together this document, including the following: 1. Topic identification, 2. Literature search, 3. Bibliometric analysis, 4. Citation analysis, as presented in Fig. 1. In the first step, we brainstormed to decide the themes to be mentioned in the paper. The mutually agreed-upon topics are then used as keywords in our search for relevant journals. The following stage will be to undertake a bibliometric analysis to identify publications by year, nation, institution, and journal, with the goal of presenting the data required for the discussion in this work.

B. Topic Identification

The fast-moving consumer goods (FMCG) sector makes a substantial contribution to a country's GDP growth. Since a result, the relevance of reverse logistics (RL) has grown, since the FMCG sector cannot escape RL. As a result, it is critical for the industry to execute RL strategies that can lead to firm competitiveness [18]. Some reverse logistics practices that need to be applied to FMCG company management are strategies for recycling, reuse, re-production, re-packaging, recall and waste disposal. Companies in the FMCG supply chain must also be able to embrace recycling as an investment in order to increase performance and move towards sustainable growth [22]. This sector will attain several aims and improve business competitiveness by implementing RL methods. The primary goal of this study was to explore RL techniques and their impact on company competitiveness [18].

C. Literature Search

Throughout the literature search “logistics provider”, “reverse logistics” and “FMCG” are used as the main keywords. We conducted a literature search using the National Library of Indonesia e-resources platform is used in this literature search. National Library of Indonesia e-resources is a platform provided by the National Library of Indonesia that includes many platforms for searching journals, articles, and e-books. Some platforms included in National Library e-resources include science direct, EBSCO Host, Wiley online library, and many more local and international search platforms (some shown in Fig. 2). The first search yields 1,138 results by entering ("Third-Party Logistics" OR "System Suppliers" OR "Transport*") AND ("Green Transportation" OR "Renewable Energy Logistics" OR "Reverse Logistics") AND ("FMCG"). After that, we removed non-journal and non-English texts, resulting in 101 journals. Furthermore, the publishing year of the 2013-2021 journal is limited to 78 journals. The final stage is to gather and analyze these journals by reading the scope, titles, and abstracts to compile 15 journals relevant to the themes we will cover. All the papers selected as being most related to the survey's subject were then utilized to conduct bibliometric, citation, and network analysis.

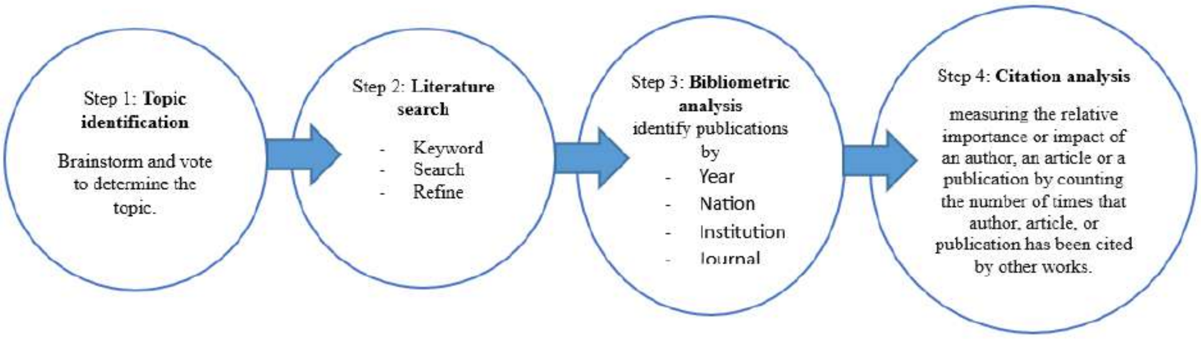

Figure 1. Research method

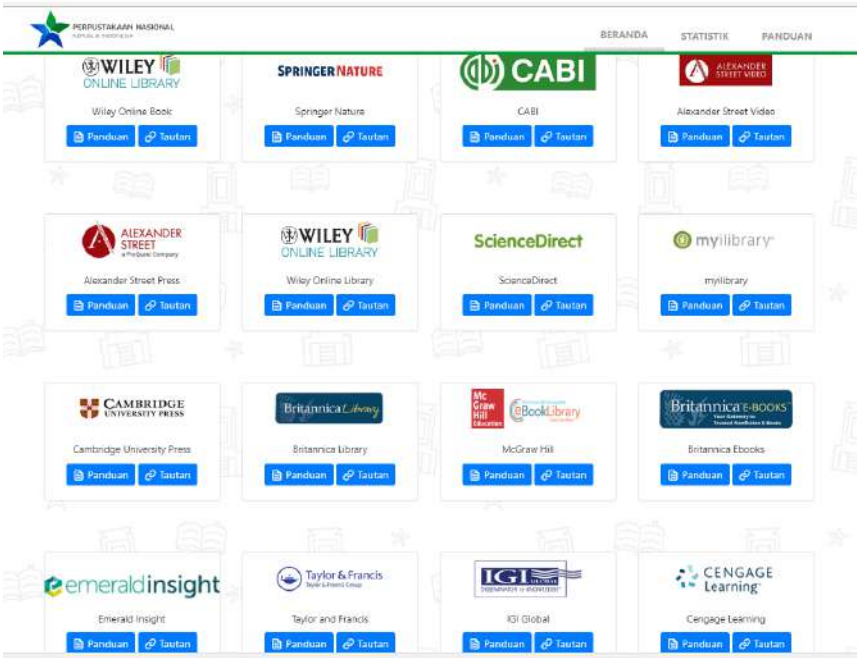

Figure 2. E- resources national library of Indonesia

3. Bibliometric Analysis

A. Publication by Years

Table 1 shows the distribution of 15 journal articles during 2016–2022. During that time, there has been no constant growth. But every year, there is at least one journal article. The most journal articles found were in 2018, 2019, and 2021, with a total of 3 journal articles. Following that, two journals will be published in 2016 and 2022. This unstable distribution shows that this research field is rarely published and that there are many gaps that need to be filled regarding the logistics of providers in FMCG. It is hoped that this trend will continue and that more articles will be published in the future.

Table 1. Years of publication

Years	No. of Article
2016	2
2017	1
2018	3
2019	3
2020	1
2021	3
2022	2

B. Publication by Countries

Table 2 shows the distribution of the number of publications of journal articles by country. We aim to identify countries that have contributed to this area of research. In the article analysis, the first author's country is considered the article's country of origin. The 15 articles we collected are spread across 11 countries. As can be seen, the highest number of publications came from South Africa with 3 articles or 20% of the total number of articles used, then followed by Germany and Serbia with 2 articles each and 8 other countries with only 1 article respectively. Trends show that research related to FMCG is not only about developed countries but also developing countries like South Africa.

Table 2. Publication by countries

Countries	No. of Publication
South Africa	3
Germany	2
Serbia	2
Belgium	1
China	1
Hongkong	1
India	1
United Kingdom	1
Malaysia	1
Slovenia	1
Sweden	1

C. Distribution of Authors in Institution

Table 3 shows the number of authors by the institution. We aim to identify institutions where authors contribute to this research field. The 15 articles we found were written by 48 people spread across 27 institutions. With an average of each journal article written by more than 3 people. These 27 institutions consist of 24 universities and 3 private organizations. One of the 48 people is affiliated with universities and research institutions. The results of the analysis show that the University of Pretoria, South Africa, is the institution with the most authors (6 articles). Followed by the University of Belgrade, based in Serbia, and the University of Antwerp, based in Belgium, with 5 authors each. The large number of authors based in South Africa shows that there is a research trend related to FMCG in that country, where research usually focuses more on developed countries.

Table 3. Publication by institution

Institution	No. of Author
University of Pretoria	6
University of Belgrade	5
University of Antwerp	5
Loughborough University London	2
Cranfield University	2
Institute of Transport Research Rutherford	2
Universiti Sains Malaysia	2
University of Bremen	2
Beijing Technology and Business University	2
Nelson Mandela University	2
Jönköping University	2
Hang Seng Management College	2
University of Defense in Belgrade	1
University of Kragujevac	1
Calcutta Business School	1
University of Maribor	1
Polytechnic University of Cartagen	1
Universiti Putra Malaysia	1
Taylor's University	1
Delhi Technological University	1
Management Development Institute, India	1
Malmö University	1
Hanken School of Economics	1
The Hong Kong Polytechnic University	1
Hellmann Worldwide Logistics Road & Rail GmbH & Co	1
Zaragoza Logistics Center	1
Beijing Food Safety Research Base	1

D. Distribution of Authors in Institution

The collected articles were published in 12 different journal outlets. Table 4 shows 20% or 3 articles published in a well-known journal, i.e. the Journal of Transport and Supply Chain Management. Furthermore, there are two articles published in the Transport journal. Various articles from different journals show that a multidisciplinary approach is needed to analyze problems and solutions related to this research field.

Table 4. Distribution of journals

Journal Name	No. of Article
Journal of Transport and Supply Chain Management	3
Transport	2
Advance in Production Engineering & Management	1
Facta Universitatis, Series: Mechanical Engineering	1
Futures	1
Journal of Shipping and Trade	1
Jurnal Pengurusan	1
Logistics	1

Logistics Research	1
Management of Environmental Quality: An International Journal	1
Research in Transportation Economics	1
Transportation Research Part D	1

E. Keywords

One of the aspects that are examined with bibliometrics is the keywords that are expected to describe the overall content of a document. We use keyword analysis to identify related FMCGs. We use VosViewer software and choose co-occurrence analysis, which can analyze the most popular or frequently used keywords from articles collected about 3rd party logistics (3PL) on FMCG. We use co-occurrence authors with 72 keyword search results. Then we exclude the searched keywords, namely FMCG, reverse logistics, 3PL, and transport. We also remove word combinations that have similar meanings to keywords, such as "fast-moving consumer goods" and “third-party logistics”. Fig. 3 shows the top keyword that is dominant which is logistics service providers then comes the service quality index.

Figure 3. Keywords network

4. Citation and Network Analysis

As part of this study, a literature review was conducted to address the research questions of transport developers with reverse logistics in FMCG (i.e., identify the most influential articles on supply chain, main topics, streams of research, and their contributions; identify the most promising and usable strategies effectively to address concerns about transport developers with backward logistics on FMCG), as shown in Fig. 4. Many studies have employed literary analysis extensively since it is acknowledged as a well-developed tool for comprehensive literature planning. This type of study may be performed not only for one year but also for up to ten years. However, as previously noted, the chronology of publication should be addressed when doing a literature analysis because it may induce biases. In this study, we look at the recent trend from the last seven years. We also employ bibliographical analysis to compensate for the limits of the literature research and get additional insights.

5. Main Research Terms Analysis

This section addresses the main research streams found during the literature analysis and explores how the evaluated publications handle “Reverse Logistics”, “Transports”, and “FMCG”, which details are in the following Table 5.

Table 5. Main research terms analysis

Article	Citation	Methodology	Research Theme
Ksenija Kuzimina, Sharon Prendeville,Dale Walker, Fiona Charnley [10]	58	Quality	FMCG
Dragan pamucar, Malisa Zizovic, Sanjib	52	Quality	Transportation

Biswas, Darko Bozanic [1]			and Logistics (TPL)
Verena Ch Ehrler, Dustin Schoder, Saskia Seidel [11]	37	Quality	Transportation
Eugene YC Wong, Allen H Tai, Emma Zhou [12]	31	Quality	Transportation
Anchal Gupta, Rajesh Kumar Singh [13]	27	Quality	Sustainable Service Quality
Katrien De Langhe, Hilde Meersaman, Christa Sys, Eddy Van de Voorde & Thierry Vanelslander [14]	20	Quality	Transportation
Nandie Coetzee, Wilna L Bean [15]	13	Various methods, theories and best practices were researched to aid in the development of the green business profitability framework	Green Logistics
KM Kumar, AA Rahman, K Jayaraman, Suzuri Abdul Rahim [16]	9	Quality	Transportation
Nagham M El-Berishy, Bernd Scholz-Reiter [3]	8	Quality	Green Logistics
Arno Meyer, Wesley Niemann, Pierre-Roux van Pletzen, Danie smit [17]	7	Quality	FMCG
Andrej Lisec, Slobodan Antic, Francisco CB, Vaska Pejic [2]	6	Simulation	Reverse Logistics
MSM Makaleng, P Hove-Sibanda [18]	2	Quality	Reverse Logistics and FMCG
Milos Milenkovic, N Knezevic, S Val, D Lutovac, N Bojovic [19]	1	Quality	Transportation
L Wang, XY Chen, H Zhang [20]	1	Quality	FMCG
Benedikte Borgstrom, Susanne Hertz, Leif-Magnus Jensen, Elvira Ruiz Kaneberg [21]	1	Quality	TPL

Increasing carbon emissions due to the increased use of transportation is attracting a lot of attention from academics, practitioners, and policy-makers who want to improve logistics and supply chains to make them more environmentally friendly. Transportation is regarded as an important component of logistics and associated supply chains [3, 11, 12, 14, 16, 19]. More scholars are focusing on supply chain transportation than ever before. The most referenced article by K. Kuzmina [10] strives to enhance green logistics transport performance in FMCG. The primary research themes concerning transportation are illustrated in the following Fig. 5.

