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Foreword

We are delighted to present Volume 7, Number 1, of the *EPI International Journal of Engineering (EPI-IJE)*, published on February 1, 2024. This edition reflects the journal's commitment to fostering innovation and the dissemination of impactful research across a diverse range of engineering disciplines.

This issue features six (6) manuscripts, each offering unique contributions to their respective fields. The first manuscript examines "Pb Adsorption of Coffee Peel Derived Activated Carbon by Varying KOH Concentration," providing insights into the utilization of sustainable materials for environmental applications. The second paper applies ABC and EOQ methods to improve inventory control of patented medicine, offering practical solutions for efficient pharmacy management.

The third manuscript focuses on "Mine Scheduling of Lateritic Nickel Ore in The Mawar Block," addressing key challenges in resource management and mining operations. The fourth paper evaluates "MICE Green Building Scores Using the GREENSHIP Rating System" through a value engineering approach, contributing to sustainable infrastructure development.

The fifth manuscript investigates the "Effect of Temperature Variation in PWHT Dissimilar Welding of Low Carbon Steel ASTM A36 with ASTM A240 Type 316L," advancing the understanding of welding processes and material performance. Finally, the sixth paper provides an "Analysis of Thermal Comfort in Office Buildings," using the Hasanuddin University Rectorate Building as a case study, highlighting essential aspects of workplace design and environmental comfort.

We extend our deepest gratitude to all the authors for their remarkable contributions and to the reviewers for their dedication in ensuring the high quality of this publication. Additionally, we thank our readers for their continued support and engagement with the *EPI-IJE*.

We hope this edition will inspire further exploration and innovation in the field of engineering and contribute to addressing global challenges with impactful solutions.

Sincerely,

Dr. Faisal Mahmuddin
Editor-in-Chief of EPI-IJE

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Pb Adsorption of Coffee Peel Derived Activated Carbon by Varying KOH Concentration

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Abstract

Turning biomass waste into added value products is crucial as it is beneficial to the environment. Coffee peel is a waste that has excellent potential to produce activated carbon. Activated carbon is carbon that has gone through an activation process and has a large surface area and higher adsorption rate. The high need for activated carbon in overcoming waste problems makes it useful to reduce its environmental impact. Activated carbon is widely used in water filtration including heavy metal Pb and Cd. The aim of this research is to study the impact of KOH (Potassium Hydroxide) concentration on Pb adsorption of activated carbon derived from coffee peel. KOH activator could enhance the performance of the activated carbon. The KOH activator concentration is varied to obtain the best-surface structure in activated carbon. The KOH concentration is 2,3 and 4 molars. Each specimen will undergo the same carbon activation process by maintaining the carbonization and drying temperature. Then at the activation stage, variations of KOH concentration will be mixed with the activated carbon and soaked for 24 hours with a weight ratio of KOH to charcoal of 1,5 to 1. The result shown that fixed carbon of 2,3,4 molar KOH concentration is 45.99%, 58.22%, 42.99% respectively, while Pb adsorption are 96.56%, 98.34% and 96.45%. In addition, the adsorption rate of activated carbon is proportional to the concentration level of the KOH solution. However, there is a limit on adsorption concentration, so there is a significant decrease when KOH exceeds the saturation point. Based on this research, Pb adsorption of coffee peel derived activated carbon is quite significant even though the amount of fixed carbon relatively low.

Keywords: Activated carbon; coffee peel; KOH; Pb

1. Introduction

The public interest growth in coffee makes the industry multiply worldwide. The increasing market demand for coffee seeds creates a new problem in the waste form. The availability of abundant coffee peels without maximum utilization in the long term can damage the ecosystem.

Coffee peel is a waste that has excellent potential to produce activated carbon. Activated carbon is carbon that has gone through an activation process and has a large surface area and higher adsorption rate

Activated carbon has a high surface area and good adsorption performance to pollutant molecules such as methylene blue, Pb, and Cd. Coffee peel used as a material for manufacturing activated carbon because of its availability in the environment.

The need for activated carbon is vast. It showed by the increased world demand for activated carbon, growing more than 6% annually and is estimated to reach 1.9 million metric tons in 2020 with a breakdown in area 27% for North America, 14% for Western Europe, 39% for the Asia Pacific, 7% for Central and South America, 7% for Eastern Europe, 6% for Africa.

Coffee peel is waste generated the moment after the production of coffee seed; In Indonesia, there is a lot of unattainable coffee peel because of the immense production of coffee seeds. The coffee peel used in this research originates from Petang District, Badung Regency. Indonesia is the fourth coffee producer after Brazil, Vietnamese and Colombia. Coffee production in Indonesia reached 612,000 tons in 2018. This waste is massive because this coffee is well-known and used by multinational companies. Indonesian effort to re-use this coffee peel is still inadequate, even though the massive volume of this coffee peel (27% of coffee fruit volume).

Pb is a heavy metal with high toxicity [1], a low melting point, and a widely used chemical as a metal mixture [2]. Pb can be found in fuel as a boost to the octane rate and as an anti-detonation or anti-nock in internal combustion engines [3]. Furthermore, Pb can be founded in dyes or paints as a pigment that gives light color [4]. Pb also functions as an anti-corrosion agent to inhibit metals' rust [5].

Heavy metals substances that enter the waters cause pollution in ground and surface waters. This groundwater

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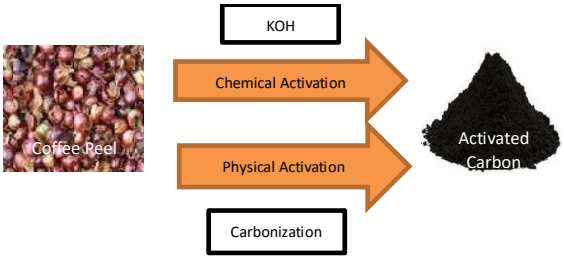

Figure 1. The production process of activated carbon using coffee peel

contamination makes the water undrinkable. Heavy metals also accumulate in living things [6]. Pb is a non-essential heavy metal where this heavy metal cannot be degraded in nature and have an unchanged form [7].

The ability of plankton to obtain heavy metals by eating is excellent [8]. Plankton, especially, Phytoplankton, are at the lowest trophic level [9]. If the plankton as the primary producer is exposed an accumulates the heavy metals, Pb can enter the food chain and reach the higher trophic level.

2. Basic Approach

2.1. Activated carbon

As Shown in Fig. 1, Activated carbon is charcoal that has gone through a process of chemical or physics. The activation definition is to open the charcoal pores from $2m^2/g$ to $300\text{-}3500m^2/g$. The composition of activated carbon consists of bonded atoms by covalent in side hexagons where the molecule-shaped plates are flat. Configuration plates stacked on top of each other with group hydrocarbons, by removing hydrogen and ingredient active (group hydrocarbons) makes the surface and center active becomes large [10].

There are several components of activated carbon parts: ash, fixed carbon, water (moisture), volatile, sulfur, and nitrogen. There are two ways to obtain activated carbon: a weak oxidation reaction using steam water at a relatively high temperature, which ranges between 900-1000°C or chemical dehydration. Many companies now produce activated carbon with the second method to produce specific large surfaces.

2.2. Coffee's peel

A coffee plant is a group of genus Coffea, family Rubiaceous. The genus Coffea has more than 100 species. Arabica Coffee, Robusta coffee and Liberica coffee are three species of coffee cultivated for commercials. Coffee fruit has two major parts: peel (cascara) and bean. Composition of a coffee peel listed below:

Table 1 displays the composition of the coffee peel. Data are expressed as the mean ± standard deviation. Values in the same column with different letters are significantly different ($p < 0.05$)

Table 1. Coffee peel composition

Composition	Acidic Soluble Dietary Fiber (ASDF)
Moisture (g/100 g DW)	3.94 ± 0.02
Protein (g/100 g DW)	2.82 ± 0.05
Ash (g/100 g DW)	2.09 ± 0.01

Acidic soluble dietary fiber is chemical method to extract from soluble dietary fiber with process that contains washed, vacuum drying, and yielding [11].

2.3. Chemical activation

Activation is the process of making carbon become activated carbon. Activation aims to increase the surface area and rate of adsorption. Chemical and physics activation are two methods often used for the activation process. In this research, chemical activation was used because the research variable variated with the concentration activator. The chemical activation method is the process which uses chemicals to break chains of carbon from organic compounds. This method requires a chemical compound as an activator. An activator is a chemical compound to activate carbon to have a higher surface area and better adsorption. The activator's function is to release water molecules and other organic substances that are still attached to the carbon at the time of carbonization.

Furthermore, it will erode pores and form new pores on the surface. Activation could conduct by soaking carbon into alkaline solutions such as KOH or NaOH. Acids like H_3PO_4 or H_2SO_4 and salts like NaCl [12].

In this research, we used KOH as an activator with varying concentrations. KOH is elected as an activator based on its function as a dehydration agent. It has a high-water affinity, functioning as a desiccant, tar transformation inhibitor, and charcoal form agent at temperatures below 200°C [13]. The effect of variations of KOH concentration in the activators determines the specific surface area and the pore distribution on the activated carbon surfaces [14].

2.4. Pb

Pb is a heavy metal pollutant with high toxicity, which causes acute and chronic poisoning. The method to reduce the concentration of Pb is by adsorption. This test was carried out using atomic adsorption spectroscopy (AAS).

$$Pb\ Degrading\ (\%) = \frac{Ci-Cf}{Ci} x100\% \quad (1)$$

The following equation calculates the Pb adsorption capacity (Q_e):

$$Q_e = \frac{\mathrm{Ci-Cf}}{\mathrm{m}} \mathrm{x}\, V \quad (2)$$

where:

Ci = Initial Concentration
Cf = Final concentration
Q_e = Rate of Pb adsorption
m = Mass of adsorbent
V = Volume of Pb solution

Description:

- Atomic Adsorption Spectrometer (AAS) measured the concentration
- m = 0.1 gr
- V = 20 ml

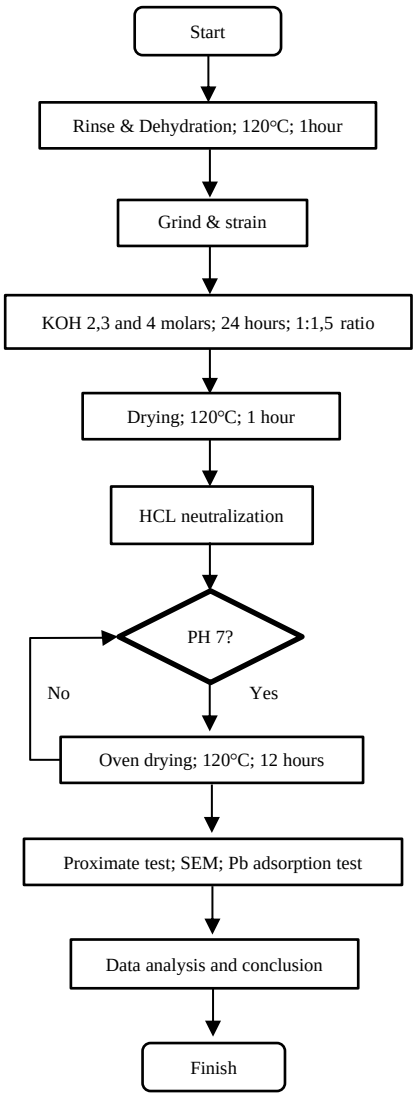

Figure 3. Research flow diagram

3. Research Method

3.1. Materials and tools

The materials and tools used in this research respectively were coffee peel waste, KOH, H_20, silicone dioxide, distilled water, aluminum foil, HCL, Pb solution and oven, jug, pan, furnace, thermocouple, mortal, filter with 100 mesh, proximate analyzer, Litmus paper, PH meter, Scanning Electron Microscope (SEM), AAS.

3.2. Research flow diagram

Reserch flow diagram is shown in Fig. 3.

4. Results and Discussion

4.1. Proximate test

The specimen labelled CSAC 2, 3 and 4 for KOH concentration of 2, 3 and 4 molar respectively. The proximate test determines the content of activated carbon such as moisture, ash, volatile, and fixed carbon.

As Shown in table 2, fixed carbon remains the highest content with the highest value of 58.22% in specimen CSAC 3. The ash, moisture and volatile content influenced the carbon score. If those three values are getting lower, the carbon score will rise.

Table 2. Proximate test

Specimen	Moisture (%)	Volatile (%)	Ash (%)	Fixed Carbon (%)
CSAC 2	7.39	33.68	12.94	45.99
CSAC 3	6.13	33.90	1.75	58.22
CSAC 4	13.14	33.99	9.88	42.99

Figure 4 shown the lowest moisture content acquired in CSAC 3 is due to the nature of dehydrating agent owned by the activator. The CSAC 3 specimen achieves the optimum KOH concentration and effectively lowering the moisture [15].

Volatile levels of specimens with variations in concentration did not show a significant difference. However, there is an increasing trend of volatile along with the increase of KOH; Inadequate temperature carbonization causes this phenomenon and makes the gasses unraveled/trapped, thus making the specimen more volatile.

Ash is a waste that could influence carbon quality. Based on SNI-06-3730-1995, an excellent activated carbon has a maximum ash content of 10%. The lowest ash content value at CSAC 3 with the value of 1.75% which is good and follows the regulation.