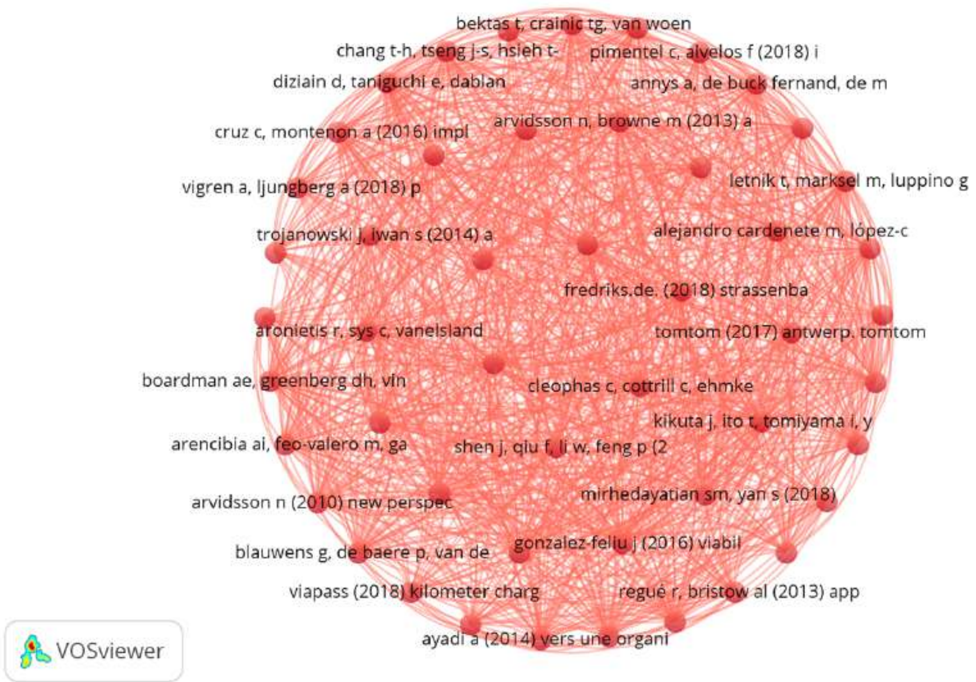

Figure 4. Network of the highly co-cited articles

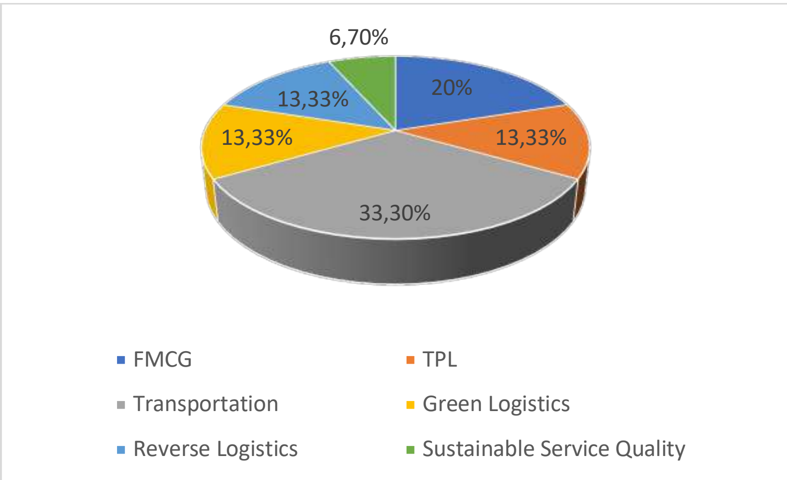

Figure 5. Research streams

6. Conclusion

This study has several implications for reverse logistics in the FMCG sector. First, the literature research revealed that while adopting environmental efforts, the buyer-supplier relationship becomes important. Environmental activities are often incorporated into buyer organizations' supplier selection criteria. The study backs up existing literature from the FMCG business. The findings revealed the effects of environmental activities on buyer-supplier relationships, including competitiveness, cost saving, and improved product quality. The current study's findings corroborate the implications found in a previous investigation by Meyer, Niemann, Van Pletzen, and Smit (2019:1-10). Secondly, the "last mile" of distribution might therefore be completed by electric cars because the distances are so low that they don't present any difficulties or call for elaborate human planning. The movable, highly adaptable micro-hub could be placed wherever necessary. Based on the lessons learned from the field tests of electric trucks presently being conducted in traditional distribution systems, it is predicted that the logistics service provider might already benefit financially from the use of electric distribution vehicles in conjunction with a micro hub. Once the project is operational, this will need to be done thoroughly. It was discovered during the performed literature review that certain of the highlighted features within the gathered studies were explored less than the others and might be further examined in future studies, which is relevant to the demands for future studies. For instance, logistic service providers were identified as a cluster but were given less attention in the most-cited papers. Therefore, employing logistics providers to manage the FMCG industry or looking at the strategies of logistics providers for renewable energy might be an intriguing future study area.

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DRY PORT LOCATION SELECTION: A CASE STUDY OF TANJUNG INTAN PORT

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Abstract
A dry port is established as an inland extension of a port. Tanjung Intan Port, which is located in Cilacap and within the range of tsunami risk zones, has no dry port to accommodate its customers. This research proposes a dry port location selection for Tanjung Intan Port with the following main criteria: adequate road and rail access, safer from tsunami risks, and achieve maximal demand coverage. By applying AHP (Analytical Hierarchy Process), the location candidates were ranked and further selected by using MCLP (Maximum Coverage Location Problem) to choose the best candidate. The study result selects Maos railway station as the most attractive dry port location. The feasibility study result shows that the location has: (1) a lower risk of tsunami impact, (2) potential for the port's market expansion, (3) less pollution potential, (4) adequate railway tracks, (5) large area, (6) good location away from densely populated areas and, (7) easy access for trucks.

Keywords:
Dry Port; AHP; MCLP; location-allocation; tsunami-risk

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1. Introduction

The Cilacap Regency is the largest district in Central Java and is situated on the boundary between the Sunda and Australian tectonic plates, making it vulnerable to earthquakes and tsunamis [1] [2]. With 823 natural disasters in 2019, Cilacap ranks first among the other regencies in Central Java for the frequency of natural disasters. The tsunami incident in Cilacap in 2006 resulted in 167 deaths, eight injuries, and thirty people being affected and displaced, in addition to the frequent occurrence of natural disasters, making Cilacap a location vulnerable to the perils of natural disasters, particularly tsunamis [3]. The only main port in Cilacap is Tanjung Intan Port, which is located in the southern part of the city and is extremely vulnerable to tsunamis [4]. Moreover, Tanjung Intan Port is adjacent to the oil fuel terminal of PT Pertamina. There is a probability that if a tsunami occurs, the port area will also be impacted by potential disasters caused by oil spills from the oil fuel terminal.

With a total weight of 1,628,977.66 kg in 2021, Tanjung Intan terminal is the second-largest loading terminal for exports from Central Java [5, 6], which makes this port a vital role in the economy of Central Java. It is also the only commercial port on Java Island's southern coast. The principal commodity of the port is dry bulk, which includes iron grit, clinkers, coal, and soybeans. However, based on initial observations and conversations with port management, it was determined that shippers and prospective shippers frequently complained about the port's difficult access and the great distances they had to travel to convey their goods. The primary reason for the complaint is the port's remote location from the primary transportation routes in northern Java. Consequently, many prospective shippers in Cilacap prefer to send their products through other ports in northern Java, such as Tanjung Emas Port in Semarang, Tanjung Priok Port in Jakarta, and Tanjung Perak Port in Surabaya, despite the fact that these ports are further away and have an average four-day dwell time. Moreover, prospective shippers did not select Tanjung Intan Port as their primary option because the quantity of goods conveyed is small and the port does not offer container handling services; consequently, it became customary to send non-bulk goods to the northern ports of Java. Despite this, the Tanjung Intan Port remains attractive for dry bulk shippers transporting large quantities of cargo because its dwell time is shorter than other major ports in northern Java. In addition, the port location's susceptibility to disaster risks such as tsunamis is one of the reasons why this is the only commercial port established on the south coast of Java. If natural disasters strike the port area, port operations will be disrupted or rendered inoperable. This may result in economic losses and supply chain disruption.

This study suggests establishing a dry port for Tanjung Intan Port in order to increase the port's appeal to shippers and reduce the risk of natural disasters affecting the port's operations. A dry port, or inland port, is a rail or barge terminal directly connected to a seaport with regular inland transport services [7]. It has the same functions as the seaport but is located far from the sea. It is equipped with high-capacity traffic modes such as rail. Shippers can leave and/or collect their goods at a dry port in intermodal loading units, as if directly to the seaport [8]. This concept eliminates the need for shippers to travel to the seaport, as their products will be transported from the dry port to the seaport by high-capacity modes of transportation such as trains. By simply delivering their products to the dry port, shippers can save time and avoid longer road congestions near seaports. With the existence of a dry port, not only can it facilitate improved logistics solutions for shippers by reducing the distance travelled by them, but it also becomes a way of shifting freight volumes from road to more energy-efficient traffic modes that are less harmful to the environment, and relieve seaport cities from congestion [9].

Currently, there is no dry port linked to Tanjung Intan port. Therefore, planning the location needs to consider various things to sustain the dry port. Site selection aims to select geographic locations for multiple elements in the supply chain [10]. Site selection is required when the organization opens a new facility. The dry port location should benefit the port's customers, such as shippers or cargo owners. Many previous studies have been conducted related to this topic. The research by [11] used Analytic Network Process (ANP) model to select the best location for a dry port in Niger. They analyzed the data based on fifteen respondents on a 22-question questionnaire. The result showed that Dosso, Gaya, and Niamey ranked first, second, and third, respectively. Based on the experts' judgments showed that demand is not the only important criteria to determine the best dry port location. Still, other factors such as cost and proximity are also critical criteria to be considered. Research by [12] applied Analytic Hierarchy Process (AHP) to determine the best location among five candidates for dry port in Turkey. The data were collected from 85 experts. The comparison judgements were made using two different scales: the Saaty's fundamental scale and the balanced scale. The results showed that based on two scales of judgments brought the same in alternatives ranking. But when doing sensitivity analysis, Saaty's fundamental scale is more sensitive than the balanced scale.

According to [7], a dry port location has to be an intermodal rail or barge terminal, is connected to a seaport through rail, barge or truck services, and is located near logistics activities and industrial zones. Hence, it is necessary to consider the distance between the dry port and the location of the cargo owners. Additionally, it is essential to establish a dry port that considers the tsunami risk zone to reduce the risk of the adverse impact of natural disasters on the port. In conclusion, this study focuses on selecting the dry port location that can cover the most demands, away from the tsunami risk zone, and ensuring the selected location is feasible for the dry port construction.

2. Literature Review

The dry port can be a solution to prevent the impact of natural disasters at a port by diverting storage, stacking and administration activities from what was previously in the port to the dry port. Dry port activities include cargo consolidation, warehousing or stacking, customs, and freight by train to port to be subsequently loaded onto ships [13]. Based on the dry port distance from the port, a dry port is divided into three categories, namely distant dry port (> 500 km), midrange dry port (50-500 km), and close dry port (<50 km) [14] [15]. With the establishment of a dry port, port activities can be minimized to loading-unloading processes and shipping activities only.

Abbasi and Pishvaee [16] used a two-stage optimization model based on Geographic Information System (GIS) to obtain optimal dry ports. The first stage is location selection using GIS and Analytical Hierarchy Process (AHP), and then the second stage uses a multi-objective integer model. The result is a dry port location that can reduce costs and pollution, increase customer satisfaction, and increase competitiveness. Burciu, et al. [17] used GIS and Mathematical Modelling of the Maximum Coverage Location Problem (MCLP), taking into account the capacity to determine the location of hubs connecting cereal producers with ports for export. Chanta and Sangsawang [18] proposed an optimization model for locating railway stations in Thailand. The research objective is to maximize the number of passengers fulfilled. Single allocation p-hub Maximum Covering Problem (p-hub MCP) and Simulated Annealing (SA) are used to solve the problem. The result is that SA gets the same optimal answer as Single allocation p-hub MCP with less time. Doerner, et al. [19] conducted a study on determining the public facilities' location in tsunami-prone areas. Minimum facility location criterion, MCLP, Genetic Algorithm (GA) is used to solve the problem.

This research used AHP and MCLP methods to solve location selection problems. AHP was used to select dry port candidates; furthermore, MLCP was used to select the location that could cover the most demands. The difference with previous studies is that this study considers tsunami-risk zone to locate a new dry port facility for the seaport. This research proposes "located in tsunami safe-zone" criteria to select dry port candidates on AHP process. Additionally, a post-disaster export supply chain network concept is proposed if the port is affected by the tsunami.

3. Methodology

This research is a quantitative study using the AHP method and MCLP modelling to achieve the research objectives. The research is divided into four stages. The first stage is problem definition, the second stage is selecting dry port candidates using AHP, and the third stage is candidate selection using the MCLP model. The last stage is feasibility analysis. The selected dry port candidate is further analyzed from market and marketing, technical/operational, and environmental impact aspects. Experiments were conducted using Expert Choice 11 software and AMPL IDE Software Version: 3.1.0.201510231950 with Gurobi 8.0.0 solver.

The locations of dry port candidates are taken from several active stations in Cilacap. The reason for this selection is based on the establishment of Gedebage Container Terminal in West Java, which used to be the Halte Gedebage before it was converted into a dry port [20]. Thus, this study proposes 16 dry port candidate locations in total. Additionally, tsunami-risk area data were obtained from literature studies.

AHP method uses ranking to determine priority [21] [22]. Saaty introduced the AHP, which is very useful when the decision-maker cannot construct utility functions [22]. The stages in the AHP method in this study are the first making a hierarchical model; the second making pairwise comparisons; and the third, selecting candidates based on experimental results [21] [23]. In this research, data on the level of importance of the criteria is obtained from interviews with the technical manager, business manager, and technical supervisor of Tanjung Intan Port. The three samples were chosen because they are the decision-makers in determining the dry port location and knowing the character of the Tanjung Intan Port customers. Data on the level of importance of the candidates are obtained from secondary data. The data are the distance from the candidate to the provincial road or national road, the number of rail lines, the furthest candidate distance to demand, considerable and vacant land around the candidate, the proximity of the candidate's location to industrial areas, distance from candidate to the nearest residential area, distance from outside the yellow zone.

The Maximum Coverage Location Problem (MCLP) method or maximum demand covering problem is a mathematical model to solve location-allocation issues with the objective is to maximize the demand met [24]. MCLP modelling can be used to determine the optimal location with a maximum number of limited or predetermined facilities built [25]. Based on Francis et al. quoted by Farahani and Hekmatfar [24], MCLP is included in covering problems that can be used in selecting warehouse locations, selecting locations for emergency services, and so on. In this research, the demand location data is the primary data obtained from Tanjung Intan Port. The following are the models for the MCLP method and its explanation [24]:

i : Demand location index with $i = 1,2,3,\dots,I$

j : Facility candidate location index with $j = 1,2,3,\dots,J$

d_{ij} : Distance from demand $i \in I$ to facility $j \in J$

S : The facility distance limit can reach the demand

h_i : Demand at node $i \in I$

P : Number of facilities to be built

$a_{ij} = \begin{cases}1\\0\end{cases}$ with 1, if candidate $j \in J$ covers demand $i \in I$, and 0, otherwise

$Z_i = \begin{cases}1\\0\end{cases}$ with 1, if demand $i \in I$ covers demand $j \in J$, and 0, otherwise

$X_j = \begin{cases}1\\0\end{cases}$ with 1, if candidate $j \in J$ is chosen and 0, otherwise

The objective function of MCLP modelling is to maximize the demand that can be met,

$$\text{Maximise} \quad \sum_{i\in I} h_i Z_i \tag{1}$$

Demand that can be reached by more than one facility,

$$Z_i \le \sum_{j\in J} a_{ij} X_j \quad \forall i \in I \tag{2}$$

where a_{ij} = 1 if $d_{ij} < S$, and 0 if $d_{ij} \ge S$

The number of facilities selected does not exceed P limit,

$$\sum_{j\in J} X_j = P \tag{3}$$

The variables X_j and Z_i are binary numbers,

$$X_j \in \{0,1\} \qquad \forall j \in J \tag{4}$$

$$Z_i \in \{0,1\} \qquad \forall i \in I \tag{5}$$

4. Result and Discussion

The determination of used criteria in this study is based on the academic literature and adjusted with the characteristics of the Tanjung Intan Port. More than 50% of Tanjung Intan Port customers are located in Cilacap; therefore, this research focuses on establishing a “close dry port” type, as it will be an added value for the customers if the dry port is built near the customers’ locations [26]. Combining criteria based on the literature study from Abbasi and Pishvaee [16] and Frost [26], it is concluded that six criteria will be used to assess the dry port location in Cilacap. One of our contributions is considering a new criterion for this research: "located in the tsunami-safe zone” to score each dry port candidate’s sites based on the safety from the tsunami risks. In addition, the distance between each candidate and the port has not deemed a criterion because, according to the dry port category, only candidates less than 50 kilometers away from the port are considered. Therefore, regardless of how near the distance is, it is assumed that it has no effect on the attractiveness of the dry port, as it is still less than 50 kilometers away.