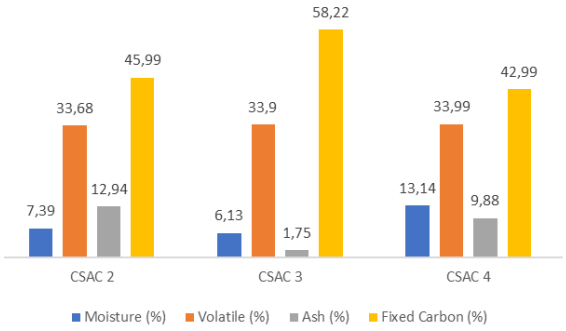

Figure 4. Proximate analysis graph

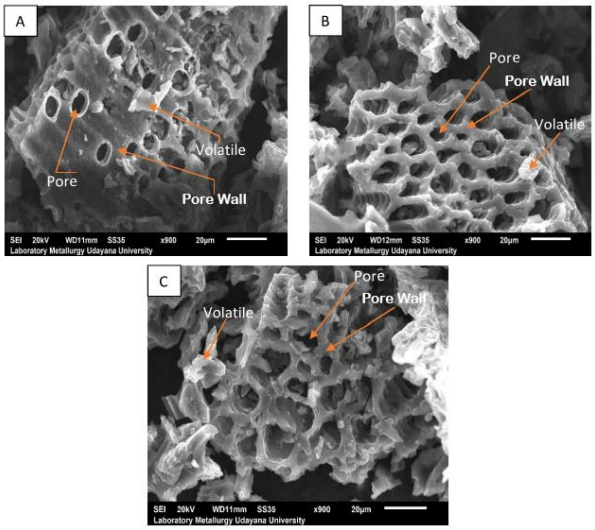

Figure 5. SEM; Activated carbon morphology with 900x magnifying; (a) CSAC 2, (b) CSAC (3), (c) CSAC (4)

Table 3. Pb adsorption test

Specimen	Ci (ppm)	Cf-Ci (ppm)	Qe (mg/g)	Pb Degrading (%)
CSAC2	0.34	9.66	193.2	96.56%
CSAC3	0.16	9.84	196.8	98.34%
CSAC4	0.35	9.65	193	96.45%

4.2. SEM

Figure 4(a) shows the morphology of the pore shape from specimen CSAC 2. few pores formed, and there is no sign of regular shapes. For specimen (b) CSAC 3, there are more pores, and it has a regular form of pore structure. In specimen (c) CSAC 4, pores are formed like the CSAC 3, but it is visible that the pore wall is damaged/collapsed; because of this, the specimen does not have a regular pore structure.

Based on the pore shape of each specimen, the concentration of KOH affects the pore shape of activated carbon. The concentration of CSAC 3 is optimum because it has a lot of pores and regular shapes of pore structure.

The SEM image shows that activated carbon has three main parts: the section of pores, wall pores and volatile (fly substances/dirt). Based on the picture, each specimen still has volatile/substance impurity caused by the washing process, which is still deficient.

Result of adsorption test shown in Table 3 indicate the ability of activated carbon to absorb Pb. The mixture of 0.1 activated carbon and ten ppm 20 ml in aluminum foil lid elementary that had been stirred for 15 minutes with a magnetic stirrer and filtered with "Whatman paper" shows that Pb adsorption is still effective even though the amount of fixed carbon relatively small and the best performance achieved by the CSAC3 specimen.

The atomic adsorption spectrometer shows that the Pb concentration in the CSAC 3 specimen has a value of 196.8 mg/g. The lowest adsorption rate occurred in CSAC 4 specimen with only 193 mg/g. CSAC 2 performance is not entirely different from CSAC 4, with a value of 193.2 mg/g. There is a considerable increase in adsorption rate between CSAC 2 and CSAC 3, but at CSAC 4 specimen with a concentration of 4 molars, the adsorption rate massively decreases to the lowest rate, which indicates the concentration value has passed the optimum limit. It shows that three molar concentration is the optimum concentration for the adsorption rate of Pb; a larger surface with a consistent adsorbent structure makes a higher adsorption rate.

Based on this research, even though the activated carbon has carbon content lower than SNI standard of 65%, it is still effective in Pb adsorption.

5. Conclusion

1. carbon content and surface morphology of the activated carbon. With an increase in concentration, 2, 3 and 4 molars, respectively, the fixed carbon content increase from 45.99% to 58.22%, then decreases to 42.99%. It concludes that the optimum concentration is in 3 molars.
2. KOH activator concentration affects Pb adsorption performance. With increasing concentrations of 2, 3 and 4 molars, respectively, the rate of Pb adsorption increased from 96.56% to 98.34%, then decreased to 96.45%. It concludes that the optimum adsorption rate is in 3 molars. In addition, even though carbon content produced less than SNI standard of 65%, The Pb adsorption is high.

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Application of ABC and EOQ Methods to Improve Control of Patented Medicine Inventory at Pharmacy A

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Abstract

The aim of this research is to analyze drug supply control at Pharmacy A using the Always Better Control (ABC) method to determine drug procurement priorities based on usage and cost guidelines, making it easier to share data regarding relevant matters and budgets for decision-making and separate items that are small in quantity but have great value. Economic order quantity (EOQ) was used to estimate the inventory that will be used, the existence of safety stock, and the time to reorder inventory. Data on drug supplies, drug unit prices, and drug use from January to December 2021 were collected and analyzed using Microsoft Excel. Medicines are classified into three groups based on their investment value. The results showed that group A had the highest investment value (80%) with 41 types of drugs, group B had a medium investment value (15%) with 24 types of drugs, and group C had the lowest investment value (5%) with 19 types of drugs. Group A's EOQ value varies from 9 item to 3170 items. This research recommends that Pharmacy A use the ABC and EOQ methods in managing drug supplies to make it more efficient, effective, and economical.

Keywords: Pharmacy; inventory control; ABC method; EOQ method

1. Introduction

In today's business world, especially in the health sector, public services have become increasingly widespread, as demonstrated by the large number of pharmacies as a means of providing medicines. To maintain the availability of these drugs, planning and procurement for diapharmacies must be managed well. In general, pharmacies plan and control inventory based on previous experience, so sometimes pharmacies experience shortages or excess supplies. This is because the number of needs always changes depending on demand [1].

Law Number 36 of 2009 concerning health states that pharmaceutical practice includes the control and distribution of drugs, drug services based on doctors' prescriptions, drug information services, and drug development must be carried out by health workers who have the expertise and authority in accordance with the provisions of legal requirements [2].

In pharmacy management, one way to support services to satisfy consumers is by providing drug supplies in pharmacies. Inventory is an important element in the operations of a business entity, including pharmacies. Effective procurement requires planning analysis in drug procurement. Good planning analysis can prevent drug shortages and the frequency of unplanned drug procurement [3]. Planning and procurement of medicines is the main key and an important initial stage in the success of the next stage, because the planning stage is very helpful in matching needs with available funds [4].

Pharmacy A is one of the pharmacies that many local people go to. The medicines at Pharmacy A consist of patent medicines and generic medicines. Patent drugs are drugs discovered by a pharmaceutical company through the research and marketing process of drugs. Meanwhile, generic drugs are drugs with names according to the active substance content determined by the Indonesian pharmacopoeia and the International Nonproprietary Names Modified (INN) from the WHO.

Based on the results of interviews with the management of Pharmacy A, the main problem that often occurs is excess and shortage of drug supplies, where excess drugs occur because drugs are rarely purchased by consumers, so the pharmacy holds too much stock of these drugs. Meanwhile, shortages of drug supplies often occur, especially for patented drugs, due to shortages of drugs at suppliers. With the high demand for patented medicines, this is not balanced by sufficient supplies, so there are often stockouts of medicines, which result in patient delays. This is based on the results of interviews with

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pharmacy owners, who said that several patients who came to the pharmacy wanting to buy the same medicine at different times were hampered by the lack of medicine in the pharmacy.

Several cases show that Pharmacy A experienced problems with late orders, which resulted in inadequate customer service and could be detrimental to the company. Based on interviews, this late order occurred because the ordered medicine did not arrive at the time promised with the company's waiting time policy of 2 days, but the order arrived later than the specified time. The following are several examples of delays in drug delivery that occurred at Pharmacy A and resulted in a shortage of available drugs.

The order for patent medicines was made on February 15, 2021, and was promised to arrive on February 17, 2021. However, the medicines experienced delays caused by some medicines from suppliers still being processed or goods that had not been sent from the distributor, so some of these patent medicines arrived late. with a range of 4–7 days to the warehouse, namely on 19, 20, 22, and 24 February 2021.

In addition, Pharmacy A experienced excess stock or overstock, which resulted in increased drug storage costs and risks such as loss, expiration, and damage to drugs. So far, Pharmacy A has controlled drug supplies by keeping stock of each drug, and orders are made if the stock of a particular drug runs out. Other problems arise due to a lack of inventory control, such as no grouping of drugs and no special calculations to determine how much to order back. As already mentioned, the control system is one of the keys to a company's production efficiency. Inventory control also functions to ensure the availability of goods and so that the company always has inventory in the right quantity, at the right time, and in predetermined specifications or quality so that business continuity can be guaranteed and costs incurred to hold inventory are minimal [5].

To carry out good drug management, it is important to plan to control drug supplies and guarantee sufficient quantities and types so that they can meet demand and are obtained quickly and on time. Effective drug supply control begins with grouping which drugs will be a priority for control using the ABC (Always Better Control) analysis method and determining how many drugs must be ordered using the EOQ (Economic Order Quantity) method.

The ABC (Always Better Control) analysis method is a classification method based on value ranking from highest to lowest and is divided into three large groups: group A with a high investment value, group B with a medium investment value, and group C with a low investment value. This method is very useful in focusing management's attention on determining the types of goods that are most important and need to be prioritized in inventory. The EOQ (Economic Order Quantity) method is an inventory method that determines the most economical order quantity, namely the amount of goods purchased that can minimize the total cost of storing goods from the warehouse and ordering costs each year [6].

One of the studies regarding inventory control using the ABC (Always Better Control) and EOQ (Economic Order Quantity) methods has the title "Medicine Planning Based on Analysis of Always Better Control (ABC) and Economic Order Quantity (EOQ) in the Pharmacy Installation of Melawi Hospital, Melawi Regency, West Kalimantan" [7]. The ABC method used can provide an overview of drug groups with various investment values from highest to lowest. Based on research results, in group A, there are 58 types of drugs with an investment value of 70.0% of the total investment value; in group B, there are 90 types of drugs with an investment value of 20.0% of the total investment value; and group C contains 374 types of medicines with an investment value of 10.0% of the total investment value. And then, as a basis for planning and procuring medicines for the next period, an analysis of the EOQ method calculation was carried out with the results for group A. The highest EOQ value was obtained with 991 items for Rifamficin 450 mg capsules, and the lowest EOQ value was 1 item for one example, namely the drug Thidim using this EOQ method. Hospitals can order drugs in optimal quantities and at economical costs. The aim of drug management at the Melawi Regional Hospital is to ensure the availability of drugs and provide more effective, efficient, and affordable drug services to patients, as well as to determine the priority of pharmaceutical preparations that must be provided by the Melawi Regional Hospital.

Research by [8] and [9] was conducted to reduce losses for hospitals due to weak planning and control. From the results of research conducted using the ABC Critical Index analysis method, seven antibiotic drugs were found that needed to be prioritized. Research conducted by [10] used the Analysis Method (ABC) and Economic Order Quantity (EOQ) Approach. The case study for this research is PT Herlinah Cipta Pratama, a company operating in the food industry that produces dodol with the trademark "PICNIC." The research conducted by [11] shows that inventory control, which causes stockouts, involves stock-taking activities. Inventory control with ABC, EOQ, and ROP analysis can avoid stockouts. ABC analysis shows that there are 36 types (12%) of generic drugs belonging to group A, namely, with a budget usage of 69.60% of the total budget usage for generic drugs. In group B, there are 52 types (17.33%), namely with a use of 20.39% of the total budget use of generic drugs, and 212 types (70.67%) of generic drugs belonging to group C, namely with a budget use of 10.01% of total generic drug budget usage. The optimum order quantity for generic drugs belonging to group A starts at 2-5265 items, group B starts at 6-6879 items, and group C starts at 1-5503 items. Reorder times for generic drugs belonging to group A start from 1-2,315 items, group B starts from 2-1,663 items, and group C starts from 1-916. The amount of safety stock that must be stored in the warehouse to avoid stockouts includes group A, starting from 3–1,442 items, group B, starting from 1–1,036 items, and group C, starting from 1–570 items.

Based on the description of the problems that occurred at Pharmacy A, it is necessary to have good inventory control so that the amount of inventory issued is appropriate and not excessive or insufficient. So the researcher wants to conduct research on drug inventory control at Pharmacy A using the ABC and EOQ (Economic Order Quantity) methods. The ABC method was chosen because it can determine drug procurement priorities based

on guidelines for the amount used and the amount of costs incurred and makes it easier to share data regarding relevant budgets for decision-making. This model can also separate items that are small in number but have great value. The EOQ method was chosen because it is one of the calculations used in determining the quantity of a company's raw material orders. In theory, EOQ only applies when demand for a product, ordering costs, and unit purchasing costs are constant values. The advantage of EOQ is that it is able to estimate the inventory that will be used, the safety stock, and the time to reorder inventory. These two methods are also often used in hospitals and pharmaceutical service facilities, especially in drug supplies. The results of this research are in the form of an implementation plan to improve inventory control at Pharmacy A. This control is expected to help maintain drug stocks and reduce conditions of excess or empty drug stock.

2. Literature Review

2.1. Patent medicine

Medicine plays an important role in protecting and restoring health and helping to maintain and improve the quality of life. Apart from that, drugs are the main component that greatly influences health services, especially in the pharmaceutical sector. In general, there are two types of drugs: patented drugs and generic drugs [12].

A patented medicine is a finished medicine with a trade name registered in the name of the manufacturer or authorized by him and sold in the original packaging from the factory that produces it [13]. This means that a patented drug is a drug that still has a patent and can only be produced by the manufacturer who holds the patent. According to Law No. 13 of 2016, Article 22, the patent protection period is granted for a period of 20 (twenty) years from the date of receipt. During these 20 years, pharmaceutical companies have had exclusive rights to produce these drugs in Indonesia. Meanwhile, generic drugs are drugs with official International Non-proprietary Names (INN) specified in the Indonesian Pharmacopoeia or other standard books for the efficacious substances they contain [14].

2.2. Inventory control

Inventory is a colloquial term that describes all the things or resources an organization keeps to meet demand [15]. Inventory control is a very important managerial function to control costs and ensure the availability of goods when needed in the queue, always ensuring that inventory does not experience stock out or overstock [5]. Inventory control is a very important managerial function because drug supplies and stocks will be costly and involve large investments in current assets; therefore, they need to be controlled effectively and efficiently. Effective inventory control involves optimizing two objectives, namely minimizing the investment value in drug inventory and selling the right variety of products to meet consumer demand [16]. Apart from that, inventory control is also carried out to maintain inventory levels at optimal levels so that savings can be obtained on these inventories, namely to show inventory levels that are in accordance with needs and can maintain production continuity at economical costs [17].