Truck-friendly road access is a common consideration for dry port locations. The delivery of goods from the dry port to the port will also be conducted by railway; therefore, the site must have rail access. Furthermore, a dry port typically requires a large area for storing goods and containers, warehouses, buildings, cranes, vehicle activities, etc.; therefore, a large vacant land for the location of the dry port candidates is an asset. Additionally, environmental and social factors are required to ensure the dry port's viability. The location of the dry port in an industrial area, as opposed to a densely populated area, is also an advantage, as the activity of trucks and heavy equipment, such as cranes, as well as the pollution caused by dry port activities, can be disruptive to adjacent residents. Dry port locations should also be avoided in tsunami-risk zones in order to reduce the likelihood of infrastructure damage caused by natural disasters. Even though the Tanjung Intan Port is in close proximity to PT Pertamina's oil terminal, the risk of explosion hazard is not included in the criteria because the scope of this study is limited to natural disasters, specifically tsunamis. The criteria are summarized in Table 1.

Table 1. Dry port location selection criteria

Criteria	Symbol
Easy access to trucking roads	C1
Connected to the railroad	C2
Proximity to customers	C3
Massive land	C4
Proximity to the industrial area	C5
Far from densely populated areas	C6
Located in a tsunami-safe zone	C7

As previously mentioned in the methodology, the locations of dry port candidates are taken from 16 active railway stations in Cilacap. A list of dry port candidates and candidates’ location points can be seen in Table 2 and Fig. 1.

Table 2. Location of dry port candidates

Station Candidates	Symbol	Station Candidates	Symbol
Kroya	A1	Randegan	A9
Sikampuh	A2	Meluwung	A10
Maos	A3	Cipari	A11
Kasugihan	A4	Sidareja	A12
Karangkandri	A5	Gandrungmangun	A13
Gumilir	A6	Kawungaten	A14
Cilacap	A7	Jeruklegi	A15
Karangtalun	A8	Lebeng	A16

Figure 1. Map location of dry port candidates

A. Selecting Dry Port Candidates using AHP Method

The stages in the AHP method in this study are divided into three, the first is the hierarchy model, the second is a pairwise comparison of criteria, and the last is dry port candidates' selection.

- Hierarchy Model

The research hierarchy is depicted in Fig. 2. The hierarchy is based on Ka [27] with a hierarchical order from top to bottom, namely goals, criteria, and alternatives. The top hierarchy shows the goals to be achieved. The goal to be achieved is the dry port location. The second level hierarchy shows the seven criteria in Table 1, and the lowest hierarchy shows the dry port candidates in Table 2.

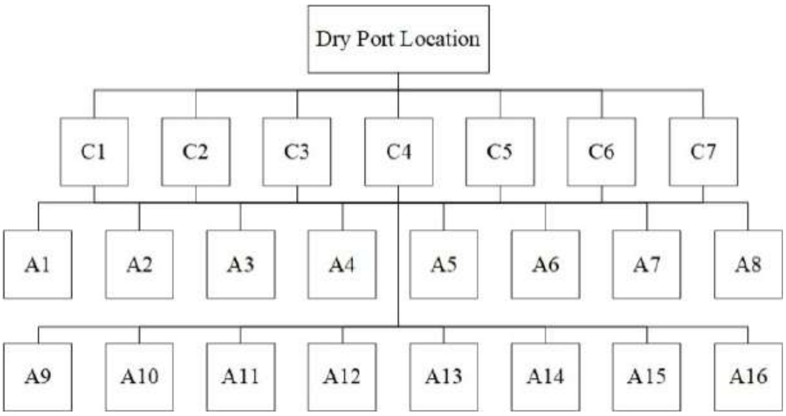

Figure 2. Dry port location hierarchy model

- Pairwise Comparison of Criteria

The pairwise comparison matrix is used to obtain the weight of the comparison of the importance of the criteria with one another. Interviews with stakeholders at Tanjung Intan Port were conducted to get the results of the comparison matrix. The respondents are the Technical Manager, Business Manager and Technical Supervisor. Those respondents were chosen because they are experts who have a role in determining the location of the dry port and are familiar with the character of the Tanjung Intan Port customers. The respondents also played a direct role in the planning and selection of dry port locations. However, insufficient circumstances and data made it

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impossible to conduct interviews with consumers of Tanjung Intan Port. Based on three expert sources who played a role in making dry port development decisions, a comparison matrix is obtained in Table 3 and Fig. 3.

Table 3. Pairwise comparison matrix of criteria.

	C1	C2	C3	C4	C5	C6	C7
C1	1	0.71	1.63	2.43	2.59	4.41	1.73
C2	1.40	1	3.46	3.80	5.85	6.85	2.82
C3	0.61	0.29	1	1.53	2.81	5.92	1.73
C4	0.41	0.26	0.65	1	1.04	3.98	1.01
C5	0.39	0.17	035	0.96	1	3.35	0.67
C6	0.23	0.14	0.17	0.25	0.30	1	0.63
C7	0.58	0.35	0.58	0.99	1.50	1.58	1

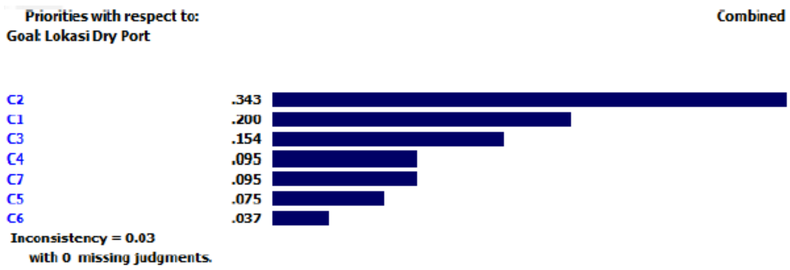

Figure 3. Criteria Priorities

Using Expert Choice 11 software, the inconsistency level is 0.03. The results of the comparison of criteria can be said to be consistent if the level of inconsistency is below 0.1; therefore, the results of the level of importance can be said to be consistent.

- Dry Port Candidates Selection

The selection of dry port candidates is based on the data that has been obtained. The data consist of all data supporting the criterion for each dry port candidate. The data shown in Table 4 was collected for each criterion. These data are further needed for data processing using the AHP method.

Table **4.** Data collection for each criterion

Criteria	Data Collection
C1	• Provincial roads and national roads around the candidate location • Overview access roads to the candidate location
C2	Number of rail tracks on each station (candidate location)
C3	The furthest distance from the customer location point to each candidate location point
C4	Size of empty land around the candidate location
C5	Distance from the candidate location to the nearest industrial area
C6	Distance from the candidate location to the nearest populated area
C7	• Tsunami hazard zones • Distance from the candidate location to the outer line of the Tsunami hazard zone

Each criterion has a criterion objective to be achieved. The details and objectives of each criterion are summarized in Table 5.

Table 5. Details and goals of each criterion

Criteria		Detail	Unit	Objectives
C1	Easy access to trucking roads	Distance from the candidate to the provincial road or national road	Kilometer	Minimize
C2	Connected to the railroad	Number of railroad track	Number	Maximize
C3	Proximity to customers	The furthest candidate distance to demand	Kilometer	Minimize
C4	Massive land	Large vacant land around the candidate	Hectare	Maximize
C5	Proximity to the industrial area	Proximity of the candidate's location to industrial areas	Kilometer	Minimize
C6	Far from densely populated areas	Distance from candidate to the nearest residential area	Meter	Maximize
C7	Located in a tsunami-safe zone	Distance from outside the yellow zone	Kilometer	Maximize

The first criterion (C1), the “easy access to trucking roads”, is assessed by analyzing whether the roads around the candidate’s location are passable by trucks. The distance from the candidate’s location to the nearest provincial or national road is also measured. If trucks can pass, the smaller the distance from the station to the provincial or national roads, the better. This criterion ranks as the second most important criterion. The result shows that 6 candidates are not accessible for trucks because there are not enough wide roads surrounding them. Those candidates are A2, A4, A5, A9, A11 and A14. On the other hand, there are 5 candidates who are located next to provincial or national roads: A12, A13, A15, and A16. Other candidates are located near provincial or national roads and still accessible for trucks, where A3 and A6 are the nearest. The second criterion (C2), “connected to the railroad”, is assessed by the number of available railroad tracks at the station. A dry port must have at least 3-4 railroad tracks, of which 1-2 tracks are for dry ports and 2 are straight railroad tracks [26]. The pairwise comparison ranks this criterion first as the most important. The result shows that A1 has the most railroad tracks of 9, followed by A3 and A8 with 7 tracks each. A7 has 5 tracks, and other candidates have below 5 tracks.

“Proximity to customers” as the third criterion (C3) ranks third most important. The closer the distance from the candidate to the furthest demand, the better. A15 has the closest distance to the furthest demand with 30,02 kilometers, followed by A8 with 34,81 kilometers. Other candidates rank from the less distance to the most distant, respectively: A16, A6, A7, A5, A4, A3, A14, A2, A9, A13, A10, A1, A12, and A11. The fourth criterion (C4) of “massive land” ranks the fourth most important. The wider the available land, the better it is to accommodate the volume demand and truck activity in the dry port. There are 10 candidates with no empty land around them, namely candidates A1, A4, A5, A6, A7, A11, A12, A13, A14, and A15. For example, candidate A1 (Kroya Station) is located in the middle of a densely populated area, making building a dry port quite challenging. On the contrary, there are 6 candidates around which there is vacant land, namely candidates A3, A2, A9, A8, A16, and A10. Candidate A3 (Maos Station) has the most vacant land around it, approximately 187 ha.

“Proximity to the industrial area” (C5) ranks the sixth most important. The criterion’s score is better if the candidate’s location is closer to the nearest industrial zone. Candidate A7 (Cilacap Station) is located closest to Tanjung Intan Port Industrial Zone, A8 (Karangtalun Station) is closest to Cilacap Industrial Zone, A5 (Karangkandri Station) is closest to Karangkandri Industrial Zone, and A3 (Maos Station) is closest to Bunton Industrial Zone. C6 criterion of being “far from a densely populated area” ranks the least important. The further the candidate is located from a densely populated area, the more suitable it is as a dry port location. A3 (Maos Station) has the furthest location from a populated area, while A1, A4, A5, A6, A7, A11, A12, A13, A14, and A15 are located the nearest.

The tsunami-prone zone is divided into two: the Tsunami Hazard Zone I or the red zone, indicating the zone is dangerous for an estimated tsunami wave height above 3 meters. Tsunami Danger Zone II, or the yellow zone, indicates that the zone is dangerous for estimated tsunami wave heights below 3 meters. The last criterion of C7, “located in the tsunami-safe zone”, is measured from the station distance from the outer line of Tsunami Hazard Zone II. One candidate is located in the Tsunami Hazard Zone I, A7 (Cilacap Station). The furthest location considered the safest is A10 (Meluwung Station), followed by A11, A12, and A13. Other candidates are located at least 11 kilometers and less from the outer line of the yellow zone.

All these data then being processed using Expert Choice 11 software to obtain dry port candidate ratings. Based on the seven criteria objectives in Table 5 above, the type of each criterion was adjusted on the Formula Grid toolbar. The increment formula type is used for maximization criteria objectives, while the decrement formula is used for the minimization. Each criterion is also measured for the lowest and highest values to serve as the lower and upper limits. Criteria data is then entered on the Data Grid toolbar. The candidate ranking results are shown in Fig. 4. Maos Station (A3), Kroya Station (A1), Karangtalun Station (A8), Cilacap Station (A7), and Jeruklegi Station (A15) are the top five dry port candidates. It was found that Maos Station resulted first on AHP because it has high scores on several important criteria. Maos Station has 7 rail tracks, which is the most important criterion for dry port location selection. The station also has easy access to trucking roads and is located quite near to the furthest customer. Although the station is located only 1,03 kilometers from the outer line of tsunami hazard zone II (yellow line), so are most other candidates, and it is still in the safe zone. Most importantly, the station wins in having massive empty land to be utilized for dry port construction and is located far away from the populated area.

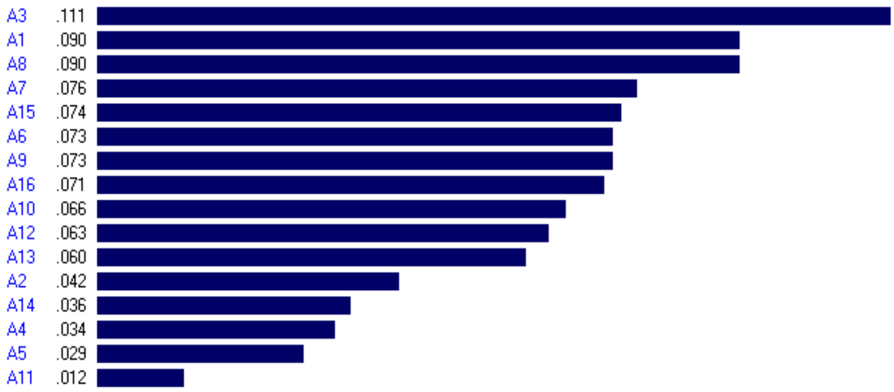

Figure 4. AHP result

B. Selecting The Best Dry Port Location using MCLP

To determine the best location, we combine the AHP and MCLP as optimization model. It is also our contribution to the paper. Combining those methods is justified to accommodate the bias when evaluating multi-criteria. The top five candidates derived from AHP are further selected by using MCLP to get the best candidate who can cover the most optimal demand. As the study focuses on the close dry port category, the distance limit $S = 50$ km of which a candidate can reach the dry port location is determined based on demand changes in modes of transport trucks to trains at a distance of 50 km [28]. It is also determined based on the characteristics of goods owners who use container services are dominated by 50% at a distance of 0-50 km [29].