2.3. ABC (Always Better Control) method

ABC classification, often also called ABC analysis, is a classification of a group of items in descending order based on the cost of using the item per time period (price per unit of item multiplied by the volume of use of the item during a certain period) or cost, or total activity [18]. This method describes Pareto analysis, which emphasizes that a small portion of the types of materials contained in inventory have a fairly large use value, which covers more than 60% of all materials contained in inventory [19].

ABC analysis, or 80-20 rule analysis, is an inventory management method with a method of grouping inventory based on usage value into 3 categories, namely: category A, category B, and category C. The ABC inventory analysis method is a simple system or method that can be used to separate several items that require special attention in terms of inventory control [20].

The main principle of ABC analysis is to place the types of drugs in order, starting with the type of drug that uses the largest budget [21]. According to [22], the ABC analysis method is the creation of groups or classifications based on the ranking of values from the highest to the lowest and divided into three large groups called group A, group B, and group C. The following is the ABC classification [19]:

1. Group A

   This is a group of goods that are critical to the function and operations of a company. The inventory levels of this group should be monitored carefully. This group of goods has a high financial volume, where the number of goods is only 10% of all inventory but covers more than 70% of finance.
2. Group B

   This is a group of items that are important but not critical. So there is no need for constant control over all types of goods. This group represents about 20% of finance and accounts for about 20% of all inventory.
3. Group C

   This is a group of goods that are not very important to a company. This group of goods may only represent 10% of the company's finances, but the number of items is 70% of all inventory [20].

According to [23] class A goods are goods with a high annual dollar value, namely 70%–80% of the overall use of money, but only represent 15% of the total inventory. Class B goods are goods with moderate annual dollar volume, namely 15%–25% of total cash use and 30% of total inventory use. Items with a small annual dollar volume are in class C, which represents only 5% of annual volume but represents 55% of total inventory items.

This method of controlling drug supplies can be carried out using the Always Better Control (ABC) method, namely a grouping method based on a range of scores from highest to lowest, which are divided into 3 groups known as group A (high investment value), group B (medium investment value), and group C (low investment value). The use of ABC analysis is very useful in focusing a drug

management system that generates order frequency and prioritizes based on the value or price of drugs because it is unrealistic to monitor inexpensive items as intensively as very expensive items [4].

2.4. EOQ (Economic Order Quantity) method

Economic order quantity (EOQ) is the amount of inventory of goods ordered in a period with the aim of minimizing the cost of inventory of an item. Two types of costs are considered in the EOQ method, namely storage costs and ordering costs [24]. The EOQ model is one of the oldest and best-known inventory control techniques. This technique is relatively easy to use but is based on assumptions [23], namely:

1. The number of requests is known, constant, and independent.
2. The inventory receipt is instant and completely complete. In other words, the inventory from an order comes in one batch at a time.
3. No quantity discounts are available.
4. Variable costs are only costs for setting up or ordering and the cost of holding inventory for a certain time.
5. Stockouts can be completely avoided if orders are placed at the right time.

Inventory models generally minimize total costs. The EOQ model is divided into two categories, namely, deterministic EOQ and probabilistic EOQ. The deterministic EOQ model takes into account the two most basic types of inventory costs, namely, ordering costs and holding costs. If we minimize ordering costs and holding costs, we will also minimize total costs. Meanwhile, the probabilistic EOQ model takes into account demand behavior and lead times that are uncertain or cannot be determined in advance with certainty. With the assumptions given above, the most significant costs are ordering costs and storage costs. The purpose of calculating EOQ is to find out how much logistics stock is economical so that logistics stock is maintained in a safe but cheap condition and can reduce inventory costs [4].

By using economical calculations, a company can, of course, regularly determine how many orders to make. Because in this case there are no costs of running out of inventory and scheduling irregularities, it will have an impact on inventory costs due to inventory piling up, so the formula for determining the optimum order quantity, according [23], is:

$$Q = \sqrt{\frac{2DS}{H}} \quad (1)$$

where,

Q = the optimal number of unity units
D = number of uses or requests for one period
S = ordering cost
H = storage costs per unit for one year

The EOQ model is used to determine the inventory order quantity that minimizes storage costs and inventory ordering costs. By setting an EOQ policy, more orders can be determined each year within a certain period of time, thus reducing the risk of running out of stock [25].

2.5. Safety stock and ROP method

a. Safety stock

Safety stock is additional inventory held to protect or maintain the possibility of inventory shortages caused by demand that is greater than originally estimated or due to delays in ordered goods arriving at the storage warehouse by determining the size of the safety stock, which is then followed by a fixed order quantity, or EOQ [26].

The factors that determine the amount of safety stock are using average raw materials; the time and cost factors used are calculated using the service level. Message delivery time (lead time), namely the time the order is made and the time the order is received, Lead time is known and is constant or fixed every time an order is made [27]. The company has established a policy that the lead time for ordering medicines until the goods arrive is 2 days.

The performance achievement standard (service level) used is 95%, which means group A has 95% availability and a 5% shortage of inventory. According to [19], if the safety stock with service level (95%) is 1.65 and the standard lead time is known to be constant, then the calculation is:

$$SS = Z \times d \times l \quad (2)$$

where,

SS = safety stock
Z = service level
d = average usage
l = lead time

Safety stock functions to protect the company against a condition where the company experiences a shortage of raw materials, delays in the supply of raw materials ordered, which hinder production activities, or unpredictable spikes in demand, so the company must increase production to meet market needs [28].

b. ROP method

According to [19], the reorder point (ROP), or what is called the reorder point, is a point or limit of the amount of inventory in an inventory where an order must be placed again. In other words, ROP is the period during which an order must be regenerated. ROP is also related to lead time and safety stock [29]. By considering safety stock, the calculation of the reorder point according to [23] is:

$$ROP = (d \times l) + SS \quad (3)$$

where,

ROP = reorder point
d = daily demand
l = lead time
SS = safety stock

3. Research Methods

The research was conducted using a quantitative approach. According to [30], quantitative research is research based on quantitative or numerical measures obtained from the results of quantitative measurements of

variables, such as through questionnaires, tests, and observations. The object of this research is the drug supply process by Pharmacy A, which is carried out using the ABC method and the EOQ method. Data collection techniques use observation and interview methods.

In making observations, by directly observing existing activities from data recording drug supplies, drug orders, and the price of each drug in Pharmacy A,. This observation was carried out to determine the condition of inventory control in the pharmacy. Furthermore, interviews were carried out to obtain data and information directly from the management of Pharmacy A. This interview activity was carried out to find out how the pharmacy controls existing drug supplies. According to [31], an interview is the process of collecting information for research purposes through the use of a question-and-answer session that takes place face-to-face between the questioner and the person being asked.

The steps in this research can be seen in detail as follows:

1. Start Identifying Problems. As a first step in this research, it is important to clearly identify the problems that occur with a particular object.
2. Preliminary Study. After the existing problem has been identified, the next step is to conduct a preliminary study using relevant sources or documents to address the problem properly. Journals, books, historical data, articles, and materials on existing topics can be used as sources and references.
3. Data Collection. The next step is to collect primary and secondary data. The primary data used is direct observation and interviews conducted with pharmacy managers to find out more about drug supplies. Secondary data is obtained from existing sources or certain references, such as books or journals and previous research.
4. Data Processing. Next, process the data in a way that is in accordance with the research objectives to be achieved. Data processing was carried out using the ABC and EOQ methods with Microsoft Excel tools.
5. Analysis and Discussion. After processing the data using the ABC and EOQ methods, analysis and discussion are then carried out as a basis for identifying proposals for improving Pharmacy A's inventory control.
6. Conclusions and Suggestions. After the analysis and discussion stages have been carried out, conclusions can be drawn that are in accordance with the researcher's problems and the research objectives that were determined at the beginning. Furthermore, suggestions are given in the form of recommendations, company expectations, and other research related to the topics discussed in the research.

4. Results and Discussion

4.1. Analysis using the ABC method

The ABC method analysis was carried out in three stages for the types of drugs with the highest sales. The data used in this method are patent medicines for the 2021 sales period and are sorted from highest to lowest revenue, then grouped into 3 groups, namely:

1. Group A with a cumulative percentage of 0-80%
2. Group B with a cumulative percentage of 15-20%
3. Group C with a cumulative percentage of 5–15%

In the ABC calculation, namely the calculation of sales of patented medicines based on income value by sorting from the highest income value to the lowest income value, it is shown in Table 1.

Table 1. Calculation of patented medicine sales based on revenue in the 2021 period

No	Name	Total Usage	Drug Price (Rp)	Income (Rp)	% Revenue	% Cumulative	Class
1	ZONAL 50MG	6498	2822	18337356	6.69%	6.69%	A
2	HELIATECH LOTION SPF 45	136	78850	10723600	3.91%	10.61%	A
3	VOMINA TAB	10587	950	10057650	3.67%	14.28%	A
4	ZELONA TAB	20693	475	9829175	3.59%	17.87%	A
5	ZULTROP KAPLET	23405	380	8893900	3.25%	21.12%	A
6	WIBROM TAB	30477	285	8685945	3.17%	24.29%	A
7	VALISANBE 2 MG	19682	333	6554106	2.39%	26.68%	A
8	WICOLD TABLET	16794	380	6381720	2.33%	29.01%	A
9	VALANSIM 10MG	9391	665	6245015	2.28%	31.29%	A
10	OA FORTE CAPLET 60S BTL	14	444600	6224400	2.27%	33.56%	A
11	MEXON TABLET	15544	380	5906720	2.16%	35.72%	A
12	METISOL 4MG 5X10	9310	570	5306700	1.94%	37.65%	A
13	SELES B6 10MG/ 1000TAB	55786	95	5299670	1.93%	39.59%	A
14	YEKANEURON TAB	9192	570	5239440	1.91%	41.50%	A
15	VALISANBE 5 MG	5240	950	4978000	1.82%	43.32%	A
16	PACETIK TAB POT ISI 1000	26180	190	4974200	1.82%	45.14%	A
17	TAB	3436	1425	4896300	1.79%	46.92%	A
18	HEMORID	7109	665	4727485	1.73%	48.65%	A
19	SELVIM 20 (5X10)	8286	570	4723020	1.72%	50.37%	A
20	YUSIMOX TAB	3698	1188	4393224	1.60%	51.98%	A
21	ZOREL 400 MG	42	102600	4309200	1.57%	53.55%	A
22	KUTOIN INJ 100MG/2ML	6540	570	3727800	1.36%	54.91%	A
23	GRESERIC 150	2032	1663	3379216	1.23%	56.14%	A
24	KUTOIN	3476	950	3302200	1.21%	57.35%	A
25	RIAMICYN TAB 10X10	434	7600	3298400	1.20%	58.55%	A
26	FLUTOP C SYRUP	979	3336	3265944	1.19%	59.75%	A
27	INTIDROL TAB 16MG	22	140600	3093200	1.13%	60.88%	A
28	FLUTIAS 125 INHALER	3169	950	3010550	1.10%	61.97%	A
29	TB VIT 6 TABLET	3127	950	2970650	1.08%	63.06%	A
30	NUFACOBAL	136	20900	2842400	1.04%	64.10%	A

No	Name	Total Usage	Drug Price (Rp)	Income (Rp)	% Revenue	% Cumulative	Class
31	KUTILOS	109	25650	2795850	1.02%	65.12%	A
32	HALMEZIN SYRUP	7323	380	2782740	1.02%	66.13%	A
33	CORONET CROWN	7215	380	2741700	1.00%	67.13%	A
34	TROPIDENE 20MG KAPSUL	2105	1283	2700715	0.99%	68.12%	A
35	METOLON TAB	2262	1188	2687256	0.98%	69.10%	A
36	GRICIN 500	2152	1235	2657720	0.97%	70.07%	A
37	YASMIN 21TAB	13	204250	2655250	0.97%	71.04%	A
38	QUANTIDEX	3328	760	2529280	0.92%	71.96%	A
39	NUVOPECT TAB	6581	380	2500780	0.91%	72.88%	A
40	SINTROL KAPLET 3X10	3630	665	2413950	0.88%	73.76%	A
41	CEDROX 500MG TABLET	1896	1235	2341560	0.85%	74.61%	A
42	POLAMEC TAB	6041	380	2295580	0.84%	75.45%	A
43	EKACETOL SYRUP	389	5700	2217300	0.81%	76.26%	A
44	INTRIZIN SYRUP 60ML	37	59850	2214450	0.81%	77.07%	A
45	FLUTAMOL SYRUP	257	8550	2197350	0.80%	77.87%	A
46	ABILIFY 10 MG	1134	1900	2154600	0.79%	78.66%	A
47	BIMADEX 0,5	6675	285	1902375	0.69%	79.35%	A
48	NUDEP	126	15048	1896048	0.69%	80.04%	A
49	JF SULFUR ACNE CARE PUTIH	177	10450	1849650	0.68%	80.72%	B
50	BIMACYL TAB	3825	475	1816875	0.66%	81.38%	B
51	CEDROX 125MG SYRUP	156	11400	1778400	0.65%	82.03%	B
52	60ML	33	53200	1755600	0.64%	82.67%	B
53	XELODA 500MG	65	26600	1729000	0.63%	83.30%	B
54	LYSIN KU	4423	380	1680740	0.61%	83.92%	B
55	NUFADEX M 0,75 MG	174	9500	1653000	0.60%	84.52%	B
56	KAPLET	4116	380	1564080	0.57%	85.09%	B
57	ULSIKUR INJ KALBE	8176	191	1561616	0.57%	85.66%	B
58	GRAXINE	136	11400	1550400	0.57%	86.23%	B
59	ZONIFAR BOX	3223	475	1530925	0.56%	86.79%	B
60	XARELTO 10mg	3196	475	1518100	0.55%	87.34%	B
61	GRATHEOS 50 (5x10)	3063	475	1454925	0.53%	87.87%	B
62	GRICIN 125	351	4085	1433835	0.52%	88.40%	B
63	FLUTAMOL CAPLET	1874	760	1424240	0.52%	88.92%	B
64	TANTUM TAB 2X6	3707	380	1408660	0.51%	89.43%	B
65	QUAMIPROX F	4874	285	1389090	0.51%	89.94%	B
66	INTIBION	2887	475	1371325	0.50%	90.44%	B
67	POLARIST TAB	2880	475	1368000	0.50%	90.94%	B
68	SIOBION KAPSUL	179	7600	1360400	0.50%	91.43%	B
69	BIMACTRIM TAB	3552	380	1349760	0.49%	91.93%	B
70	QUANTIDEX SYRUP	109	12350	1346150	0.49%	92.42%	B
71	INTIBROX TAB	2355	570	1342350	0.49%	92.91%	B
72	LYTACUR SYRUP	535	2375	1270625	0.46%	93.37%	B
73	ACEPRESS 25MG	2005	570	1142850	0.42%	93.79%	B
74	EFLAGEN 50MG	2383	475	1131925	0.41%	94.20%	B
75	EFLIN TABLET	826	1330	1098580	0.40%	94.60%	B
76	OBIVIT	750	1425	1068750	0.39%	94.99%	B
77	ULTRAVITA KAPL	763	1378	1051414	0.38%	95.38%	B
78	LYVIT SYRUP	67	15200	1018400	0.37%	95.75%	C
79	OA PLUS 60KAPLET	109	9025	983725	0.36%	96.11%	C
80	HAEMOGAL CAPLET	119	7600	904400	0.33%	96.44%	C
81	OBIMIN AF	447	1900	849300	0.31%	96.75%	C
82	LYTAMIN SYRUP	122	6650	811300	0.30%	97.04%	C
83	UTROGESTON 200MG	36	20900	752400	0.27%	97.32%	C
84	RHODIUM (30TAB)	95	6650	631750	0.23%	97.55%	C
85	SINRAL 5 MG	110	5700	627000	0.23%	97.78%	C
86	JF SULFUR FAMILY	64	9500	608000	0.22%	98.00%	C
87	ORANGE BARSOAP	19	31350	595650	0.22%	98.22%	C
88	XARELTO 15mg	364	1568	570752	0.21%	98.43%	C
89	DACIN TAB 300MG	197	2660	524020	0.19%	98.62%	C
90	METHYLON TAB 4MG 10X10	79	6270	495330	0.18%	98.80%	C
91	OXAN KAPLET	294	1520	446880	0.16%	98.96%	C
92	TB ZET TABLET 10X10	427	1045	446215	0.16%	99.12%	C
93	POLYSILANE TAB	54	7600	410400	0.15%	99.27%	C
94	SINRAL 10 MG	168	2138	359184	0.13%	99.40%	C
95	NUCRAL 60 TABLET	63	5643	355509	0.13%	99.53%	C
96	RHINOS SR TAB	188	1520	285760	0.10%	99.64%	C
97	MEVITON TAB	134	1425	190950	0.07%	99.71%	C
98	LYCALVIT TAB	362	475	171950	0.06%	99.77%	C
99	SELVIPLEX KAPSUL	112	1425	159600	0.06%	99.83%	C
100	TROVILON TAB	317	475	150575	0.05%	99.88%	C
101	SELEDRYL TAB	46	2090	96140	0.04%	99.92%	C
102	RHINOFED TAB (50)	48	1900	91200	0.03%	99.95%	C
103	ULCUMAAG KAPLET	48	1425	68400	0.02%	99.98%	C
104	ODANOSTIN	42	1425	59850	0.02%	100.00%	C
Total	417612		273927595				

Table 2. Drug groupings based on ABC analysis of investment value

Drug Group	Number of Types Drugs	Usage Value	Number of Types Drugs	Nilai Investasi (Rp)
A	41	352298	84.57%	188145542
B	24	56099	13.47%	36062044
C	19	8192	1.97%	11832280
Total	84	416589	100%	236039866

Based on Table 2, it can be seen that there are 41 patented medicine items included in Group A, or 84.57% of the total medicine supply, with a total investment value of Rp.88145542. There are 24 patented medicines included in Group B, or 13.47% of the total medicine inventory, with a total investment of Rp.36062044. Meanwhile, there are 19 patented medicines included in Group C, or 1.97% of the total medicine supply, with a total investment of Rp.11832280.

Based on Fig. 1, it can be seen that the drugs included in group A account for 79.709% of the total investment in drugs. Medicines included in Group B make up 15.278% of the total investment in medicines. Meanwhile, Group C made up 5.013% of the total investment in medicines.

4.2. Calculation analysis of the EOQ method

After the data is grouped using the ABC method, the next step is to determine the EOQ for products that fall into group A, inventory that has a percentage of 0%–80%. Inventory management in this group necessitates a great deal of attention. In administering medicines at the Pharmacy A, no special calculations are made regarding the number of medicines ordered. To find out the optimum order quantity every time you order patent medicines at the Pharmacy A, the EOQ (Economic Order Quantity) method can be applied. EOQ calculations are carried out based on the following formula [23]

To determine EOQ, calculations are needed regarding

demand for one period, ordering costs, and storage costs. The number of requests has been calculated using ABC analysis.

a. Ordering Costs

Based on data from pharmacy A, it is known that the cost per order for patent medicines in terms of telephone costs and administration costs is IDR 2225. This data is used in the EOQ calculation in Table 3.

b. Storage Fees

Carrying costs include costs associated with holding inventory for a certain time. The provision for storage fees from Pharmacy A is 26% of the price of the goods. After knowing the amount of medication used, ordering costs, and storage costs, a calculation is made regarding the optimum order quantity for each order.

Based on table 4, the maximum optimum order quantity for the SELES B6 1000Tab drug is 3170 items per order,

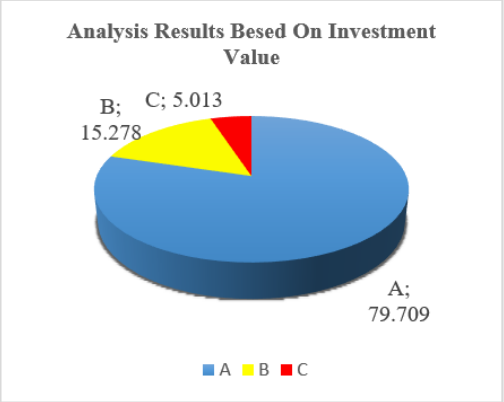

Figure 1. Analysis results based on investment value

Table 3. Total costs per order at pharmacy A

No	Order Fees	Order Fee (Rp)
1	Telephone Fee	625
2	Administration Fees (ATK)	1600
	Total Cost per Order	2225

and the minimum optimum order quantity for the KUTILOS drug is 9 items per order. For example, the EOQ calculation is for Zonal 50 mg as follows:

Number of uses = 6498 pcs
Storage costs = Rp. 73372
Ordering fee = Rp. 2225

So the Economic Order Quantity (EOQ) is:

$$Q = \sqrt{\frac{2.D.S}{H}} = \sqrt{\frac{2\ x\ 6498\ x\ 2225}{733.72}} = \sqrt{39410.72} = 199$$

and the frequency of purchasing Zonal 50Mg medication in a year = $\frac{6498}{199} = 33$.

Based on calculations using the Economic Order Quantity (EOQ) method above, the most economical order quantity for Pharmacy A to order 50 mg of Zonal medicine per year is 199 pieces for one order. Meanwhile, the frequency of orders for Zonal 50 mg was 33.

4.3. Analysis of safety stock and ROP calculations

After grouping the data using the ABC and EOQ methods, it is necessary to determine the safety stock of group A products, namely the percentage from 0% to 80%. Stock in this group requires high attention to inventory control because products in Group A need to be kept in safety stock. The service standard used is 95%, which means group A has 95% availability and a 5% shortage of inventory. The percentage used is 95%, so the Excel service factor used is 1.65. The results of the safety stock calculation can be seen in Table 5.

Table 4. Calculation of EOQ for Group A patented medicines

NO	Name	Total Usage	Order Fees (Rp)	Storage Fees (Rp)	EOQ	F(x) Purchases
1	ZONAL 50MG	6498	2.225	733.72	199	33
2	VOMINA TAB	10587	2.225	247	437	24
3	ZELONA TAB	20693	2.225	123.50	863	24
4	ZULTROP KAPLET	23405	2.225	98.80	1027	23
5	WIBROM TAB	30477	2.225	74.10	1353	23
6	VALISANBE 2 MG	19682	2.225	86.58	1006	20
7	WICOLD TABLET	16794	2.225	98.80	870	19
8	VALANSIM 10MG	9391	2.225	172.90	492	19
9	MEXON TABLET	15544	2.225	98.80	837	19
10	METISOL 4MG 5X10	9310	2.225	148.20	529	18
11	SELES B6 10MG/ 1000TAB	55786	2.225	24.70	3170	18
12	YEKANEURON TAB	9192	2.225	148.20	525	17
13	VALISANBE 5 MG	5240	2.225	247	307	17
14	PACETIK TAB POT ISI 1000	26180	2.225	49.40	1536	17
15	TAB	3436	2.225	370.50	203	17
16	HEMORID	7109	2.225	172.90	428	17
17	SELVIM 20 (5X10)	8286	2.225	148.20	499	17
18	YUSIMOX TAB	3698	2.225	308.88	231	16
19	KUTOIN INJ 100MG/2ML	6540	2.225	148.20	443	15
20	GRESERIC 150	2032	2.225	432.38	145	14
21	KUTOIN	3476	2.225	247	250	14
22	RIAMICYN TAB 10X10	434	2.225	1.976	31	14
23	FLUTOP C SYRUP	979	2.225	867.36	71	14
24	FLUTIAS 125 INHALER	3169	2.225	247	239	13
25	TB VIT 6 TABLET	3127	2.225	247	237	13
26	NUFACOBAL	136	2.225	5.434	11	13
27	KUTILOS	109	2.225	6.669	9	13
28	HALMEZIN SYRUP	7323	2.225	98.80	574	13
29	CORONET CROWN	7215	2.225	98.80	570	13
30	TROPIDENE 20MG KAPSUL	2105	2.225	333.58	168	13
31	METOLON TAB	2262	2.225	308.88	181	13
32	GRICIN 500	2152	2.225	321.10	173	12
33	QUANTIDEX	3328	2.225	197.60	274	12
34	NUVOPECT TAB	6581	2.225	98.80	544	12
35	SINTROL KAPLET 3X10	3630	2.225	172.90	306	12
36	CEDROX 500MG TABLET	1896	2.225	321.10	162	12
37	POLAMEC TAB	6041	2.225	98.80	522	12
38	EKACETOL SYRUP	389	2.225	1.482	34	11
39	FLUTAMOL SYRUP	257	2.225	2.223	23	11
40	ABILIFY 10 MG	1134	2.225	494	101	11
41	BIMADEX 0,5	6675	2.225	74.10	633	11

The following is an example of calculating Safety Stock (SS) and Zonal ROP 50 mg:

Number of drug uses (d) = 6498 pcs
Lead time (l) = 2 days
Service level = 95%
Z (95%) = 1.65

The number of days in a year is 365 days, so the average number of uses per day (d)

= 6498 pcs / 365
= 18 pcs

Safety stock calculations are carried out using the following formula [32]:

$SS = Z \times d \times l$
= 1.65 × 18 × 2
= 58.75 or 58 pcs

And for the ROP calculation, it is known:

D = 18 pcs
l = 2 days
SS = 58 pcs

$ROP = (d \times l) + SS$
= (18 × 2) + 58
= 94 pcs

From the safety stock calculation that has been carried out with the example of the Zonal 50 mg drug with the time between ordering until the goods arrive 2 days with an average demand per day of 18 items, the results of the safety stock calculation for the Zonal 50 mg drug are 59 items per product inventory, with 95 items remaining. Use the safety stock above. If the order ordered from the supplier, when the product quantity reaches the reorder point, experiences delivery problems so that the product arrives from the supplier at the wrong time and demand is high at that time, the company will use this safety stock product to overcome the shortage. stock. The purpose of the reorder point above is that if the company places an order before the number of products stored is 95, it will experience a buildup of excess products or overstock, which can be detrimental to the company.

Table 5. Calculation of safety stock and ROP

No	Name	Total Usage	Average Usage / Day	Lead Time	Service Level (95%)	Savety Stock	ROP
1	ZONAL 50MG	6498	18	2	1.65	59	94
2	VOMINA TAB	10587	29	2	1.65	96	154
3	ZELONA TAB	20693	57	2	1.65	187	300
4	ZULTROP KAPLET	23405	64	2	1.65	212	340
5	WIBROM TAB	30477	83	2	1.65	276	443
6	VALISANBE 2 MG	19682	54	2	1.65	178	286
7	WICOLD TABLET	16794	46	2	1.65	152	244
8	VALANSIM 10MG	9391	26	2	1.65	85	136
9	MEXON TABLET	15544	43	2	1.65	141	226
10	METISOL 4MG 5X10	9310	26	2	1.65	84	135
11	SELES B6 10MG/ 1000TAB	55786	153	2	1.65	504	810
12	YEKANEURON TAB	9192	25	2	1.65	83	133
13	VALISANBE 5 MG	5240	14	2	1.65	47	76
14	PACETIK TAB POT ISI 1000	26180	72	2	1.65	237	380
15	TAB	3436	9	2	1.65	31	50
16	HEMORID	7109	19	2	1.65	64	103
17	SELVIM 20 (5X10)	8286	23	2	1.65	75	120
18	YUSIMOX TAB	3698	10	2	1.65	33	54
19	KUTOIN INJ 100MG/2ML	6540	18	2	1.65	59	95
20	GRESERIC 150	2032	6	2	1.65	18	30
21	KUTOIN	3476	10	2	1.65	31	50
22	RIAMICYN TAB 10X10	434	1	2	1.65	4	6
23	FLUTOP C SYRUP	979	3	2	1.65	9	14
24	FLUTIAS 125 INHALER	3169	9	2	1.65	29	46
25	TB VIT 6 TABLET	3127	9	2	1.65	28	45
26	NUFACOBAL	136	0	2	1.65	1	2
27	KUTILOS	109	0	2	1.65	1	2
28	HALMEZIN SYRUP	7323	20	2	1.65	66	106
29	CORONET CROWN	7215	20	2	1.65	65	105
30	TROPIDENE 20MG KAPSUL	2105	6	2	1.65	19	31
31	METOLON TAB	2262	6	2	1.65	20	33
32	GRICIN 500	2152	6	2	1.65	19	31
33	QUANTIDEX	3328	9	2	1.65	30	48
34	NUVOPECT TAB	6581	18	2	1.65	59	96
35	SINTROL KAPLET 3X10	3630	10	2	1.65	33	53
36	CEDROX 500MG TABLET	1896	5	2	1.65	17	28
37	POLAMEC TAB	6041	17	2	1.65	55	88
38	EKACETOL SYRUP	389	1	2	1.65	4	6
39	FLUTAMOL SYRUP	257	1	2	1.65	2	4
40	ABILIFY 10 MG	1134	3	2	1.65	10	16
41	BIMADEX 0,5	6675	18	2	1.65	60	97

After analyzing the data, present the research results descriptively. An analysis of drug stock at Pharmacy A shows that inventory control carried out by Pharmacy A is not efficient. Pharmacies only reorder drugs when they run out of stock, leading to erratic orders for any purchases over the next period. In administering medicines at Pharmacy A, no special calculations are made regarding the number of medicines ordered. The time an order is made at Pharmacy A is done every month, but there is no definite schedule for when the order will be made.