When the number facility built is limited to $P = 1$, the result shows that Maos Station (A3) is the chosen candidate with 100% of demands that can be reached by dry port from a total of 93 existing demands. The result shows that Maos Station is the selected candidate with an AHP score of 0.11 and an MCLP result of 100% demands are covered.

C. Feasibility Analysis

The analysis of selected dry port candidates is reviewed based on the business feasibility. A business feasibility study is an in-depth study of a business to be carried out to determine whether the business is feasible or not [30]. The business feasibility is divided into seven aspects: legal aspect, market and marketing aspect, financial aspect, technical/operational aspect, management and organization aspect, economic and social aspect, and environmental impact aspect. Based on the research of Black, et al. [31], Crainic, et al. [15] and Dadvar, et al. [32], the business feasibility analysis discussed in this study only focuses on market and marketing aspects, technical/operational aspects, and environmental impact aspects.

a. The Market and Marketing Aspect

This aspect discusses the real market, potential, and marketing strategies [30]. The actual market is a collection of customers with interest, income, and access to certain products or services, which means that these customers are sure to make transactions. Market potential is new customers who desire to buy or use certain products or services.

Using the assumption that all Tanjung Intan Port customers are the dry port's actual market, the dry port’s existing market is industries. Although in the MCLP the location of Maos Station can cover all demand, if seen from the distribution strategy based on the closest distance, Maos Station will more effectively accommodate 60% of demand, and the port can accommodate 40%. Fig. 5 shows the export supply chain strategy of Tanjung Intan Port using dry port and can also be used for other seaports in general.

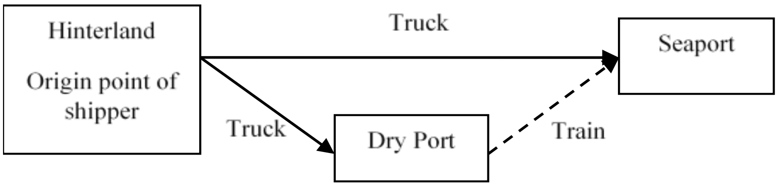

Figure 5. Export Supply Chain Strategy

The general benefit of dry ports associated with this aspect is opening new markets [14]. If seen from the benefits of a dry port and the purpose of this research, the location of Maos Station is suitable for the establishment of a close dry port because, as illustrated in Fig. 6, with an assumed dry port and port range of 50 km, the location of Maos Station has new market potential outside Cilacap, such as Purwokerto while still be able to reach all existing demand. Based on the actual market and existing market potential, the marketing strategy is focused on bringing ports closer to customers and opening up new markets outside the Cilacap Regency.

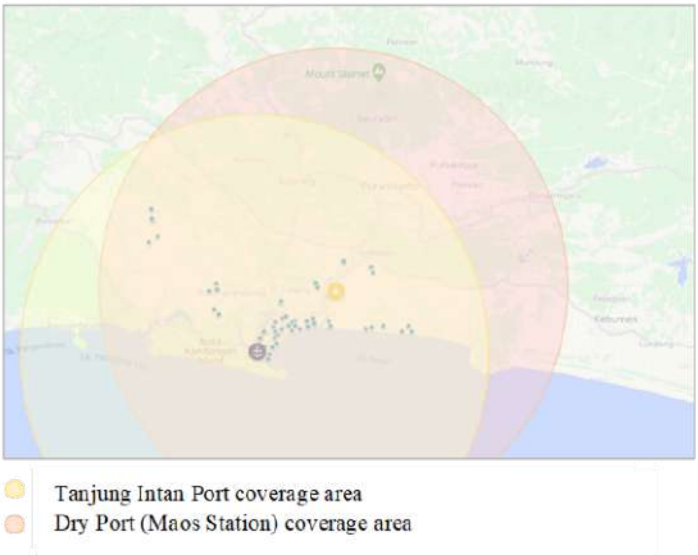

Figure 6. Port and Dry Port Market Coverage Areas

b. Technical/Operational Aspect

This aspect discusses determining the required facilities' location, layout design, and design [30]. The location determination assessment has been carried out using the AHP method. The layout design focuses on the flow of goods into the dry port until the goods arrive at the port. The design of the required facilities is seen from the dry port facilities in Indonesia and the facilities available at the port.

Based on the technical/operational aspects, the location is feasible to establish a dry port with the advantages of an adequate number of available lanes, extensive land, and being far from densely populated areas. Another advantage is the truck road access to the dry port because of its location next to the national highway.

The overview of the inbound and outbound in the layout of the dry port is created. The inbound and outbound dry port layouts can be seen in Fig. 7. The design of the dry port railway route to the port can be seen in Fig. 8.

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Figure 7. Overview of inbound and outbound dry port layout

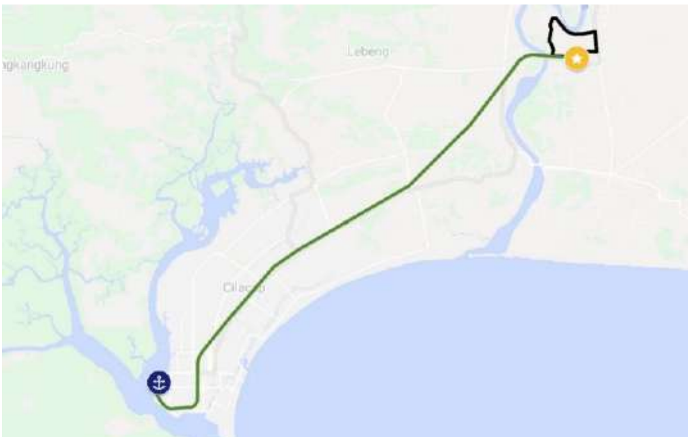

Figure 8. Design of distribution route by train from Maos dry port to Tanjung Intan port

In general, dry port facilities must be available: an intermodal terminal, a strategic location (situated inland), and a rail connection to the port with scheduled and reliable services. It also must provide services available at the freight terminal and port, such as container maintenance, container storage, forwarding, road haulage, and customs clearance [33]. Using the assumption that the area of storage and warehouse required by the dry port is the same as the port, and the construction of a dry port is at least 50 m from TBBM Pertamina Maos to prevent fire and explosion hazards [34]. The facilities that a dry port requires are as follows:

- Land facilities (the total land available = 165 ha)
    - A minimum of 8,7 ha of yard
    - Container yard
    - Empty container yard
    - A minimum of 7.100 m^2 of warehouse
- Area for truck activities (parking, road, et cetera)
    - Building facilities
    - Intermodal terminal
    - Integrated customs
    - Office

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- Equipment facilities (crane, forklift, etc.)

c. Environmental Impact Aspect

Environmental benefits of having a dry port for the port include reducing CO_2 emissions and congestion [14]. Despite the lack of research on the environmental impact of the dry port on the environment around the dry port, it is necessary to pay attention to the potential environmental impacts that may arise during pre-construction, during construction, post-construction, and during operation [30]. This aspect analyses the environmental impact around the dry port caused by the dry port, both positive and negative impacts, analysis of potential disasters at the location, and prevention of the impact of these potential disasters.

From the point of view of the potential for non-natural disasters, the potential problem in establishing a dry port at the Maos Station location is that it is located close to TBBM Pertamina Maos, which can create a risk of fire and explosion disasters [34]. The radius of fire exposure is in the range of 13-20.7 m. The radius of heat exposure is in the range of 5-50 m from outside the tank [34]. To prevent fire and explosion hazards, constructing a dry port is at least 50 m away from TBBM Pertamina Maos.

Due to the dry port location is safer from potential tsunami impacts than the port location, the natural disaster prevention analysis is focused on the port by utilizing the dry port location. In this study, the authors propose a supply chain network concept to overcome the problems of the port export supply chain network due to the tsunami disaster. In the event of a tsunami disaster and the port is affected (Fig. 9 and Fig. 10), cargo owners who are not affected by the tsunami can send their exported goods to the dry port through other nearby ports, such as Tanjung Mas Port, until the recovery period Tanjung Intan Port is finished and the port can normally run again.

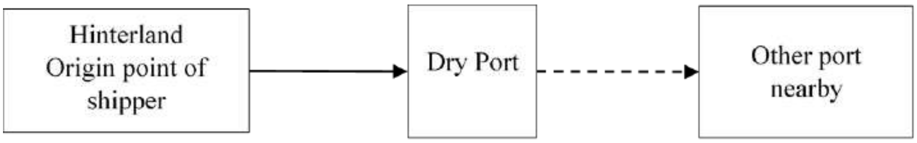

Figure 9. Export supply chain network after disaster

Figure 10. Dry port coverage area post-disaster

4. Conclusion

This study used the AHP method and MCLP modelling to select the most attractive location for the dry port of Tanjung Intan Port, which meets the criteria such as adequate road and rail access, being safer from potential tsunami impacts, and able to cover the demand points of cargo owners. Using AHP, seven criteria need to be considered in choosing the dry port location; (1) easy access to trucking roads (2) connection to the railroad, (3) proximity to customers, (4) massive land, (5) proximity to the industrial area, (6) far from densely populated areas, and (7) located in a tsunami-safe zone. MCLP modelling aims to choose the best dry port location that can cover as many demands as possible.

Maos Station is the best dry port location in terms of these seven criteria, and the location can cover all customer locations. Based on the market and marketing analysis results, the dry port marketing strategy at Maos Station is focused on bringing the port closer to customers and opening up new markets outside Cilacap regency because of its location, which can reach a broader market potential. Based on the technical/operational aspects, the location is feasible to establish a dry port with the advantages of an adequate number of available railway trucks, massive land, and being far from densely populated areas. Another advantage is the truck road access to the dry port because of its location next to the national highway. Based on the environmental impact aspect, dry ports generally provide the benefit of reducing total CO_2 emissions and reducing road loads. The selected dry port location is also safer from tsunami risk, and thus the dry port could be used as a buffer point if the seaport was affected by the disaster.

This study still has not considered a dry port investment and operating costs. Furthermore, it does not pay attention to dry port and train capacity and analysis from other business feasibility (legal, financial, management, organization, economic, and social). Further research is needed in terms of cost comparison between truck and train transportation to determine the level of competition for freight transport modes to improve marketing strategies in terms of price. Further research is also needed regarding the required dry port capacity and dry port layout so that the layout can be designed in more detail. It is hoped that in future research, these things can be considered.

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ANALYSIS OF MAINTENANCE OPTIMIZATION ON MEDIUM VOLTAGE OVERHEAD LINES (SUTM) IN REDUCING ENERGY NOT SUPPLIED (ENS) AT PT. PLN (PERSERO) ULP TARAKAN

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Abstract
The background of this research is an analysis of equipment disturbances that occur in distributing electrical energy. The disturbance is a blackout. Power outages cause a decrease in the continuity of service to customers and result in a lot of loss of electrical energy that is not distributed to customers. The research objectives are to find out the optimization technique of distribution network maintenance, how to reduce the value of energy not supplied (ENS), find out the losses due to ENS, and find out the total electrical energy distributed after preventive maintenance is carried out. This research uses a preventive maintenance method, which is maintenance that can prevent unexpected damage to distribution system networks and equipment. This research optimized preventive maintenance actions by reducing disturbances after preventive maintenance from 7 disturbances in February to 2 disturbances in March. Before preventive maintenance, the loss due to ENS amounted to Rp. 36,192,017.626, and the total electrical energy not distributed was 25,025.76 kWh. After preventive maintenance, there was a significant decrease in the total loss due to ENS of Rp. 953,516,447, and the amount of electrical energy not distributed was 659.28 kWh. This research can increase maintenance efficiency due to electrical energy losses by 97.36% at the time interval when this research data is managed when data collection is carried out in the field.

Keywords:
Electric energy; disruption; distribution system; preventive maintenance; PT. PLN (Persero) ULP Tarakan

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1. Introduction

Increasing population growth accompanied by rapid technological development has increased the demand for electricity for daily needs. Therefore, an electric power system is required to have good reliability in the distribution of electrical energy in the distribution network. In its realization in the field, the distribution system is inseparable from various disturbances that can disrupt the continuity of the distribution of electrical energy to customers/consumers [1]. So that the direct impact felt by customers feel is blackouts, frequent power outages certainly disrupt the activities of customers activities. In addition to losses on the customer side, blackouts also cause losses on the PLN side, namely decreasing customer continuity and resulting in a lot of energy not being distributed to customers. Maintenance activities on the repeater with potential interference are needed to minimize this disturbance. Effective maintenance can be realized by using preventive maintenance methods because preventive maintenance is maintenance that can prevent unexpected damage to the network and can maintain the life of equipment installed on the electricity network by optimizing maintenance activities can minimize the value of electrical energy that is not distributed to customers [1]. Thus, optimizing maintenance using preventive maintenance methods can reduce losses experienced by the company because it can distribute more energy (kWh) to customers and ensure satisfaction on the customer side.

2. Experimental Section

A. Place and Time of Research

This research was conducted at PT. PLN (Persero) ULP Tarakan on Feeder 4 within a period of data collection for four months.

B. Preventive Maintenance

This research uses a preventive maintenance method where preventive maintenance is maintenance to prevent interference with the network and to maintain network work so that it always operates with high conditions and efficiency [3]. The theory in this study follows the title of the discussion to be studied, and references are obtained from various journals, books, and others.

C. Electric Energy (kWh)

Energy is defined as the rate at which electrical power is used multiplied by the time it is used. There are several kinds of energy, such as mechanical energy, electrical energy, heat energy, and so on. From one, energy can be converted into another. The amount of electrical energy can be determined by voltage, current, and time [2]. The formula for electrical energy is as follows:

$$W = P \,.\, t \tag{1}$$

By:
W = Energy (kWh)
P = 1 phase power (Watt)
t = time (hour)
The SI unit for electrical energy is the joule (J) or watthour (Wh).
In a 3-phase system, the energy calculation formula in kilowatt hour (kWh) is:

$$W\ (kWh) = \frac{\sqrt{3} \text{ x } V_L \text{ x } I_L \text{ x} \cos\theta \text{ x t}}{1000} \tag{2}$$

Where:
W = Energy (kWh)
V_L = Line voltage (volts)
I_L = Line current (amperes)
Cos θ = Power factor
t = time (hour)

$$\text{Ct} = \text{W (kWh) x C} \tag{3}$$

With:
Ct = Losses due to ENS
C = Selling price of electricity

D. Research Procedure

Data is co by direct observation and conducting interviews with the parties concerned. After obtaining the data, the next step is calculating the total initial ENS before maintenance and describing and analyzing the maintenance process. Then recalculate the total ENS after maintenance, the data obtained is analyzed as a result of the research, and conclude a confirmation of the results of the research that has been done.

3. Results and Discussion

A. Disturbance Data Before Preventive Maintenance

Table 1 shows disturbances at several key-point in February 2021 in Feeder 4 of PT. PLN (Persero) ULP Tarakan.

Table 1. Disturbance Data Before Preventive Maintenance

No	Keypoint	Current (A)	Load (kW)	Outage time (hours)	ENS (kWh)	Total loss (Rp)
1.	Simpang Intraca	71,83	1.988,29	0,57	1.133,33	1.639.214,408
2.	REC 613	93,31	2.582,86	3,59	9.272,5	13.411.597,957
3.	Trk 4	140,72	3.895,38	1,5	5.843,08	8.450.946,014
4.	Trk 4	13,15	364.26	8,37	3.048,86	4.406.652,834
5.	Trk 4	11,01	304.85	7,19	2.191,94	3.169.368,413
6.	Trk 4	14,82	410.24	7,28	2.986,61	4.319.537,424
7.	Simpang Intraca	29,05	554.98	0,99	549,44	794.700,576
Total undelivered kWh					25.025,76	
Total loss due to ENS						Rp.36.192.017,626

Based on the data in Table 1, in this case, it is taken from the first key point of the Intraca Junction with a measured current of 71,83 A, a load of 1.988,29 kW with a blackout time of 0,57 hours and the amount of energy that is not distributed is 1.133,33 kWh so that the total rupiah at the keypoint is 1.639.214,408 rupiah.
Then the data obtained from PT. PLN (Persero) ULP Tarakan voltage of 20 kV cos θ of 0.8, the amount of energy that is not distributed can be calculated as follows:

$$W(\text{kWh}) = \frac{\sqrt{3} \times V_L \times I_L \times COS\theta \times t}{1000}$$

$$W(\text{kWh}) = \frac{\sqrt{3} \times 20000 \times 71{,}83 \times 0{,}8 \times 0{,}57}{1000}$$

$$W(\text{kWh}) = \frac{1.134.648{,}47}{1000}$$

$$W(\text{kWh}) = 1.134{,}64 \text{ kWh}$$

According to TUL III-09 (electricity sales report), the selling price of rupiah/kWh is Rp. 1.444,70/kWh. By multiplying the amount of kWh against the selling price of electricity, the rupiah estimate is obtained as follows:
Rupiah = 1.134,64 x Rp.1.444,70
Rupiah = Rp. 1.639.214,408
For calculations at other key-point carried out in the same way as above, the results of calculating undistributed energy at other key points can be seen in Table 1 above.

B. Maintenance Data

Maintenance data in March on Feeder 4 can be seen in Table 2 below.

Table 2. Maintenance Data on Feeder 4

No	Feeder	Location	Jobs
1	Feeder 4	Jl. Aki balak juata krikil	Transformer grounding replacement
2	Feeder 4	Jl. Aki balak juata krikil	Transformer grounding replacement
3	Feeder 4	Juata Kopri	Transformer grounding replacement
4	Feeder 4	Jl. Aki Balak	Substation handle replacement

5	Feeder 4	Jl. Jembatan Kuning Juata	7-point tree-guard installation
6	Feeder 4	Jl. Jembatan Kuning Juata	FCO cover installation of two sets
7	Feeder 4	Jl. Jagung Persemaian	3-point tree-guard installation
8	Feeder 4	Jl. Jagung Persemaian	Installation of FCO cover 1 set
9	Feeder 4	Juata Laut	FCO cover installation of five sets
10	Feeder 4	Juata Laut	5-point tree-guard installation
11	Feeder 4	Jl. P. Aji Iskandar	FCO cover installation of two sets
12	Feeder 4	Jl. P. Aji Iskandar	Replacement of FCO jumper cables in two sets
13	Feeder 4	Jl. P. Aji Iskandar	2-point tree-guard installation

B. Maintenance Performed

The maintenance process is carried out in several locations in Feeder 4. The maintenance carried out is the replacement of transformer grounding at the location of Jl. Aki Balak Juata Krikil and Juata Krikil, the time required to perform maintenance is about 1 hour. The process of replacing the old grounding cable transformer grounding is replaced with a new grounding cable. Then the new grounding pipe is planted until it gets a predetermined grounding resistance value. Transformer grounding is installed to anticipate damage to transformer equipment due to lightning strikes. Then the replacement of the substation handle is carried out at the location of Jl. Aki Balak, the time required to perform maintenance is about 1 hour. A substation handle is a tool that functions as a switch on the substation. Replacement of substation handles is done because the old ones are no longer suitable for use, so they are replaced with new ones. For maintenance, a tree guard is installed at Juata yellow bridge, Jl. Jagung Persemaian, Juata Laut, and Jl. P. Aji Iskandar; the time needed to carry out maintenance at each location is about 1 hour. A tree guard is installed to prevent outages due to animals. Tree-guard is an electrical cable wrapper on the power grid; tree-guard protection can prevent phase-to-phase or phase-to-ground contact. Then the FCO cover is installed at the Juata yellow bridge, nursery corn, Juata Laut, and Jl. P. Aji Iskandar; the time needed to carry out maintenance at each location is about 1 hour. FCO cover is a material used to protect FCO cover protection can prevent interference caused by animals.

Furthermore, the replacement of jumpered cables is carried out at the location of Jl. P. Aji Iskandar; the time required for maintenance is around 30 minutes. The jumper cable is an A3C type cable because the cable does not yet have a protector, unlike the A3CS cable, which already has a protector. The following are the jumper cable of the FCO replacement work steps.

C. Disturbance Data After Preventive Maintenance

Table 3 shows the disturbance data after preventive maintenance is carried out in Feeder 4.

Table 3. Disturbance Data After Preventive Maintenance

No	Keypoint	Current (A)	Load (kW)	Outage time (hours)	ENS (kWh)	Total loss (Rp)
1	Rec 613	109,95	3.043,5	0,06	182,61	Rp. 264.120,054
2	Rec 613	101,29	2.803,9	0,17	476,67	Rp. 689.396,393
Total undelivered kWh					659,28	
Total loss due to ENS						Rp.953.516,447

Based on the data after preventive maintenance, in Table 3, the first keypoint rec 613, the measured current is 109,95 A, the system voltage is 20 kV cos θ is 0,8, and the outage time is 0,06 hours. And the amount of energy that is not distributed is 182,61 kWh, so the total rupiah at the keypoint is 264.120,054 rupiah.

$$W(\text{kWh}) = \frac{\sqrt{3} \times V_L \times I_L \times COS\theta \times t}{1000}$$

$$W(\text{kWh}) = \frac{\sqrt{3} \times 20000 \times 109{,}95 \times 0{,}8 \times 0{,}06}{1000}$$
$$W(\text{kWh}) = \frac{182.821{,}42}{1000}$$
$$W(\text{kWh}) = 182{,}82 \text{ kWh}$$

According to TUL III-09 (electricity sales report), the selling price of rupiah/kWh is Rp. 1.444,70/kWh. By multiplying the amount of kWh against the selling price of electricity, the rupiah estimate is obtained as follows:

Rupiah = 182,82 x Rp.1.444,70
Rupiah = Rp. 264.120,054

For calculations at other key-point carried out in the same way as above, the results of calculating undistributed energy at other key points can be seen in Table 3 above.

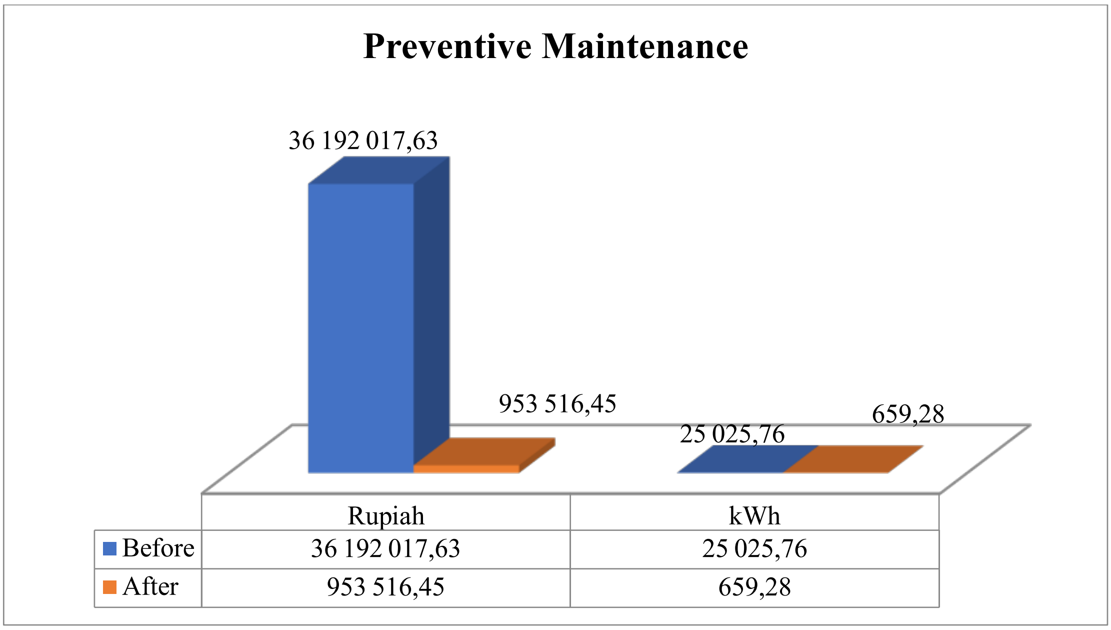

Figure 1. Comparison Chart of Results Before and After Preventive Maintenance

Fig. 1 above shows the difference data from calculating total undistributed kWh (kWh) and total losses due to ENS (Rp) before and after preventive maintenance. Before preventive maintenance, the total undistributed kWh was 25.025,76 kWh, and the total loss due to ENS was Rp. 36.192.017,626, while after preventive maintenance, there was a significant decrease in the amount of energy that was not distributed; namely 659,28 kWh and the total loss due to ENS was Rp. 953.516,447. So that it can be seen the results of the comparison of the difference in the amount of energy (kWh) that can be distributed after the preventive maintenance is carried out by 24.366,48 kWh, and the difference in total losses due to ENS (Rp) after preventive maintenance is Rp.35.238.501,179. So from the above analysis, maintenance carried out on the feeder four medium voltage network using the preventive maintenance method is very effective as a form of effort in reducing energy not supplied (ENS).

4. Conclusion

Based on the results of research on maintenance optimization analysis on medium voltage overhead lines (SUTM) in reducing energy not supplied (ENS) at PT PLN (Persero) ULP Tarakan, conclusions were obtained, among others: The total energy in feeder four that was not supplied (ENS) before preventive maintenance was 25.025,76 kWh while after preventive maintenance the total energy not supplied was only 659,28 kWh so that the percentage reduction in energy not supplied (ENS) before and after preventive maintenance was 97,36%. The total loss due to ENS in feeder four before preventive maintenance is Rp.36.192.017,626, while after preventive maintenance, the total loss due to ENS is Rp. 953.516,447, so the difference in losses due to ENS before and after preventive maintenance is Rp. 35.238.501,179.

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ONE STEP HYDROTHERMAL SYNTHESIS OF NICKEL DOPED TIO2 NANOTUBE

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Abstract
TiO_2 is one of the photocatalyst materials that is widely used and proven for environmental treatment. To increase the activity of TiO_2, TiO_2 has been modified into a nanotube shape with nickel metal doping. The TiO_2 nanotubes with Ni doping have been synthesized with one step hydrothermal process. In this research, it shows that nickel doped with TiO_2 led to a reduction of crystal size and band gap energy. The smaller crystalline size and lower band gap energy enhanced its photocatalytic activity. The best results for photocatalytic activity were TiO_2/Ni with a crystal size of 7.30 nm and a band gap energy value of 3.12 eV. The photocatalytic activity of TiO_2/Ni was tested by degrading methylene blue under mercury lamp radiation, with the best result of 92.73 % degradation of methylene blue, within 240 minutes of photocatalytic activity.

Keywords:
TiO_2 nanotubes; Ni-doping; hydrothermal process; photocatalytic methylene blue degradation

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1. Introduction

Indonesian textile industry is growing rapidly to fulfill the demand from society. Indonesia Central Bureau of Statistic [1] reports that the growth of the Indonesian textile industry continues to increase by around 2.8% per year. The growth also increases the usage of textile dyes. Indonesian textile industry uses around 10,000 types of dyes each year. About 10-15% of textile dyes used in the dyeing process will be dumped along with wastewater. This wastewater can pollute the environment and can cause health problems because some of the dyes used can decompose into toxic and carcinogenic compounds [2].

Several studies have been carried out to remove organic compounds and dyes contained in wastewater such as filtration, precipitation, coagulation, electrocoagulation, and adsorption using activated carbon. However, this method is considered inefficient due to high operational costs and can only transfer contaminants from one phase to another without any destruction [3]. Therefore, a better and more efficient way is needed to overcome this problem, such as photocatalysis process. The photocatalysis method is considered more effective in separating pollutants, decomposing wastewater and polluted air, and have ability to decompose of organic pollutants [4].

One of the proven materials for a photocatalyst is TiO_2. Titanium dioxide or TiO_2 is a semiconductor that has a wide band gap (3.2 eV-3.8 eV) which has photocatalytic efficiency around 5% of solar energy [5]. In addition, TiO_2 is relatively cheaper, stable, non-toxic, and can be used repeatedly [6, 26-28]. However, the wide band gap energy in TiO_2 limits its photocatalytic activity. The TiO_2 have higher activity in the UV region with a wavelength of 388 nm, while the desirable process will be in visible light region [7].