If there is a stock shortage, it can result in inadequate service to patients or consumers, which can reduce profits. On the other hand, if there is excess stock, it will result in overstock, which will result in additional costs due to drug storage. This is due to the implementation of drug inventory control in pharmacies that has not been implemented. To carry out inventory control efficiency at Pharmacy A, researchers conducted an analysis using the ABC and Economic Order Quantity (EOQ) methods.

4.4. Discussion of the ABC Method

After analyzing drug inventory control using the ABC method, ABC grouping results were obtained. Group A, a group of goods that are critical to the function and operations of a company in carrying out higher control and supervision, has a high monthly volume. In Group A, there are 41 drugs with a percentage of 84.57% and an investment value of Rp.188,145,542. The drug with the highest investment value for group A is Zonal 50 mg, with a total use of 6498 pcs and a revenue value of Rp.18,337,356. Group B is a group of goods that are important but not critical, which must also be monitored and controlled for supplies that are included in the group B category.

In Group B, there are 24 medicines with a percentage of 13.47% and an investment value of Rp.36,062,044. The drug with the highest investment value for group B is Bimacyl Tab, with a total use of 3825 pieces and an income value of Rp.1,816,875. Group C, a group of goods

that are not very important to a company but are also considered in inventory control, is included in the group C category. In Group C, there are 19 medicines with a percentage of 1.97% and an investment value of Rp.11,832,280. The drug with the highest investment value for group C is EFLAGEN 50 mg, with a total usage of 2383 and an income value of Rp.1,131,925.

After knowing what types of drugs are included in the grouping categories, it can be seen that drugs that are included in the group A category must be strictly observed in inventory control. If products in this category are not controlled in terms of inventory control, this will lead to increased storage or overstock, and the medicine may expire. However, if the inventory is too small, it will cause stockouts because the goods are not in stock when customers need them.

4.5. Discussion of the Economic Order Quantity (EOQ) method

The items that will be calculated using the EOQ method are items that are included in group A in the ABC analysis because the items that are included in this group have a high cumulative cost percentage, which of course has a high monetary value. Determining the optimum order quantity using the EOQ method requires calculations regarding drug demand, ordering costs, and storage costs. The number of requests known from the previous ABC analysis was 416,589 drugs. The ordering fee covers the costs required to place an order, including telephone fees and administration fees.

Based on interviews, the average time required for each order is 4-5 minutes. Local telephone rates are Rp. 250 per 2 minutes (PT. Telkom Indonesia, 2016), so the telephone cost per minute is Rp.125. So the cost for 5 minutes is Rp. 625. And the administration costs used by Pharmacy A are order letters, invoice exchange books, and printer ink. Storage costs, according to Heizer and Render (2010), are 26% of the unit cost or price of goods. After the ordering costs and storage costs are known, the data is entered into the formula. Based on the Economic Order Quantity (EOQ) method in group A, the maximum optimum order quantity for the SELES B6 1000Tab drug was 3170 items per order, and the minimum optimum order quantity for the KUTILOS drug was 109 items per order.

4.6. Discussion of the safety stock and Reorder Point (ROP) methods

After the data has been grouped using the ABC method and the optimum order quantity has been determined using the EOQ method, the next step is to determine the safety stock for products included in Group A, inventory that has a percentage of 0-80%. Safety stock is a method used to determine safety stock in inventory. This aims to prevent stockouts from occurring in the warehouse. The service standard used is 95%, which means group A has 95% availability and a 5% shortage of inventory. The percentage used is 95%, so the service level used is 1.65. According to the informant, the lead time required from ordering medicine until the goods arrive is 2 days. From the safety stock calculation that has been carried out with the example of the Zonal 50 mg drug with the time between orders until the goods arrive 2 days with an average demand per day of 18 items, the results of the safety stock calculation for the Zonal 50 mg drug are 58.75 items per supply. There are still 94 items remaining in the product. If an order ordered from a supplier when the product quantity reaches the reorder point experiences delivery problems so that the product arrives from the supplier at the wrong time and demand is high at that time, the company will use this safety stock product to overcome the stock shortage.

A reorder point is a method used to determine the point for ordering raw material requirements or a product. This ordering point plays an important role in inventory control in order to minimize storage costs in the warehouse and overcome stockouts. From the reorder point calculation that has been carried out using the example of the drug Zonal 50 mg, the results obtained for the reorder point are when there are 94 items of the drug in the warehouse. If the company places an order before there are 94 items in stock, it will experience a buildup of excess product, which will reduce warehouse capacity. However, if the company places a reorder when the amount of inventory is below the reorder point, for example, for the Zonal 50 mg drug product, it is at the 94 item point, then if demand increases, there will be a stockout.

5. Conclusion

Based on the results of the analysis and discussion, the conclusion of this research is that the supply of patent medicines at Pharmacy A uses the ABC (Always Better Control) method, namely that class A patent medicines produce 41 items of medicine, or 84.57% of all types of drug supplies. patent with a usage value of 352,298 and an investment value of Rp.188145542, or 80% of the total investment. Class B patented medicines amount to 24 or 13.47% of all patented medicines, with a usage value of 56,099 and an investment value of Rp.36062044 or 15% of the total investment in patented medicines. Meanwhile, class C patent medicines account for 19 or 1.97% of all patent medicines, with a usage value of 8.192 and an investment value of Rp.11832280, or 5% of the total investment. After knowing what types of drugs are included in the grouping categories, it can be seen that drugs that are included in the group A category must be paid strict attention to in inventory control. By implementing the ABC method, it is hoped that Pharmacy A will find it easier to determine which type of medicine to prioritize when making a purchase.

Based on the results of calculations using the Economic Order Quantity method, the economic order quantity for group A varies in the range 9–3170 items per type of drug; namely, the maximum optimum order quantity is for the drug Sels B6 1000 Tab with a quantity per order of 3170 items, and the minimum optimum order quantity is for the drug KUTILOS with a quantity per order of 11 items. For example, to order Zonal 50 mg medication for the 2021 period, Pharmacy A can order 199 pieces in one order with an order frequency of 33 orders and make a reorder if the supply of Zonal 50 mg medication has reached the point of as many as 94 pieces. It can be concluded that before this method existed, there

was no specific calculation regarding how many orders would be placed and when reorders would be made, so problems could occur such as excess stock and drug shortages. And with the Economic Order Quantity (EOQ) method, controlling Pharmacy A's drug inventory will be more helpful in reducing excess stock and drug shortages.

Suggestions for Pharmacy A need to apply the ABC analysis method to patented drugs to give different priorities to each group of drugs because drugs with high investment value require stricter supervision than drugs with low investment value. And it is necessary to apply the EOQ method to patented drugs so that there is no excess stock or shortage of drugs. It is hoped that future research will be able to more critically analyze Pharmacy A's inventory control based on the ABC-VEN method. This method combines the ABC method with the VEN method (Vital, Essential, and Non-essential) which classifies inventory items based on their impact on health. This method is suitable for controlling drug supplies in hospitals or pharmacies. Probabilistic EOQ is a modification of the EOQ method which considers the uncertainty of demand and delivery time and is dynamic. EOQ method: This method is a modification of the EOQ method which takes into account changes in the price of goods in inventory over time. This method can be used to determine the optimal time and order quantity so that total inventory costs are minimal.

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Mine Scheduling of Lateritic Nickel Ore in The Mawar Block of PT Ang and Fang Brother Site Lalampu, Central Sulawesi Province, Indonesia

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Abstract

PT Ang and Fang Brothers planned to open a new pit of lateritic nickel ore in Mawar Block. Mine scheduling of open-pit mines is an important thing in surface mine planning so the purpose of this research is to provide an overview of pit design and mining sequences, amount of production and number of equipment allocated in each sequence. The production targeted by the company was 50,000 tons by considering the mine recovery factor of 90%. Mine scheduling requires several data, namely cycle time, loss time, block model, equipment specifications and availability, slope and mine haul road geometry, and topography. The data used to design pit limits, mining sequences, and production scheduling. Based on the design of the mine pit, the total overburden that must be removed is 365,589 bcm and the total laterite nickel ore that must be stripped is 169,240 tons with a stripping ratio of 2.2:1 which is divided into three mining sequences. Total tonnage of lateritic nickel ore in the first to the third sequence is 55,677 tons, 55,518 tons, and 58,045 tons with overburden of 143,764 bcm, 136,055 bcm, and 85,770 bcm respectively. The equipment fleet of the first to the third sequence is 4 units' loader with 17 units' hauler, 4 units' loader with 17 units' hauler, and 3 units' loader with 13 units' hauler respectively.

Keywords: Mine scheduling; lateritic nickel; overburden; stripping ratio; mining sequence

1. Introduction

PT Ang and Fang Brother Site Lalampu is one of the nickel mining companies. The company's location is in Lalampu Village, Bahodopi District, Morowali Regency, Central Sulawesi Province. Site Lalampu is divided into Mining Permit 576 (576 hectares) and 199 (199 hectares). The research activity was carried out in the Mawar Block area. Mawar Block is one of four blocks in IUP 199 and the surface area is 4.8 hectares which has not been carried out with production activities. The planned nickel laterite production uses the open-pit mining method [1].

Nickel natural resources mainly occur as two types of sulfidic and lateritic (oxidic) ores. Despite the large share of the world lateritic nickel resources about 70%), nickel is mostly extracted from sulfides [2]. Lateritic nickel deposits classified in three main groups: oxidic or "limonitic" deposits, smectitic or "clay mineral" deposits, and hydrous Mg-Si-silicate deposits [3]. Classification of the laterite type does not follow a formal scheme but is conveniently made on the basis of the dominant Ni-host phase [4]–[6].

The formation of Ni laterites involves the interaction of numerous geological and environmental factors. Most lateritic nickel deposits consist of an oxide-style zone overlying a clay silicate or hydrous Ni-Mg-silicate zone [7]. The profile of lateritic nickel deposits in Mawar Block consists of overburden with main composition are Fe, Cr, Mn, and Co [8], limonite zone, saprolite zone, and blue zone (bedrock). The appearance of the overburden layer, limonite zone, and saprolite zone can be seen in Fig. 1.

The bedrock zone can be seen in Fig. 2. The Mawar Block will be mined by open pit mining method. Mine planning is one task to add considerable value to a mining business by using different strategy such as maximizing the NPV, extending the life of the mine, and minimizing risks [9].

Mine planning begins with designing a mining pit which is adjusted based on the shape of the lateritic nickel ore deposit in the mining area. Total volume of minerals based on the design of the mining pit becomes a reference in designing the mining sequence that show how a pit will be mined from the initial stage to the final stage of mine design (pit limit) [10].

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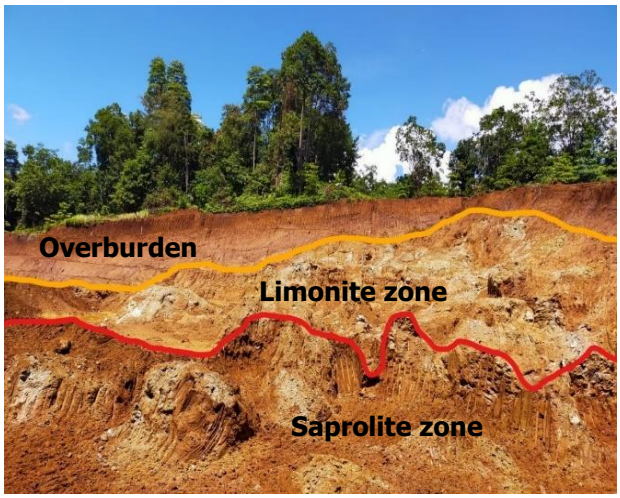

Figure 1. Overburden in lateritic nickel deposit at PT Ang and Fang Brother (February 17, 2021)

Figure 2. Bedrock in lateritic nickel deposit at PT Ang and Fang Brother (February 17, 2021)

The development stage translates mine planning studies into mine design by determining the mining method, which consists of the geometrical arrangements of structure, estimating production capacity and structure capital, and performing detailed engineering design [11].

Mine scheduling is an illustration of the amount of production and the number of equipment allocated in each mining sequence based on time and mining design. Its decisions are critical for a mining company to determine the periodical metal production and the financial returns [12]. Mine scheduling in open pit mining consists of long-term, medium-term, and short-term production scheduling. Long-term production scheduling is defined the yearly production schedules, meanwhile short-term scheduling is defined monthly, weekly, or even daily production schedules which are based on medium- and long-term scheduling [13].

Production scheduling is a very important part of the mining process therefore this research purpose is to set up mine scheduling of lateritic nickel ore at the Mawar Block of PT Ang and Fang Brother.

2. Research Methods

2.1. Data collection

Data collection in this study consisted of:

- Cycle time

This data consists of the cycle time of loader and hauler in the activity of overburden stripping and laterite nickel ore mining. The distance between the mining pit to the stockpile is ±1000 meters and the distance between the mining pit to the disposal is ±500 meters.

- Loss time

The data obtained from the Mine Plan Engineer Department included standby time, delay time, and repair time.

- Availability of equipment

Data on the availability of equipment were obtained from the Mine Plan Engineer Department. Data on equipment availability show the number of equipment owned and rented by the company.

- Equipment specification

Equipment specification data was obtained from the Cat 320, Komatsu 210, and Hitachi 350 type handbook of loader equipment specifications. The equipment specification data used was bucket capacity: Cat 320 was 1.19 m^3, Komatsu 210 was 1.2 m^3, and Hitachi 350 was 1.5 m^3 [14]–[16].

- Slope geometry and haul road geometry

Slope geometry data were bench height (5m), berm width (2m), and slope angle (60^o) used in pit design and mining sequences. Haul road geometry data were road width (10m) and grade (10%). The data were obtained from the Mine Plane Engineer Department.

- Block model

The data was obtained from the Exploration Department and it was the basic model that used in pit design. The block model can be seen in Fig. 3.

- Topography

The data is topographic of the research location in January 2021 and obtained from the Mine Plan Engineer Department (Fig. 4).

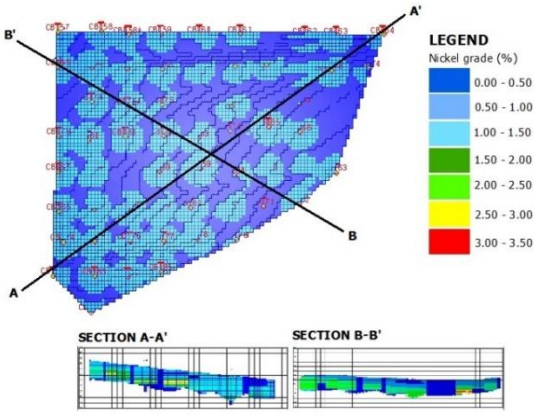

Figure 3. Block model of Mawar Block

Figure 4.The topography of Mining Permit 199

2.2. Data processing

The data processing with the following stages:

- Mine pit design

Mine pit design is the initial stage in designing a mining sequence that used block model and topographic data. Mine pit in this research designed by using Micromine 2018 where the width of mine haul road determined according to AASHTO using Eq. 1 [17]:

$$L_{min} = n \times Wt + (n+1)\ (0.5 \times Wt) \quad (1)$$

where,
L_{min} : minimum haul road width (m)
n : number of lanes
Wt : maximum hauler width (m)

- Mining sequences design

The data used in mining sequence design were block model and topographic data.

- Mine scheduling

Scheduling is carried out with the aim that production activities can be completed on time based on predetermined production targets and can maximize productivity. The data used for the calculation of equipment productivity were equipment availability, equipment specifications, equipment work efficiency, cycle time, working hours, and loss time. The steps taken in calculating equipment productivity were calculation of equipment efficiency the available working hours in one shift is nine hours in accordance with company regulations, while the loss time can be calculated based on several factors, namely standby time, delay time, and repair time.

The effective of working hours of the equipment was calculated by using Eq. 2 [18].

$$Ewh = Available\ hour - loss\ time \quad (2)$$

where Ewh is the effective of working hours.

After knowing the effective working hours, the next step was determining the working efficiency of the equipment (E) with Eq. 3 [18].

$$E = \frac{Effective\ working\ hours}{Working\ hours\ available} \ x\ 100\% \quad (3)$$

Cycle time of loaders were calculated by using Eq. 4 [18].

$$CTL = W_g + W_{am} + W_b + W_{ak} \quad (4)$$

where,
CTL : cycle time of loader
W_g : digging time
W_{am} : swing load time
W_b : dumping time
W_{ak} : swing empty time

Cycle time of haulers were calculated with Eq. 5 [18].

$$CTH = W_q + W_{ml} + W_l + W_{md} + W_d + W_{tb} \quad (5)$$

where,
CTH : cycle time of hauler
W_q : queueing time
W_{ml} : maneuver loading time
W_l : loading time
W_{md} : maneuver dumping time
W_d : dumping time
W_{tb} : turn back time

The equation used in calculating the productivity of the loader is shown in Eq. 6 [18].

$$QL = \frac{Kb \times E \times Ff \times Sf \times 3600\ second/hour}{CTL} \quad (6)$$

where,
QL : productivity of loader
Kb : bucket capacity
E : efficiency of equipment
Ff : fill factor
Sf : swell factor

The equation used in calculating the productivity of hauler is shown in Eq. 7 [18].

$$QH = \frac{(Kb \times n) \times E \times Ff \times Sf \times 60\ minute/hour}{CTH} \quad (7)$$

where,
QH : productivity of hauler
Kb : bucket capacity
n : the number of bucket stuffing
E : efficiency of equipment
Ff : fill factor
Sf : swell factor

The number of equipment planned to operate in each sequence is calculated based on the tonnage of lateritic nickel ore and overburden to be removed in each mining sequence, the productivity of each equipment, and working days.

The number of equipment used in each mining sequence was calculated by using Eqs. 8 and 9 [19].

$$Number\ of\ loaders = \frac{Ton\ Ore\ /\ Vol\ OB}{(QL\ x\ Working\ days)} \quad (8)$$

$$Number\ of\ haulers = \frac{Ton\ Ore\ /\ Vol\ OB}{(QH\ x\ Working\ days)} \quad (9)$$

In an effort to improve the quality of the work system, it is necessary to pay attention to the match factor between each operating equipment [18]. The value of MF can be known by using Eq. 10.

$$E = \frac{NH \times (CTL \times Number\ of\ bucket\ filling)}{NL \times CTH} \quad (10)$$

where,
NL : number of loaders
NH : number of haulers
CTL : cycle time of loader
CTH : cycle time of hauler

3. Results and Discussion

3.1. Mining pit design

The mining method that will be apply in Mawar Block is an open pit mining. The cutoff grade (COG) value of 1.4% and density of 1.5 kg/m^3 used to determine total tonnage of lateritic nickel ore. Based on pit limit design (Fig. 5), obtained 169,240 tons of lateritic nickel ore (Table 1) and 365,589 bcm of overburden to be removed (Table 2), therefore the stripping ratio value is 2.2:1.

The highest grade of lateritic nickel is 3.2% and the largest tonnage of 37,304 tons which is found in the grade range of 1.4% to 1.5%. The grade values that were below cutoff grade (COG) then categorized as waste.

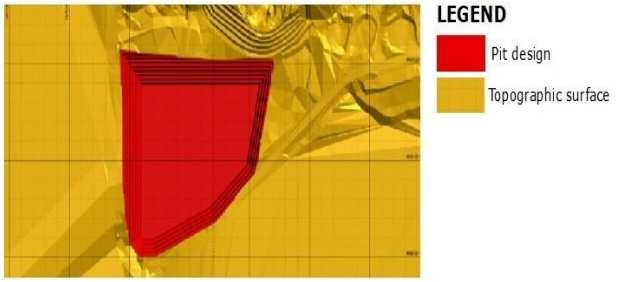

Figure 5. Pit limit design of Mawar Pit

Table 1. Total tonnage of lateritic nickel ore

Layer	Range of Ni Grade (%)	Volume (bcm)	Tonnage (tons)	Ni (%)	Fe (%)
	1.4 – 1.5	24,869	37,304	1.44	27.76
	1.5 – 1.6	22,269	33,404	1.54	21.81
	1.6 – 1.7	15,444	23,166	1.65	19.25
	1.7 – 1.8	13,950	20,925	1.75	18.07
	1.8 – 1.9	8,825	13,237	1.84	21.39
	1.9 – 2.0	7,207	10,810	1.95	17.96
Overburden	2.0 – 2.1	4,976	7,463	2.04	20.42
	2.1 – 2.2	2,819	4,228	2.14	19.47
	2.2 – 2.3	6,213	9,319	2.23	16.01
	2.3 – 2.4	1,900	2,850	2.33	13.85
	2.4 – 2.5	1,326	1,987	2.47	14.26
	2.5 – 2.6	50	75	2.54	16.99
	2.6 – 2.7	1,525	2,288	2.63	17.51
	2.7 – 2.8	956	1,434	2.76	15.41
	2.8 – 2.9	31	47	2.80	16.74
	3.1 – 3.2	469	703	3.12	13.31
Total			169,240		

Table 2. Total volume of overburden

Layer	Range of Ni Grade (%)	Volume (bcm)	Ni (%)	Fe (%)
	0.0 – 0.1	129,581	0.00	00.00
	0.3 – 0.4	5,869	0.38	37.74
	0.4 – 0.5	17,319	0.45	41.10
	0.5 – 0.6	31,662	0.54	43.22
	0.6 – 0.7	34,794	0.64	44.59
Limonite,	0.7 – 0.8	19,231	0.74	44.96
Saprolite	0.8 – 0.9	19,119	0.85	46.22
	0.9 – 1.0	16,237	0.94	45.31
	1.0 – 1.1	18,663	1.04	40.37
	1.1 – 1.2	22,619	1.14	44.41
	1.2 – 1.3	26,557	1.25	32.94
	1.3 – 1.4	23,938	1.34	31.38
Total Volume		365,589		

The largest volume of overburden is 129,581 bcm which is in the range of 0.0% to 0.1%.

3.2. Mining pit design

Mine sequence design process is strictly dependent on the economic variables of the orebody having an effect on the physical parameters of the intended mining system [20].

Mining sequence design based on production targets of 50,000 tons/month. Mine recovery factor in nickel mining could be 95% [21] or at least 90% based on Decision of The Minister of EMR Regarding 1827 K/30/MEM/2018 about Implementing Guidelines on Good Mining Practices.

PT Ang and Fang Brother used mine recovery of 90%; therefore, the production target increased to 55,000 tons.

The width of the largest hauler, Hino 500 type is 2.490 meters. The number of lanes taken into account in the haul road design is two lanes, so the results of the calculation of the minimum haul road width based on Equation 1 was 8,6 meters. The mining sequence of Mawar Pit is divided into three sequences, namely:

- Sequence I

In the sequence I there are 55,677 tons of lateritic nickel ore and 143,764 bcm of overburden to be removed with stripping ratio value is 2.5:1. Sequence I design can be seen in Fig. 6.

- Sequence II

Based on the sequence II design (Fig. 7) there are 55,518 tons of lateritic nickel ore and 136,055 bcm of overburden to be removed. The stripping ratio is 2.4:1.

- Sequence III

There are 58,045 tons of lateritic nickel ore and 85,770 bcm of overburden to be removed in Sequence III. The value of stripping ratio is 1.4:1. The design can be seen in Fig. 8.

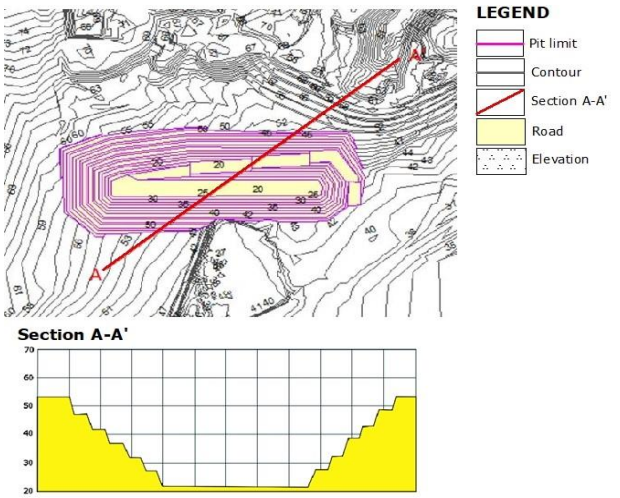

Figure 6. Design of Sequence I

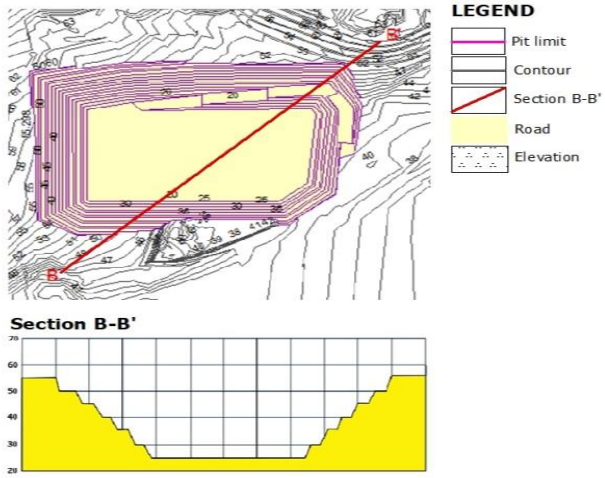

Figure 7. Design of Sequence II

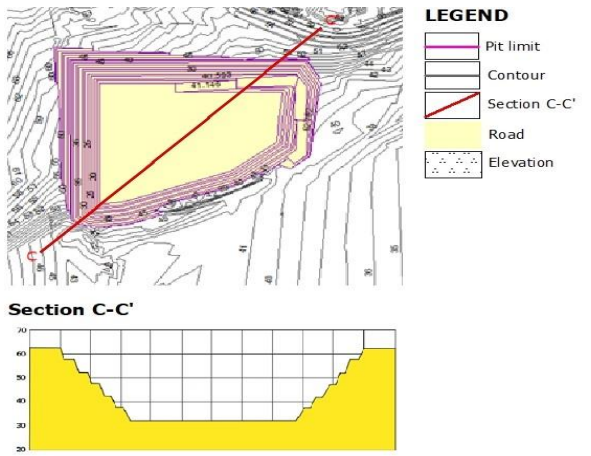

Figure 8. Design of Sequence III

3.3. *Mine scheduling*

Production planning in this research is to determine the amount of lateritic nickel ore and overburden that will be removed every month based on the capacity of the equipment fleet. Mine scheduling requires to select and schedule blocks in a sequence that maximizes or minimizes a specific goal, minimizes deviations from planned production targets [22].

Production scheduling of open-pit mines is an important problem that arises in surface mine planning. It can be summarized as follows the ore body is represented as a three-dimensional array of blocks [12]. The parameters used in mine scheduling are:

- Work Efficiency

The factors that affect the work efficiency of the equipment are loss time, effective working time, and available time. Loss time data can be seen in Table 3. The largest total loss time for loader was Cat 320 of 178.71 minutes/day and for hauler was Hino 500 of 124.94 minutes/day.

The effective working time calculated using Equation 1 based on total loss time (Table 5) and company working time of company of 9 hours or 540 minutes. The results can be seen in Table 4.

The results in Table 6 are used to calculate the work efficiency of the equipment by using Eq. 2, which can be seen in Table 5. The results show that the loader of Hitachi 350 and the hauler of Fuso 220 have the highest work efficiency.