The photocatalytic activity of TiO_2 can be increased in various ways, including by adding doping, making composites using other semiconductors, or increasing TiO_2 active sites [8]. Nanostructured TiO_2 claimed have higher active sites compared to nanoparticle shaped. The well proven nanostructured shape of TiO_2 that has higher active sites such as nanotubes and nanowires. Doping acts as electron trapping which can increase the photocatalytic activity of TiO_2 by minimizing recombination between holes and electrons [9]. The addition of doping in the structure of TiO_2 led to change the electron structure of the TiO2 photocatalyst [10]. By changing the electron structure of TiO_2, the responsiveness to light absorption are changes. Several types of metals that are often used as doping on TiO_2 are platinum (Pt), nickel (Ni), molybdenum (Mo), and palladium (Pd), all the metals have high activity during photocatalysis process. However, due to the high prices of platinum, molybdenum, and palladium, the usage of Ni metal is preferred because it is abundant and cheaper compared to noble metals [11]. The use of Ni metal as doping on TiO_2 can increase its photocatalytic efficiency in the visible light region and reduce the energy band gap in TiO_2 [12].

The process to modify TiO_2 nanoparticles into TiO_2 nanotubes can be done by several methods such as anodization and hydrothermal methods. The nickel metal doping into TiO_2 can be done by various methods such as anodization, hydrothermal, and sol gel methods. In this research, we combine both the modification of TiO_2 nanoparticles into TiO_2 nanotubes and the Ni metal doping with one step hydrothermal process. The hydrothermal process is chosen since the process is simple, low cost and scalable. In this study, we fabricated Ni doped TiO_2 nanotubes catalysts via one step hydrothermal method. The effect of Ni doping has been investigated for photocatalytic reduction of methylene blue.

2. Experimental Section

A. Ni doped TIO_2 nanotubes synthesis

TiO_2/Ni was prepared by the hydrothermal process. The mixture of components TiO_2 (P25, Degussa) and $Ni(CH_3CO_2)2.4H_2O$ (Sigma Aldrich) was prepared according to Table 1. Then the mixture was placed into a 100 ml beaker then 60 ml of 10 M NaOH (Sigma Aldrich) was added. The mixtures were stirred for 1 hour on a hotplate. Then the mixture was put into an autoclave and then heated in an oven for 24 hours at a temperature of 120 °C. The results obtained in the form of solids were washed with 0.1 M HCl (Sigma Aldrich) until they reached a pH of 1-2. After pH 1-2 was reached, the samples were washed with distilled water by using a centrifuge until they reached a neutral pH. The solids from the centrifuge were dried in an oven at a temperature of 80 °C for 6 hours. The solids were then annealed in a furnace at a temperature of 450 °C for 2 hours.

Table 1. The molar ratio between TiO2 and Ni precursors

Samples Name	**Molar Ratio of TiO_2 (P25) and $Ni(CH_3CO_2)_2.4H_2O$**
A	20 : 0
B	20 : 0.5
C	20 : 1
D	20 : 1.5
E	20 : 2

B. Characterization

The synthesized of Ni doped TiO_2 nanotubes (TiO_2/Ni) was characterized by using X-Ray Diffraction (XRD) to analyze the crystal phase and degree of crystallinity. The Diffuse Reflectance Spectroscopy (DRS) has been used to analyze the band gap value of the material. UV Vis spectroscopy has been used to analyze the absorbance of the sample during photocatalyst degradation of methylene blue.

C. Photocatalyst activity on methylene blue degradation

A total of 0.1 grams of solid TiO_2/Ni were weighed and put into a glass container whose surface was covered with aluminum foil. Then 100 ml of 20 ppm methylene blue solution was added and stirred for 1 hour. After stirring, 2 ml of the sample was taken, then put into a centrifuge tube and recorded as the 0^{th} time. The hotplate and glass container containing the sample and stirrer were placed into the photocatalyst reactor.

For the methylene blue degradation, the experiment for arrange calibration curve has been done. UV-Vis Spectroscopy is used for the absorbance value of sample. Based on calibration curve, the concentration of methylene blue can be calculated from equation (1). The Y axis is absorbance value and X axis is concentration of methylene blue.

$$y = 0{,}1853x + 0{,}0052 \quad (1)$$

The photocatalyst test was carried out in the photocatalyst reactor for 4 hours (mercury lamp, blower, and hotplate were turned on). The 2 mL of samples were taken during time interval at 15, 30, 60, 120, 150, 180, and 240 minutes. All samples were centrifuged at 7000 rpm for 10 minutes. After centrifugation, 1 ml of liquid was pipetted and then 2 ml of distilled water was added for the measurement of methylene blue contents by using absorbance method on UV-Vis spectrophotometer.

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3. Result and Discussion

The synthesized TiO2/Ni was characterized using XRD to determine the crystallinity of samples. The TiO2/Ni diffraction pattern for each sample that has been characterized using XRD is shown in Fig 1. Based on the TiO2/Ni diffraction pattern (Fig. 1), all samples were only in the anatase phase. The rutile phase was not detected in the TiO2/Ni diffraction pattern in each sample because the formation of rutile phase began at a calcination temperature of more than 800 ˚C, while in this study the calcination temperature is 450 ˚C. Nickel diffraction peaks that did not appear during XRD characterization indicated that nickel atoms had entered the TiO2 lattice [13, 14]. From the Fig. 1, it was processed using the Scherrer equation to determine the crystallite size.

$$D = \frac{0{,}89\,\lambda}{\beta \cos \theta} \tag{2}$$

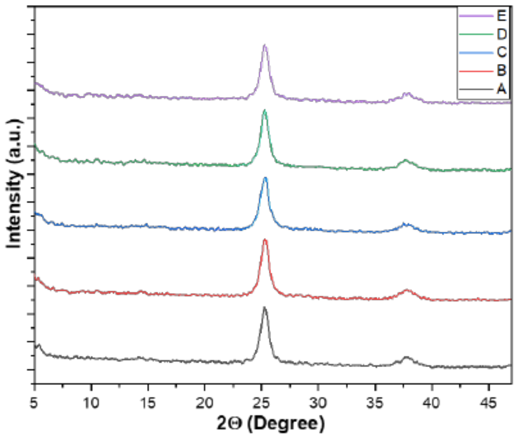

Figure 1. X-Ray diffractometer result of TiO_2/Ni samples

Table 2. Crystallites size of TiO2/Ni sample

Samples	Molar Ratio of TiO_2 and Ni	2θ (˚)	D (nm)
A	20 : 0	25.36	8.09
B	20 : 0.5	25.36	7.88
C	20 : 1	25.26	7.30
D	20 : 1.5	25.19	7.84
E	20 : 2	25.27	8.17

Table 2 shows the crystallite size decreased when nickel doping was added. From Table. II, sample A without nickel doping had a crystal size of 8.09nm, while samples B, C, and D with nickel doped addition has lower crystallite sizes. The addition of doping can affect the physical properties of TiO_2 nanotubes, one of which is to produce a small crystallite size [15]. Photocatalysts with small crystal sizes can induce a larger band gap due to the increased reduction-oxidation ability so as to increase the photocatalytic activity. Materials with nano size (1-100 nm) can provide high photocatalytic activity. The smaller crystal size led to the larger the crystal surface area [16]. The large surface area of the crystal enhances the rate of the photocatalytic reaction, due to the increased availability of active sites in the photocatalyst [15].

The characterization of the synthesized TiO_2/Ni using a DRS spectrophotometer was carried out to determine the light absorption area to calculate the band gap energy value. The band gap energy values will affect during electron excitation process of TiO_2/Ni [17]. In addition, the band gap energy value will also affect the absorption of the required light energy [18,19]. A small band gap energy value will only require a small amount of light energy. Fig. 2 shows the absorbance spectra of the synthesized material at a wavelength of 200-800 nm. From Fig.2, an increase in absorbance begins to occur at a wavelength of 400 nm for all samples. On the curve it can be seen that all samples absorb well in the UV light region where the wavelength is less than 380 nm.

From Fig.2, further analysis was carried out using the Kubelka-munk theory approach to determine the absorption properties of the synthesized material. The relationship between optical absorption coefficients is derived mathematically through the equation F(R) = (1-R)2/2R whose value is proportional to the value of the absorption coefficient per scattering or the value of k/s, where F(R) is the Kubelka-munk factor. The relationship between the Kubelka-munk factor and photon energy is shown in Fig. 3.

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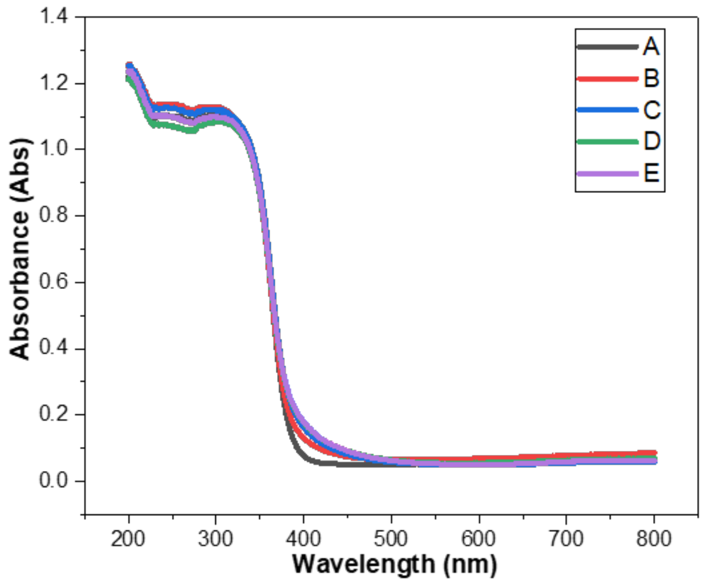

Figure 2. Diffuse reflectance spectroscopy (DRS) of TiO_2/Ni samples

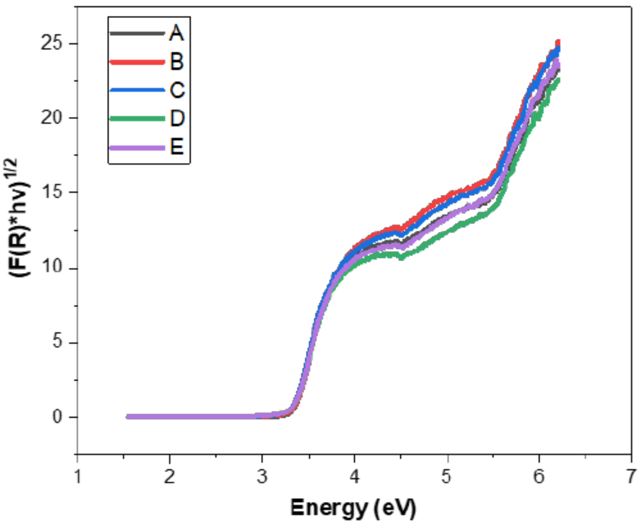

Figure 3. The relationship between Kubelka-munk factor and photon energy for TiO_2/Ni Samples

Based on Fig. 3, the band gap energy value for each sample can be determined by linear extrapolation on the area of the graph that has the highest slope. The results of the linear extrapolation performed on each sample are shown in Table III.

Table 3. Band gap energy of TiO_2/Ni samples

Samples	Band Gap Energy (eV)
A	3.16
B	3.15
C	3.12
D	3.14
E	3.20

Based on Table 3, sample A which was not added with nickel doped had a higher band gap energy value than samples B, C, and D were added with nickel doped. This evidence proves that the addition of nickel doping can reduce the band gap energy value of the synthesized material. The decrease in the energy value of the band gap is due to the formation of new energy levels by nickel doping, so the distance between the valence band and the conduction band is reduced. The smaller the band gap energy value led to the increase of photocatalyst activity to capture the light with lower energy levels such as visible light. Angel et.al mentioned that lower band gap TiO_2 has higher photocatalytic activity for water treatment [29]. The band gap value is increasing again after sample C. This phenomenon happens since there is a possibility of agglomeration of doped metal that led to increasing band gap value.

The photocatalytic activity of TiO_2/Ni was analyzed based on its ability to degrade the pollutant methylene blue. The degradation reaction of methylene blue is shown in Equation 3 below.

$$C_{16}H_{18}N_3SCl + 25,5O_2 \rightarrow HCl + H_2SO_4 + 3HNO_3 + 16CO_2 + 6H_2O \quad (3)$$

The solution of TiO_2/Ni degradation in methylene blue was tested by using a UV-Vis spectrophotometer at a wavelength of 660 nm. This wavelength is the wavelength used to detect methylene blue.

Testing of the photocatalytic activity of TiO_2/Ni was carried out with an initial concentration of 20 ppm methylene blue solution. The selection of this initial concentration is based on the content of dye in the waste produced in the textile industry, which is around 20 to 30 ppm [20]. In the photoreactor, each mixture of TiO_2/Ni and methylene blue will be irradiated using a mercury lamp for a certain time. Prior to irradiation, the sample was dispersed for 1 hour in the dark (without light). It aims to achieve equilibrium conditions for the adsorption of reactants on the surface of the catalyst. During this process there was no degradation of methylene blue which was indicated by the unchanged concentration of methylene blue before and after the dispersion took place.

0	15	30	60	120	150	180	240
minute							

Figure 4. The photocatalytic activity results of TIO_2/Ni samples on methylene blue degradation

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Fig. 4 shows a solution of methylene blue that has been degraded by TiO_2/Ni at test times of 0, 15, 30, 60, 120, 150, 180, and 240 minutes for all samples. The left side samples on Fig.5 are samples at 0 minute. From the visual analysis, there is a decrease in color intensity over time. After being examined using a UV-Vis spectrophotometer at a wavelength of 660 nm, the absorbance value of each sample decreased. The longer the time of irradiation by a mercury lamp to a mixture of TiO_2/Ni with methylene blue, the smaller the absorbance value.

The results of the degradation of methylene blue at 240 minutes for each sample are shown in Table IV and Fig. 5. From Table IV, it shows that samples B, C, and D have a higher percentage of degradation compared to sample A. This indicates that nickel doped samples has higher photocatalytic activity on methylene blue degradation. The smaller crystallite size and lower band gap value had the important effect on photocatalytic activity. This conclusion has been proved by Tan [15] ,where the addition of doping was able to increase the photocatalytic activity of the synthesized material. Tan [15] also study the relation between crystallite size and active surface area, smaller crystallite size led to larger active surface area. The large surface area of the photocatalyst will increase the rate of photocatalytic degradation of organic pollutants because the availability of active sites in the photocatalyst increases [15].