- Cycle time

The calculation of the cycle time is carried out on the loader (Table 6) and hauler (Table 7) by using Eq. 3.

Table 3. Total loss time of equipment

Equipment Type	Delay Time (minutes)	Standby Time (minutes)	Repair Time (minutes)	Total Loss Time (minutes)
Cat PC 320	73.44	82.30	3.46	159.21
Komatsu 210	73.45	82.34	3.65	159.44
Hiitachi 350	73.32	82.37	1.54	157.23
Hino 500	57.68	83.34	1.69	141.71
Fuso 220	57.71	82.37	1.54	141.63

Table 4. Effective working hours of equipment

Equipment	Equipment Type	Effective Working Hour	
		Minutes	Hours
Loader	Cat PC 320	380.79	6.35
	Komatsu 210	380.56	6.34
	Hiitachi 350	382.77	6.38
Hauler	Hino 500	398.29	6.64
	Fuso 220	398.37	6.64

Table 5. Calculation of the equipment efficiency

Equipment	Equipment Type	Equipment Efficiency (%)
Loader	Cat PC 320	70.52
	Komatsu 210	70.47
	Hitachi 350	70.88
Hauler	Hino 500	73.76
	Fuso 220	73.77

Table 6. Cycle time of loader

Equipment Type	Cycle Time (Second)	Activity
Cat 320	17.30	Nickel ore loading
Komatsu 210	17.81	Overburden loading
Hitachi 350	22.04	Overburden loading

Table 7. Cycle time of hauler

Equipment Type	Cycle Time (minutes)	Activity
Hino 500	11.51	Nickel ore hauling
Fuso 220 pair with Komatsu 210	8.27	Overburden hauling
Fuso 220 pair with Hitachi 350	7.18	Overburden hauling

The Cat 320 has a bucket capacity of 1.19 bcm, the Komatsu 210 has a bucket capacity of 1.20 bcm, and the Hitachi 350 has a bucket capacity of 1.50 bcm. Based on the calculation results of the loader and hauler equipment cycle time in Table 8, it can be concluded that the smaller the bucket capacity of an equipment, the smaller the cycle time allocated to operate in one cycle.

The distance between the mining pit to the stockpile is ±1000 meters, while the distance between the mining pit to the disposal is ±500 meters so that the cycle time shows that the time taken by the hauler to the disposal is smaller than to the stockpile.

- Productivity of equipment

Equipment productivity is used to determine the amount of lateritic nickel tonnage and overburden production based on a certain unit of time. The loader's productivity was calculated using Eq. 5 (Table 8) and the hauler's Eq. 6 (Table 9).

Table 8. Productivity of loader

Description	Ore Production	Overburden Production	Overburden Production
	Cat 320	Komatsu 210	Hitachi 350
Kb (bcm)	1.19	1.2	1.5
E (%)	71%	71%	71%
Ff	1	1	1
Sf	0.9	0.9	0.9
CTL (Second)	17.30	17.81	22.04
Density (Ton/m3)	1.5	1	1
Q (bcm/hour)	158.23	154.99	156.56
Q (Ton/hour)	237.35	154.99	156.56
Q (Ton/day)	3,014.39	1,965.35	1,997.72

Table 9. Productivity of hauler

Description	Ore Production	Overburden Production	Overburden Production
	Hino 500 pair with Cat 320	Fuso 220 pair with Komatsu 210	Fuso 220 pair with Hitachi 350
Kv (bcm)	8.33	9.6	5.6
E (%)	74%	74%	74%
Ff	1	1	1
Sf	0.9	0.9	0.9
CTL (Second)	14.81	9.50	7.30
Density (Ton/m3)	1.5	1	1
Q (bcm/hour)	22.48	40.38	30.82
Q (Ton/hour)	33.71	40.38	30.82
Q (Ton/day)	576.08	616.01	443.46

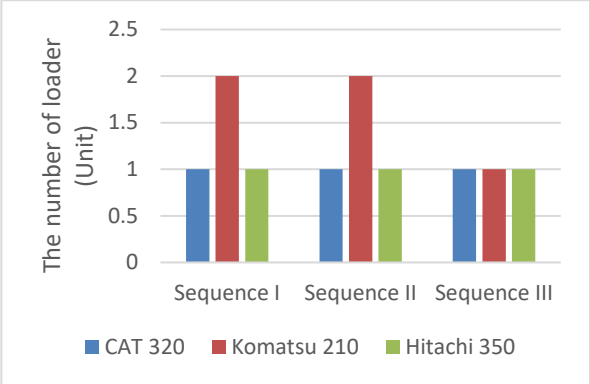

Figure 9. The number of loaders allocated

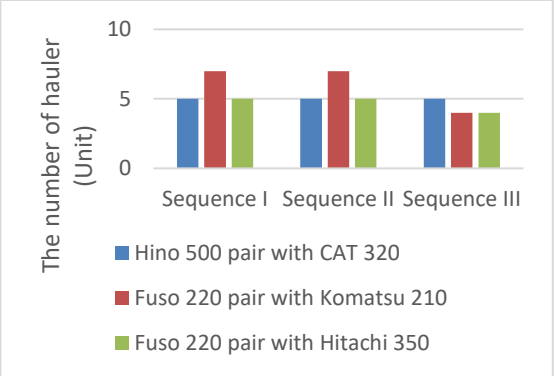

Figure 10. The number of haulers allocated

- The number of loader and hauler

The equations used in calculating the number of loader and hauler are Equation 7 and Equation 8.
The results of loader allocated in each sequence can be seen in Fig. 9.

Based on Fig. 9, it can be seen that the number of loaders in the first and second sequences is the same, while the third sequence has decreased. The decrease in the number of loaders was caused by the reduced volume of excavated material to be removed in sequence. The results of the hauler allocated in each sequence can be seen in Fig. 10.

Figure 10 shows the number of haulers in the first sequence and the second sequence is the same, while there is a decrease in the third sequence. This is due to the reduced volume of excavated material to be removed and the number of haulers served in the third sequence.

The number of loaders and haulers is used in calculating the match factor by using Eq. 10. The results of the match factor calculation for each mining sequence are:

- Sequence I

The result of match factor for loader and hauler that will be allocated for activities of lateritic nickel ore mining and overburden stripping in Sequence I can be seen in Table 10.

The match factor on fleet I and II is <1; therefore, the loaders work less than 100%, while the haulers work 100%, so there is a waiting time for the loaders. The match factor of fleet III = 1 means that the loaders and haulers work 100%, so there is no waiting time for the equipment.

Table 10. Match factor of equipment in Sequence I

Fleet	Loader Type	Number (Unit)	Hauler Type	Number (Unit)	Match Factor
I	Cat 320	1	Hino 500	5	0.7
II	Komatsu 210	2	Fuso 220	7	0.9
III	Hitachi 350	1	Fuso 220	1	1.0

Table 11. The equipment match factor of Sequence II

Fleet	Loader Type	Number (Unit)	Hauler Type	Number (Unit)	Match Factor
I	Cat 320	1	Hino 500	5	0.7
II	Komatsu 210	2	Fuso 220	7	0.9
III	Hitachi 350	1	Fuso 220	5	1.0

Table 12. Match factor of equipment in Sequence III

Fleet	Loader Type	Number (Unit)	Hauler Type	Number (Unit)	Match Factor
I	Cat 320	1	Hino 500	5	0.7
II	Komatsu 210	1	Fuso 220	4	1.0
III	Hitachi 350	1	Fuso 220	4	0.8

- Sequence II

The match factor of loader and hauler that on each fleet will be allocated for mining activities of lateritic nickel ore and overburden stripping in the Sequence II can be seen in Table 11.

The match factor on fleet I and II <1, therefore the loaders work less than 100%, while the haulers works 100%, so there is a waiting time for the loaders. The match factor of fleet III = 1 means that the loaders and haulers work 100%, so there is no waiting time for the equipment.

- Sequence III

The match factor of each fleet from pairing the loader and the hauler in Sequence III can be seen in Table 12. The match factor of fleet I and III <1 which is means that the loaders work less than 100%, while the haulers work 100%, so there is a waiting time for the loaders. The match factor of fleet II = 1 means that the loaders and haulers work 100%, so there is no waiting time for the equipment.

4. Conclusion

Mawar Block has 169,240 tons of lateritic nickel ore and 365,589 bcm of overburden which is divided into three sequences. The first sequence has a tonnage of lateritic nickel ore of 55,677 tons with an overburden volume of 143,764 bcm. The second sequence has a tonnage of lateritic nickel ore of 55,518 tons with an overburden volume of 136,055 bcm. The third sequence has a tonnage of lateritic nickel ore of 58,045 tons with a volume of overburden of 85,770 bcm.

To achieve the production target, equipment fleet will be allocated for the first mining sequence to the third mining sequence in a row is 4 units, 4 units, and 3 units. The number of haulers allocated in the first mining sequence to the third mining sequence in a row is 17 units, 17 units, and 13 units.

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Assessment of MICE Green Building Score Utilizing GREENSHIP Rating System: Value Engineering Approach

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Abstract

The building industry used for meetings, incentives, conventions, and exhibitions (MICE) is one of the industries that has high economic attractiveness for investors. Regulations and user requests for new buildings must meet environmentally friendly building standards. The GREENSHIP green building certification system is issued by the Green Building Council Indonesia. To obtain a platinum rating, a minimum total of 56 points requires additional investment costs but will result in operational cost savings. This paper aims to find out what factors influence the optimization of construction costs through value engineering to achieve a green building rating tool with optimum costs in MICE green building design. The findings show that energy is the most influential factor in obtaining platinum rating certification, so it requires value engineering to achieve optimal investment costs. The novelty of this research is that the selection of materials/machines and work methods for environmentally friendly concepts that save energy needs to be done from the start of design to achieve a payback period for the additional cost that can be returned in 3 years and 2 months that is feasible for new investments, which can be a commitment for company owners to build MICE green buildings.

Keywords: Green building; MICE; value engineering

1. Introduction

MICE (Meeting, Incentive, Convention, Exhibition) is a place for meetings and exhibitions in a broad sense, which includes various types of meetings, incentives, conventions, exhibitions, event venues, and other meeting places as shown in Fig. 1 [1]. The meeting, incentive travel, convention, and exhibition (MICE) industry is considered one of the industries with strong economic attractiveness, which has developed rapidly in China in recent years [2].

Tourism with visitors intended for business (MICE/business visitors) is different in terms of needs, handling tourism with the aim of recreational visitors (leisure visitors). In terms of foreign exchange earnings that affect the economic sector, this is the reason, that MICE expenses/business visitors are greater than visitors for recreational purposes, plus the supply of buildings used for MICE currently available, both in Singapore and in Indonesia, are old and not integrated with other supporting facilities such as hotels, restaurants, and malls which will reduce the comfort of visitors, making it attractive for capital owners to build buildings that can be used for MICE activities [3]. The tourism sector is growing steadily in Indonesia is the second largest foreign exchange earner and is the main driver of the Indonesian economy. According to the World Travel & Tourism Council, Indonesia's tourism industry is the twentieth largest in the world, smaller than Thailand and Australia [4].

Numerous factors must be considered during the design phase of a green building. The building's environmental aspect necessitates consideration of site selection, design features, construction practices, and ongoing maintenance. Significant quantities of energy, water, materials, and natural resources are consumed throughout the construction and operational phases. Buildings exert various environmental impacts, including waste generation, air and water pollution, indoor air quality issues, heat island effects, stormwater runoff, and noise pollution. These impacts can adversely affect human

Figure 1. Building design concept for MICE

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health, contribute to environmental degradation, and deplete natural resources.

The increase in costs for the construction of a Green Building concept building has been studied to increase construction costs ranging from 4.5% to 7% compared to conventional buildings, but results in rental prices that have premiums that can be higher between 5% to 10% [5].

Based on a case study of Green Building in Poland whereby following Green Building standards, the trend has been to increase profits by 26% per year, and good application of green technology can save energy between 30% to 80%, as stated by the United Nations Environment Program [6].

To evaluate a building's environmental friendliness, standardized measurements are essential. Various institutions and standards exist for green building assessments globally, including BREEAM in the UK, LEED in the US, NABERS and GREEN STAR in Australia, and GREEN MARK in Singapore. In Indonesia, the GREENSHIP standard, overseen by the Green Building Council Indonesia (GBCI), serves as the benchmark for green building assessments [7].

The current research concentrates on the expenses of MICE activities required to achieve a GREENSHIP certification with a platinum rating, specifically reducing initial costs without compromising quality and functionality. The cost reduction method employed is Value Engineering, a crucial tool in the civil engineering construction industry. Value Engineering offers significant benefits in terms of cost savings and project enhancements. By implementing Value Engineering, it is anticipated that costs will rise as conventional buildings are optimized to meet green building standards. The Value Engineering process involves several stages, making it essential to identify which stage's indicators most significantly impact cost performance [8].

2. Literature Review

2.1. Green building rating standard

Most countries have developed green building rating tools that are based on social, environmental, and economic dimensions [7]. What is meant by green buildings can be in stages as the design, construction, and operation of buildings with maximum conservation of resources (energy, land, water, and materials), pollution reduction, environmental protection, and providing a place for healthy and comfortable people indoor space [7]–[9].

2.2. GREENSHIP

There are several GREENSHIP rating tools, new building, existing building, interior, home, and neighborhood. The building certification system in Indonesia for new buildings can be carried out in the design stage and the building construction stage called the GREENSHIP New Building. The project team can create a comprehensive green building with innovative and creative approaches and ideas from the design to the operational stages of obtaining certification.

GREENSHIP New Building Certification, there are 2 (two) stages of assessment: are 2 (two) stages of assessment:

a. Stages of Design Recognition (DR), a maximum score of 77 points. If the building is still in the design phase, the performance of the final design and planning will be assessed against the GREENSHIP assessment tool.
b. Stages of Final Assessment (FA), a maximum score of 101 points. In the final stage, the overall performance of the building is assessed thoroughly both from the design and construction aspects based on the GREENSHIP assessment tool.

The rating from Design Recognition (DR) and Final Assessment (FA) is shown in Table 1.

2.3. Factors affecting green building

There are Eligibility provisions and six assessment categories to get the GREENSHIP New Building certification. Each category consists of several criteria containing Prerequisites, Credit Points, and Bonus Points. The six categories are as follows Appropriate Site Development (Table 2), Energy Efficiency and Conservation (Table 3), Water Conservation (Table 4), Material Resources and Cycle (Table 5), Indoor Health and Comfort (Table 6), and Building and Environmental Management (Table 7).