From several research, TiO_2 with the addition of metal doping in the form of iron (Fe), fluorine (F), and boron (B) can degrade methylene blue in the UV light region by 72%, 92%, and 98% [21-25]. Meanwhile, in this study, the addition of nickel (Ni) doping on TiO_2 was able to degrade methylene blue under UV light by 92.73% (sample C). This shows that the use of nickel metal as doping in TiO_2 semiconductors is better than iron and fluorine metals[21-25]. The highest photocatalytic activity of sample C shows that low band gap has effect for photocatlytic activity, as it is proven also by several study [29-30]..

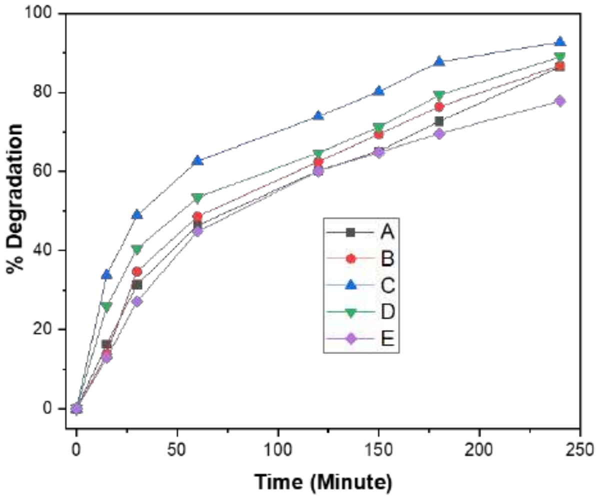

Figure 5. The photocatalytic activity of TiO2/Ni samples during methylene blue degradation

Table 4. The Degradation of methylene blue for TiO_2/Ni samples after 240 minutes

Samples	Degradation of Methylene Blue (%)
A	86. 47
B	86.81
C	92.73
D	88.99
E	77.83

4. Conclusion

The TiO_2/Ni photocatalyst can be synthesized from TiO_2 (P25) and $Ni(CH_3CO_2)_2.4H_2O$ by using one step hydrothermal method in an autoclave at 120 ˚C for 24 hours. From the analysis using X-Ray Diffraction (XRD) the crystal sizes for samples A, B, C, D, and E were obtained, was 8.09, 7.88, 7.30, 7.83, and 8.16 nm. From the analysis using the DRS spectrophotometer, the band gap energy for samples A, B, C, D, and E was obtained, was

3.16, 3.15, 3.12, 3.14, and 3.20 eV. The results of XRD and DRS showed that the addition of nickel doping on the TiO_2 lattice has effect on reduction of crystallite size and the band gap energy value, that led to increasing of its photocatalytic activity. Sample C with a molar ratio of TiO_2 and Ni of 20:1 was able to degrade 92.73% of methylene blue in 240 minutes. While samples A, B, D, and E were able to degrade 86.47%, 86.81%, 88.99%, and 77.83% methylene blue.

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FLAVONOID EXTRACTION FROM PAPAYA (CARICA PAPAYA L.) SEED USING ULTRASOUND – ASSISTED EXTRACTION METHOD AND DETERMINATION OF ITS SPF VALUE

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Abstract
Synthetic compounds with photoprotective property have their limited concentration in sunscreen formulation. Therefore, reaching the maximum UV protection by themselves is difficult. Natural compounds are good consideration to include in sunscreen formulations. Papaya seeds contain large amounts of nutraceutical compounds. However, their presence is often considered as waste. One of many benefits it has is due to the presence of flavonoids, phenols, alkaloids, saponins, and tannins. Flavonoid is one of the alternative compounds that provide beneficial effects on skin UV-protection. Therefore, this study aimed to extract the flavonoid compounds in papaya seeds and test its sun protection factor (SPF) value. Extraction was carried out by varying the mass ratio of the solid/solvent (1:10, 1:20, and 1:30), and the solvent concentration of ethanol (50%, 70%, and 96%) at 45°C for 45 minutes. The results of this study indicate the presence of these compounds in papaya seed extract which was extracted using the ultrasound-assisted extraction method with the maximum extraction yield (11.888%) obtained at 1:30 mass ratio with a 50% ethanol concentration; the highest total flavonoid content was 2.854 mg quercetin equivalent (QE)/g papaya seed at 1:30 ratio with 96% ethanol concentration, and the highest SPF value was at a 50% ethanol concentration which was 12.0775 (at 300 ppm).

Keywords:
Papaya seed; ultrasound-assisted extraction; total flavonoid content; mass transfer coefficient; sun protection factor

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1. Introduction

Ultraviolet (UV) radiation exposure to human is closely unavoidable. Unfortunately, UV is considered carcinogenic and being the cause of numbers of skin disorders [1]. UV radiation is classified based on the wavelength: UVA (320-400 nm), UVB (290-320 nm), and UVC (200-290 nm) [2].

Sunscreen is designed to protect human from sun's UV rays. Nowadays, commercial sunscreen consists of inorganic compound (physical sunscreen) and organic compound (chemical sunscreen). However, these sunscreens each have concentration limitation in formulating sunscreen to reach optimum, yet safe SPF value based on regulation concern [3]. Therefore, we need other organic compounds derived from natural sources so that they are safe for daily use. Flavonoid has been studied to be compounds that can counteract UV-induced radicals, act as antioxidant & anti-inflammatory agent, provide protective effect and absorb UV rays which make it able to protect skin from sun's UV [3].

Papaya seed was found containing phenolic compounds, phenolic acids, and carotenoid with one of which is flavonoids [4]. Ironically, approximately 20% of the total weight of papaya is papaya seeds and account for 30-35% of the waste from papaya which is usually disposed of [4]. There have been previous studies on flavonoid extraction from papaya seed with the variation of extractant used with microwave-assisted extraction method [5], flavonoid extraction on different parts of papaya plant with water as extractant [6], optimizing flavonoid extraction from papaya seed using ultrasound-assisted extraction method [7], and flavonoid extraction from papaya seed with varying drying pre-treatment method with maceration method [8]. By this time, there have not been any studies on flavonoid extraction from papaya seed with ethanol concentration variation, its mass transfer coefficient, and SPF value. Furthermore, the utilization of papaya seeds will highlight its potential and reduce environmental pollution.

Flavonoid extraction of papaya seeds in this study was carried out using the ultrasound-assisted extraction (UAE) method since compared to other methods, especially conventional methods, UAE required low amount of solvent, energy, temperature, and process time [9]. The mechanism of UAE fundamentally consists of the cavitation phenomenon [10]. When the bubbles created from ultrasonic waves collapse near the surface of the plant solute, they will cause the fragmentation, erosion, and destruction of plant structures that leads to solvent entry into the matrix, decreasing particle size, penetrating solvent better, and releasing the extract from the matrix [11].

In this study, we did the optimization for ultrasound assisted extraction of antioxidant from papaya seed. The optimization in this study is related with ratio of papaya seed with solvent amount and the concentration of solvent. From the best sample, we conducted the experiment to calculate the mass transfer coefficient. Furthermore, analysis for the SPF ability of extract papaya has been investigated in our study.

2. Experimental Section

A. Plant material preparation

Fresh papaya (*Carica papaya* L.) seeds were dried by air-drying method at room temperature in well-ventilated room with no direct contact with sunlight for 5 days. The seeds were then ground using an electric blender.

B. Ultrasound-assisted extraction

Finely ground and dried papaya seeds that had been weighed were then put into Erlenmeyer flask and mixed with the solvent. Ethanol, the solvent used, was varied in concentration by 96%, 70%, and 50% with the amount of each being based on the ratio of solvent/solute that had been determined, which were 1/10, 1/20, 1/30 (g/ml).

Extraction was carried out using an ultrasonic water bath at atmospheric pressure with a temperature of 45^{o}C for 45 minutes. The extract obtained was then filtered using a vacuum filter. The filtrate was separated from the solvent with a vacuum oven afterward at 40-50^{o}C and 0.2 atm. The extract yield of each variation is calculated as % (wt/wt) using the equation:

$$\%yield = \frac{dried\ papaya\ seed\ extract\ mass}{dried\ \&\ ground\ \ papaya\ seed\ mass} \times 100\% \quad (1)$$

C. Phytochemical screening

Flavonoid Test. 1 ml of extract was mixed with 1 ml of 96% ethanol and 0.1 gram of Mg powder followed by 10 drops of concentrated HCl. Red, yellow, or brownish orange colour indicates the presence of flavonoids.

Tannin Test. 2 ml of extract was mixed with 2 ml of aquadest and few drops of 1% $FeCl_3$. Blue or blackish green colour indicates the presence of tannin.

Phenolic Compound Test. 1 ml of extract was mixed with 3 drops of 1% $FeCl_3$. Green, red, violet, blue, or black colour indicates the presence of polyphenols.

Triterpenoid Test. 2 ml of extract was mixed with 10 drops of glacial acetic acid and 2 drops of concentrated H_2SO_4. The mixture was shaken well and allowed to stand for a few minutes. The red or violet colour indicates the presence of triterpenoid.

Alkaloid Test. 10 ml of extract was mixed with 1.5 ml of 2 M HCl, then heated for 5 minutes followed by the addition of 5 drops of Dragendroff's reagent. The orange colour and formation of precipitate indicate the presence of alkaloid.

Saponin Test. 2 ml of extract was mixed with 10 ml of hot aqua dest, then shaken for 15 minutes followed by the addition of few drops of 2 M HCl. The formation of stable and persistent froth indicates a positive test for saponin.

D. Determination of total flavonoid content (TFC)

TFC of papaya seed was determined by using the $AlCl_3$ colorimetric method, and the results were expressed as µg quercetin (QE)/g papaya seed. Quercetin was used to make the standard calibration curve.

5 mg of quercetin was dissolved in 5 ml of 96%, 70%, and 50% ethanol then diluted to 40, 60, 80, 100, and 120 µg/ml. 0.5 ml of standard solution of each concentration and 0.5 ml of each extract solution were put separately into vials. To each vial, 0.1 ml of 10% $AlCl_3$, 0,1 ml of 1 M potassium acetate, and 2.8 ml of aquadest were added and mixed well. Each mixture was incubated for 30 minutes at 25^{o}C. The absorbance of each mixture was measured at 438 nm with ethanol 96%, 70%, and 50% as blank. Absorbance data of the vials with standard solution was then

plotted as standard curve calibration, while the absorbance data of the vials with extract solution was used to calculate the TFC using the equation:

$$TFC = \frac{c \times V \times f}{m} \tag{2}$$

where TFC is the total flavonoid content (µgQE/mg dry weight), c is quercetin equivalent (µg/ml), V is extracted total volume (ml), f is dilution factor (1), and m is papaya seed mass (mg).

E. Determination of sun protection factor (SPF)

Dried papaya seed extract of 96%, 70%, and 50% ethanol was dissolved in each ethanol concentration to the concentration of 300 ppm. SPF value was determined by firstly calculated the area under the curve (AUC) of absorbances at 280-400 nm with 5 nm intervals using the equation:

$$[AUC] = \frac{A_a + A_b}{2} \times (dP_{ab}) \tag{3}$$

with A_a is absorbance at wavelength an nm, A_b is the absorbance at wavelength b nm, and dP_{ab} is a difference in wavelengths and b. The AUC of each wavelength segment is summed up to calculate the SPF value using the equation:

$$\log SPF = \frac{\sum AUC}{(\lambda_n - \lambda_1)} \tag{4}$$

with λ_n is the longest wavelength (400 nm), and λ_1 is the shortest wavelength (290 nm).

F. Determination of mass transfer coefficient

Mass transfer coefficient determination was done for the highest TFC extract. Extraction was done in 5 minutes, 15 minutes, 30 minutes, 45 minutes, and 60 minutes. The extracts were put into 5 different Erlenmeyer flask for easy sampling every extraction time mentioned before. Each sample was then vacuum filtered followed by calculating the total flavonoid content by the $AlCl_3$ method for its concentration. The mass transfer coefficient was then calculated by the following equation:

$$k_L a.t = \ln \frac{C_s}{(C_s - C_L)} \tag{5}$$

where k_La is volumetric mass transfer coefficient (min^{-1}), t is time (min), C_s is a concentration of flavonoid at equilibrium (ppm QE), and C_L is a concentration of flavonoid at time t (ppm QE). The mass transfer coefficient was obtained from the slope of the plot of $\ln(C_s/(C_s-C_L))$ versus t.

3. Result and Discussion

The result showed that as the solute-solvent ratio or solid to liquid ratio (SLR) improved from 1/10 to 1/30, the higher yield obtained as seen on Fig. 1. This is occurred due to an increase in solvent diffusivity into plant cells, thereby accelerating the solute dissolution and mass transfer [12]. The improved solute-solvent ratio also makes the ultrasonic wave intensity higher, causing more fragmentation, erosion, and pore formation effects, thereby increasing yield [13]. In addition, the large difference in ratio increases the contact area between the solute and solvent so that it also increases the yield [13].

Table 1. Yield determination in papaya seeds correspond with ethanol concentration and SLR variation

Ethanol Conc.	Solid-Liquid Ratio (SLR)	Yield (%)
96%	1/30	9.7282
	1/20	8.3825
	1/10	5.9288
70%	1/30	10.6689
	1/20	9.4443
	1/10	6.9779
50%	1/30	11.8888
	1/20	10.8839
	1/10	8.0250

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Meanwhile, the higher the ethanol concentration, the lower the yield. This shows that increasing the concentration of water in the solvent increases the extraction yield, in accordance with previous studies [14],[15],[16]. This is because compounds other than flavonoids, and other polar compounds were also extracted and contributed to this higher yield, which are flavonoid glycosides [17], tannin, saponin [18], and ferulic acid [19].

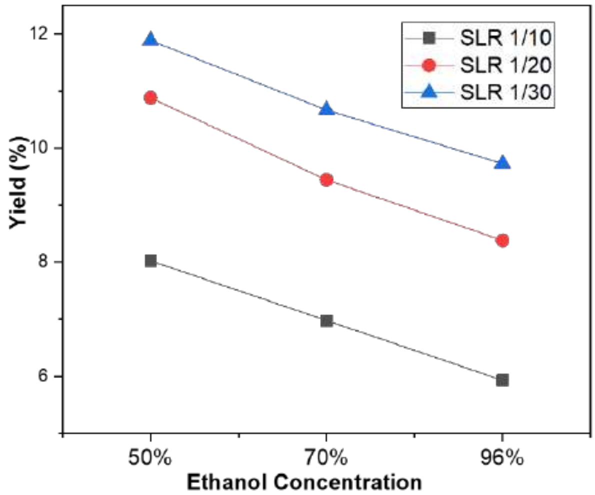

Figure 1. Effect of ethanol concentration and solid to liquid ratio on extraction yield of papaya seed

Phytochemical screening of papaya seed extract is shown on Table 2. From phytochemical screening test, extract of papaya seed contains mixture of flavonoid, phenolic compound, tannin, alkaloid, saponin and triterpenoid.

Table 2. Phytochemical screening results of papaya seed extract

Phytochemical	Result	Compound Example
Flavonoid	Brownish orange (+)	Quercetin, kaempferol [20], naringenin [21], quercetin-3-o-galactoside, quercetin-3-o-glycoside [6]
Phenolic Compound	Green (+)	Caffeic acid, p-hydroxybenzoic acid, ferulic acid, coumaric acid [20], gallic acid [22]
Tannin	Dark green (+)	Tannin [21]
Alkaloid	Orange + precipitate (+)	Quinine, ribalidine [21]
Saponin	Stable froth (+)	Sapogenin [21]
Triterpenoid	No changes (+)	

Table 3. Calibration curve equation of quercetin

Ethanol Concentration	Equation	R^2
96%	$y = 0.0040x – 0.0103$	0.9915
70%	$y = 0.0048x – 0.0184$	0.9932
50%	$y = 0.0050x – 0.0183$	0.9935

Equation of calibration curve of quercetin standard is as seen on Table 3. The result of papaya seed extract total flavonoid content (TFC) showed that 96% ethanol extraction with solid to liquid ratio (SLR) of 1:30 had the highest TFC compared to other variation. The units for represent TFC is mg quercetin (QE) per gram papaya seed. From Fig 2., higher value of SLR resulting in higher the TFC obtained. This could be due to the increasing diffusivity of the solvent into the cell and supporting the dissolution of flavonoids [12]. As the SLR increases, the viscosity and concentration of the extractant will also decrease thereby increasing the cavitation effect in the UAE method [13] and maximizing the extraction process.

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Table 4. TFC determination in papaya seeds correspond with ethanol concentration and SLR variation

Ethanol Conc.	Solid-Liquid Ratio (SLR)	TFC (mg QE/g-papaya seed)
96%	1/30	2.8540
	1/20	2.4388
	1/10	1.9009
70%	1/30	2.5632
	1/20	2.0955
	1/10	1.7229
50%	1/30	TF
	1/20	2.0199
	1/10	1.4070

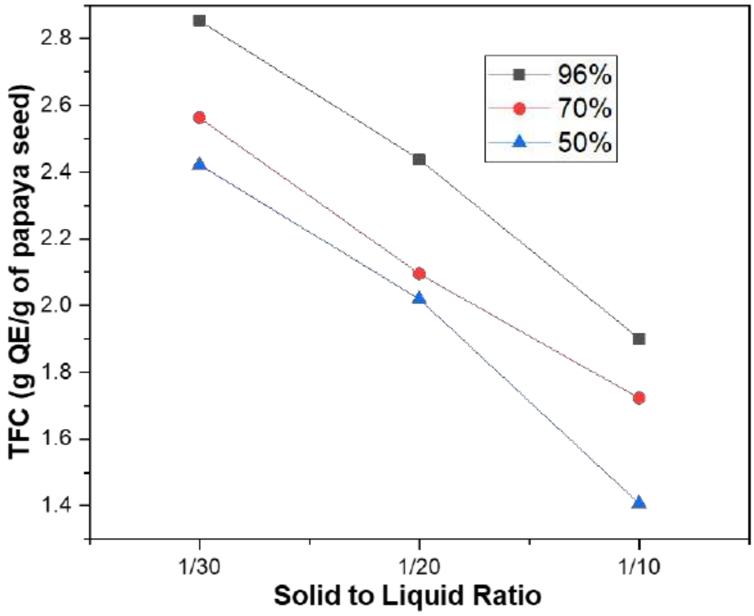

Figure 2. Effect of ethanol concentration and solid to liquid ratio on total flavonoid content (TFC) of papaya seed extract

Meanwhile, the increase in TFC along with the increase in ethanol concentration occurred due to the same level of polarity of ethanol and flavonoids (like-dissolves-like). Solvent with low viscosity and surface tension such as ethanol can also provide good cavitation effects in the UAE process [23].

To design and analyse the extraction process on a large scale, relevant kinetic studies are required. In the extraction process, no chemical reaction is involved, so the mass transfer kinetic model is used to represent the experimental data [24]. Based on the mass transfer theory, during the extraction process of the desired compound, the highest mass transfer resistance in the whole process is involved with the rigid structure of the plant cell wall used and the extraction is considered an irreversible process so it can be concluded that the first order extraction kinetics can be used [25]. The use of first-order kinetics is also determined by the external mass diffusion rate (lumped model) from papaya seeds to the bulk solvent phase with the following assumptions [26]:

- Flavonoids were uniformly distributed in papaya seeds, so that there is no concentration gradient in papaya seeds,
- Samples of papaya seeds are in spherical shape,
- The effective diffusion coefficient of flavonoids remains constant throughout the extraction process,
- Since the ultrasonic process can cause convection in the liquid medium, the extraction solvent was assumed to be well mixed in the extractor and the external resistance to mass transfer in the liquid phase is negligible,
- Mass transfer resistance in the liquid phase is negligible,
- The transfer of flavonoids from solid particle to the liquid phase takes place by diffusion,

There is no chemical reaction or ultrasonic degradation of flavonoids during the extraction process [27].

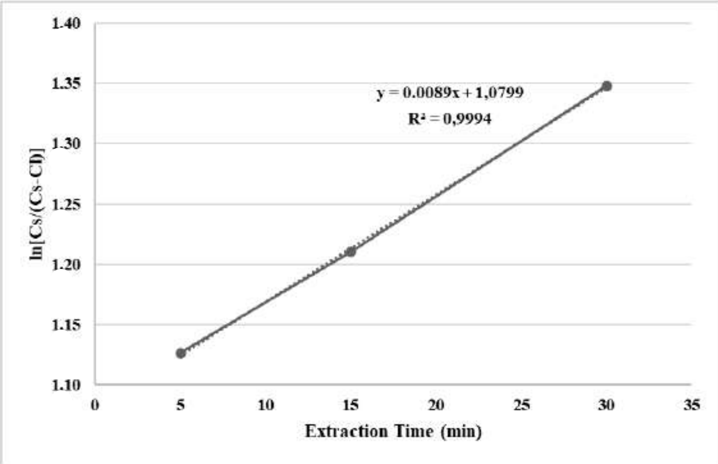

Figure 3. First-order kinetic model of papaya seed extraction

From several research, the mass transfer kinetic model for the extraction of fruit seed is following first order kinetic model that mentioned in equation (5). By using the first-order kinetic model that is approached based on Fick's law [28], the plotted result is shown on Fig. 3 above. The concentration at equilibrium (C_s) used was when the extraction reached the highest TFC which was 71.7 ppm QE with 45 minutes extraction time. After calculating and plotting, the result shown that first-order kinetic was proven as fitted model for the experimental data with R^2 of 0.9994 with the k_La reach 0.0089 min^{-1} or 8.9 mg QE/(g-ethanol. minute).

SPF value of papaya seed extract at 300 ppm was the highest in 50% ethanol extract as shown in Table 4. The results showed that the higher the ethanol concentration, the lower the SPF value obtained. The same result was also obtained for the yield which the lower the ethanol concentration, the higher the extract yield. Meanwhile, the result of the SPF value was contrary to the trend of the TFC value obtained. Although flavonoids have been widely studied and are more responsible for providing protection against UV radiation [31], some phenolic compounds also have the potential for photoprotection [3]. From this research, the obtained TFC content was small so that the SPF value obtained might because of the high total phenolic content (TPC) value which was not tested quantitatively in this study. This result is similar to few studies before, where the SPF value was parallel to the TPC in the *Crataegus pentagyna* extract using methanol as the extractant with UAE method [29], and in the *G. versteegii* leaves extract using various ethanol solvents by maceration where the highest SPF value was at 50% ethanol extract with the highest TPC value [30].

On the other hand, the higher the ethanol concentration, the lower the TPC value, and the maximum TPC achieved in 50% ethanol solvent [32]. This means that the TPC in papaya seed extract had higher polarity than the TFC, so that at 50% ethanol, there were more phenolic compounds, and at 96% ethanol, there were more flavonoid compounds. In addition, according to [4],[6],[20], the TPC in papaya seeds was indeed far more than the TFC content, thereby possibly in this extract, TPC was more influential and had good correlation with the SPF value. Although the one that is known to be more potent with its photoprotective potential is flavonoids. The compounds in papaya seed that are proven more soluble in 50% ethanol are caffeic acid, coumaric acid, p-hydroxybenzoic acid, and ferulic acid [33] which are the most phenolic content in papaya seed [20]; rutin, naringin, quercetin rhamnoside, quercetin glycoside, and kaempferol rhamnoside (flavonoid glycosides) as studied in [6],[34],[35].

The increase in the SPF value which is not proportional to the TFC value in this study might be due to the $AlCl_3$ method for TFC test is only able to detect flavonoids from flavones and flavonols subgroup, while the anthocyanidins (cyanidins), flavanols (catechin), flavanones (naringenin) [36] which also contained in papaya seeds were not detectable [37].

The highest SPF value in this research was 12,0775 of papaya seed extract with 50% ethanol. The value was considered as maximum protection to the classification based on Wilkinson & Moore [38], and based on EU guidelines, approximately considered as low category [39]. The low SPF value of the extract does not mean that papaya seed extract cannot be utilized as sunscreen. According to previous studies, mixing flavonoids from natural sources with synthetic compounds can be used to support an adequate and safe SPF value, for example: a mixture of 0.1% rutin and 6.0% benzophenone increased the SPF from 24.3 to 33.3 when flavonoids were involved, as well as when 10% of rutin and quercetin were combined with TiO_2 and ZnO, the SPF value became around 30 [40].

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Table 5. IR spectrum interpretation of papaya seed extract

Bond	Wavelength frequency (cm^{-1})	50% Ethanol Extract (cm^{-1})	70% Ethanol Extract (cm^{-1})	96% Ethanol Extract (cm^{-1})	Identification Result
-OH	3200-3500	3392.1730	3415.3140	3411.4570	Phenols, Flavonoids, Tannin, Alkaloid, Saponin
-OH water	3100-3700	3392.1730	3415.3140	3411.4570	Hydrate
C-H aliphatic	2700-3000	2838.7030	2842.5600	2838.7030	Ethanol, Tannin, Saponin
-OH alcohol	2700-3000	2950.5500	2954.4110	2952.4820	Ethanol
C=O	1650-1900	1650.7670	1658.4810	1650.7670	Flavonoids, Tannin, Phenols, Saponin
C=C aromatic	1475-1500	1454.0640	1450.2970	1411.6380	Flavonoids, Tannin, Phenols, Alkaloids, Saponin
C-O alcohol	1000-1260	1022.0870	1112.7250	1110.7970	Alcohol, Flavonoids, Tannin, Alkaloids, Saponin
C-O ether	1085-1150	1110.7970	1025.9440	1110.7970	Flavonoids, Tannin, Phenols
C-H aromatic	650-1000	636.3940	688.4626	673.0349	Flavonoids, Tannin, Phenols, Alkaloids
C-OH aromatic	375-450	431.9766	437.7620	408.8350	Phenols
C-N	1020-1250	1022.0870	1025.9440	1022.0870	Alkaloids
C-O-C dan carboxylic ester group	1062-1256	1110.7970	1112.7250	1110.7970	Saponin
Fingerprint region of flavonoid	900-1300	1110.7970	1025.9440	1110.7970	Flavonoids
Fingerprint region of tannin	950-1500	1110.7970	1112.7250	1022.0870	Tannin

From the result of the FTIR analysis as seen on Table 5 and Fig. 4, it shows that the papaya seed extract contains groups of compounds of the phytochemical compounds tested before, which were flavonoids, phenols, alkaloids, saponin, and tannin.

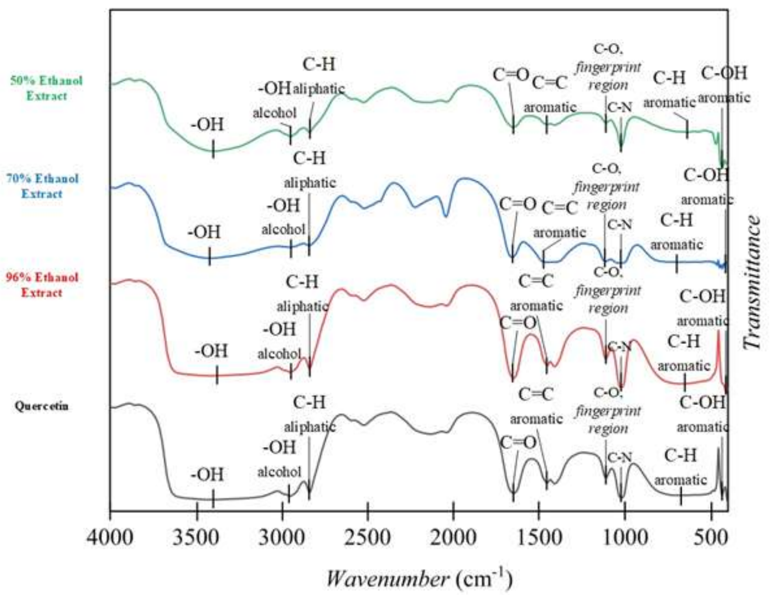

Figure 4. FTIR transmittance spectra of papaya seed extract

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4. Conclusion

In the present work, extraction of flavonoid from papaya seed extract is carried out using ultrasound-assisted extraction method with varying the solvent concentration (ethanol) and ratio. It can be concluded that the smaller the ethanol concentration, the greater the yield value, but the smaller the value of the total flavonoid content obtained. According to recent studies, it was found that by using higher concentration of ethanol (more polar), more other photoprotective compounds were dissolved (ferulic acid, rutin, p-hydroxybenzoic acid, flavonoid glycosides, etc.)

The optimum condition to obtain the highest yield is at a ratio of 1:30 solid to solvent and 50% ethanol concentration, which was 11.8888%wt. Meanwhile, the optimum condition for obtaining the highest TFC was at a solid to liquid ratio of 1:30 and 96% ethanol concentration, which was 2.8540 mg QE/g papaya seed. By using the optimum condition to get the highest TFC, the mass transfer coefficient (k_La) was 0.0089/min or 8.9000 mgQE/(g-ethanol. minute). Furthermore, the highest SPF value of papaya seed extract was obtained at SLR of 1:30 and 50% ethanol concentration with a value of 12.0775.

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