Table 1. Rating Design Recognition (DR) and Final Assessment (FA)

Rating	Percentage	Score Minimum DR	Score Minimum FA
Platinum	73%	56	74
Gold	57%	43	58
Silver	46%	35	46
Bronze	35%	27	35

Source: [10]

Table 2. Appropriate site development

Factor	Indicator	Point
Basic Green Area	E.1.1	Prerequisite
Site Selection	E.1.2.	2
Community Accessibility	E.1.3.	2
Public Transportation	E.1.4.	2
Bicycle Facility	E.1.5.	2
Site Landscaping	E.1.6	3
Microclimate	E.1.7	3
Stormwater Management	E.1.8	3
Total Category		17

Table 3. Energy efficiency and conservation

Factor	Indicator	Point
Electrical Sub Metering	E.2.1.	Prerequisite
OTTV Calculation	E.2.2.	Prerequisite
Energy Efficiency Measures	E.2.3.	20
Natural Lighting	E.2.4	4
Ventilation	E.2.5	1
Climate Change Impact	E.2.6	1
On-Site Renewable Energy	E.2.7	5 (Bonus)
Electrical Sub Metering	E.2.1.	Prerequisite
Total Category		26

Table 4. Water conservation

Factor	Indicator	Point
Water Metering	E.3.1.	Prerequisite
Water Calculation	E.3.2	Prerequisite
Water Use Reduction	E.3.3.	8
Water Fixtures	E.3.4.	3
Water Recycling	E.3.5	3
Alternative Water Resources	E.3.6	2
Rainwater Harvesting	E.3.7	3
Water Efficiency Landscaping	E.3.8	2
Total Category		21

Table 5. Material resources and cycle

Factor	Indicator	Point
Fundamental Refrigerant	E.4.1	Prerequisite
Building and Material Reuse	E.4.2	2
Environmentally Friendly Material	E.4.3	3
Non-ODS Usage	E.4.4	2
Certified Wood	E.4.5	2
Prefab Material	E.4.6	3
Regional Material	E.4.7	2
Fundamental Refrigerant	E.4.1	Prerequisite
Total Category		14

Table 6. Indoor health and comfort

Factor	Indicator	Point
Outdoor Air Introduction	E.5.1	Prerequisite
CO_2 Monitoring	E.5.2	1
Environmental Tobacco Smoke Control	E.5.3	2
Chemical Pollutant	E.5.4	3
Outside View	E.5.5	1
Visual Comfort	E.5.6	1
Thermal Comfort	E.5.7	1
Acoustic Level	E.5.8	1
Total Category		10

Table 7. Building and environmental management

Factor	Indicator	Point
Basic Waste Management	E.6.1	Prerequisite
GP as a Member of the Project Team	E.6.2	1
Pollution of Construction Activity	E.6.3	2
Advanced Waste Management	E.6.4	2
Proper Commissioning	E.6.5	3
Green Building Submission Data	E. 6.6	2
Fit Out Agreement	E.6.7	1
Occupant Survey	E.6.8	1
Total Category		26

2.4. Building under study

The Mata Elang International Stadium MICE building is located on Jalan Jenderal Sudirman Kav C 11 PIK2, Tangerang Regency, Banten Province. It is one of the buildings in the PIK2 Complex which was developed by the Agung Sedayu Group and Mata Elang Group, which is an independent city area on the edge of Jakarta with a land area of 183,579 M^2 and a building area of 573,674 M^2 which is designed to be a MICE Green Building.

2.5. Value engineering

Building stages can be evaluated in three stages design (architectural, structural, mechanical, electrical, and other works), construction (architectural, structural, mechanical, electrical, and other works), and operation (maintenance, energy, worker/employee, and other work) [11].

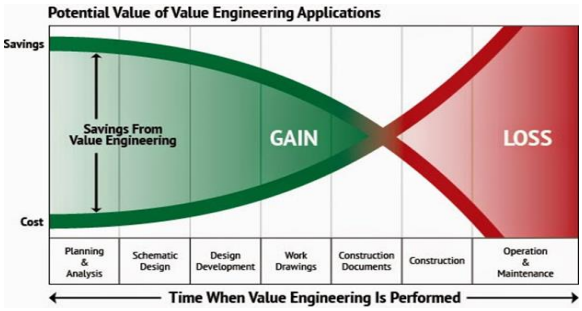

Figure 2. Cost-saving value engineering

These are the phases in value engineering [12] as follows: Preparation, Information, Function Analysis, Creative, Evaluation, Development, Presentation, Implementation and Follow-up [13], [14].

Applying the Value Engineering method to construction projects is particularly effective at the initial stages of construction activities. Conducting a value engineering process is most beneficial during the planning phase, as it allows for the early identification and optimization of cost elements. Performing value engineering analysis during the construction phase can lead to increased work time, additional consultation costs, and various other losses. This concept is illustrated in Fig. 2.

3. Research Methods

The Green Building Council Indonesia has developed a GREENSHIP standard assessment framework, divided into six distinct categories. These criteria encompass two types: prerequisite criteria and assessment criteria. Prerequisite criteria are mandatory within each category and must be met before further evaluation. On the other hand, assessment criteria are also present in each category, and their fulfillment must be tailored to the building's capabilities. Each criterion comprises one or more indicators, each with varying scoring systems. The number of assessment factors, categories, criteria, and indicators for green building evaluation are detailed in Tables 2 to 7.

To qualify for a green building designation assessed by a GREENSHIP rating from the GCBI, several prerequisites must be met. Before the certification process, the project must satisfy specific conditions, including (1) a minimum building area of 2500 m2, (2) adherence to local government planning regarding the building's designated function, (3) implementation of an environmental management plan, and monitoring system, (4) compliance with earthquake resistance standards in building specifications, (5) adherence to fire safety standards, (6) conformity with disability accessibility standards, and (7) provision of building data accessible to the GBCI for certification purposes.

The green building measurement process comprises four stages, outlined in Figure 1. The initial stage involves analyzing prerequisite criteria. If the analysis reveals that these criteria have not yet met the required standards, the criteria cannot be scored, halting the assessment process. However, in this study, if any prerequisite criteria were found to be unmet, they were assumed to be fulfilled

subsequently. Details of the prerequisite criteria for each category are provided in Table 8.

The second phase involved evaluating the building against the GREENSHIP criteria for new buildings version 1.2. Data gathering was conducted through interviews with selected individuals including the experts in green building, and the building designer, all of whom were considered knowledgeable about the building's design and operational management. Interview results were translated into scores for each assessment indicator. Subsequently, a comprehensive gap analysis was performed to ascertain the building's score and compare it against the GREENSHIP standard.

Moving to the third stage, the building's category on the GREENSHIP rating scale was determined. This rating system comprises four categories: bronze, silver, gold, and platinum. A building wants to get a platinum rating at a reasonable cost. In the fourth phase, the obtained results were evaluated to formulate recommendations. These recommendations were derived from research findings and in-depth interviews conducted with green building experts based on value engineering.

Table 8. Categories in GREENSHIP Measurement V1.2

Categories	Number of Criteria		Number of Indicators	
	Prerequisite	Assessment	Indicators	Scores
Appropriate Site Development/ASD	1	7	18	17
Energy Efficiency &Conservation /EEC -Incl. Bonus	2	5	13	26
Water Conservation/WAC	2	6	11	21
Material Resource and Cycle/MRC	1	6	9	14
Indoor Health and Comfort/IHC	1	7	14	10
Building Environment Management/BEM	1	7	9	13
Total	8	38	76	101

4. Results and Discussion

The analysis of prerequisite criteria revealed that nearly all prerequisites within this category had yet to be fulfilled. Some required documents or programs were either unavailable or not yet developed by the building management, indicating a lack of readiness for the green building assessment process. The subsequent step involved assessing the building across six categories, each encompassing various aspects detailed in Table 8.

In the category of Appropriate Site Development (ASD) MICE green building attained a score of 8 out of a possible 17. This category comprises seven criteria. The building design achieved a score of 2 for Site Selection, 2 for Community Accessibility, 1 for Public Transportation, 1 for Bicycle Facilities, 1 for Site Landscaping, and 1 for Microclimate.

Community Accessibility necessitates provisions for access and amenities for public vehicles. Key criteria include reducing reliance on private motor vehicles, enhancing greenery through increased vegetation coverage, employing green roofs to mitigate heat effects, managing water through runoff volume reduction, implementing standard operating procedures (SOPs) for pest control, and establishing social programs for local communities. Details of the scores obtained in the ASD category are presented in Table 9.

4.1. Energy Efficiency and Conservation (EEC)

The subsequent category examined was Energy Efficiency and Conservation (EEC). Within this category, the building received a score of 21 out of a total of 26 points available. A significant portion of this score, 15 points, was attributed to optimized efficiency in building energy performance. This achievement was utilizing calculations in a worksheet, every 2% decrease in energy usage compared to the baseline design earns one point. These savings are computed starting from a 10% reduction in energy consumption compared to the baseline building. The worksheet is supplied by GBCI. Additionally, the building secured 4 points for Natural Lighting, achieved through energy-saving practices in room lighting power, resulting in illumination power that is 20% more efficient. Key requirements for this category include Energy Monitoring & Control, 1 for ventilation, and 1 effects of climate change. Details of the scores obtained within the EEC category are outlined in Table 10.

Table 9. Appropriate Site Development (ASD**)**

Assessment Criteria	Prerequisite Criteria	Score
Site Selection	- Select a development area with the building floor coefficient (KLB) >3 - Carrying out revitalization and development on land that has a negative value and is unused due to former development or negative impacts.	2
Community Accessibility	- Open pedestrian access other than the main road outside the site which connects it with secondary roads and land owned by other people so that access is available at a minimum of 3 public facilities for 300 m for pedestrians. - Open the ground floor of the building so that it can provide safe and comfortable pedestrian access for a minimum of 10 hours a day	2
Public Transportation	- Provide pedestrian path facilities within the building area to get to the nearest public transport stop or station that is safe and comfortable by considering Minister of Public Works Regulation 30/PRT/M/2006	1
Bicycle Facilities	- There is a safe bicycle parking area of 1 parking unit per 20 building users up to a maximum of 100 bicycle parking units	1
Site Landscaping	- Use of plants that have been cultivated locally on a provincial scale, amounting to 60% of the mature canopy area of the landscape area	1
Microclimate	- Use various materials to avoid the heat island effect on the roof area of the building so that the albedo value (solar heat reflection power) is a minimum of 0.3 according to calculations.	1

Table 10. Energy Efficiency and Conservation (EEC)

Assessment Criteria	Requirement	Score
GBCI Standard Worksheet	- By utilizing calculations in a worksheet, every 2% decrease in energy usage compared to the baseline design earns one point. These savings are computed starting from a 10% reduction in energy consumption compared to the baseline building. The worksheet is supplied by GBCI.	15
Natural Lighting	- Efficient utilization of natural light ensures that a minimum of 30% of the working floor area receives a natural light intensity of at least 300 lux. - a lux sensor is installed to automatically adjust artificial lighting when natural light falls below 300 lux.	4
Ventilation	- Do not provide air conditioning in toilet rooms, stairs, corridors, and lift lobbies, and equip these rooms with natural or mechanical ventilation.	1
Effects of Climate Change	- Assessing the effects of energy conservation involves calculating the reduction in CO2 emissions. This reduction is determined by comparing the energy needs of the building's design to those of the baseline, using the grid emission factor. This factor, which converts between CO2 emissions and electrical energy consumption, was established in the DNA decision B/277/Dep III/LH/01/2009.	1

4.2. Water Conservation (WAC)

The third assessment category addressed Water Conservation (WAC), encompassing seven criteria and resulting in a total score of 21 points. Within this category, the MICE Building received a score of 17 points. Freshwater efficiency entails the implementation of programs aimed at reducing water consumption. Details of the scores obtained within the WAC category are presented in Table 11.

Table 11. Water Conservation (WAC)

Assessment Criteria	Requirement	Score
Water Use Reduction	- The consumption of clean water should primarily be sourced from primary sources, with up to 80% coming from these sources, while still meeting the per capita water demand as specified in SNI 03-7065-2005.	1
	- There has been a 30% reduction in the consumption of clean water from primary sources.	6
Water Fixture	- Water features must comply with the discharge capacity below the maximum standard capacity of the water output device as specified in the attachment. At least 50% of the total procurement of water feature products should meet this requirement.	2
Water Recycling	- Utilize all recycled grey water for flushing and cooling tower systems.	3
Alternative Water Resources	- Rainwater is used for alternative water resources	1
Rainwater Harvesting	-Using alternative water recycling and or water for make-up water cooling tower	3
Water Efficiency Landscaping	-Implementing innovative irrigation technology to manage water requirements for landscaping based on the specific needs of plants	1

4.3. Material Resource and Cycle (MRC)

The fourth category under assessment focused on Material Resource and Cycle (MRC), comprising 6 (six) criteria and yielding a score of 14 points. MICE achieved a score of 12 points, primarily attributed to material management practices.

Building management is encouraged to prioritize the utilization of environmentally friendly materials, locally sourced products, certified SNI (Indonesian National Standards) materials, recycled, reused, and renewable products, certified wood products, and products with minimal environmental impact. Furthermore, procurement documentation demonstrating the purchase of environmentally friendly materials is required. Details of the scores obtained within the MRC category are provided in Table 12.

Table 12. Material Resource and Cycle (MRC)

Assessment Criteria	Requirement	Score
Environmentally Friendly Material	- Using materials with environmental management system certification in production is worth a minimum of 30% of total material costs. The certification is valid if it remains so during the purchase process.	1
	- Utilizing materials derived from a recycling process accounts for at least 5% of the total material costs.	1
	- Using materials predominantly sourced from a renewable resource	1
Non-ODS Usage	- AC refrigerant used by Suva ex Dupont (HFC-134^{a})	2
Certified Wood	- Using materials predominantly sourced from renewable resources (such as processed wood transport invoices/FAKO, company certificates) and Forest Stewardship Council (FSC)	2
Prefab Material	- More than 30% of designs use modular or prefabricated materials	3
Regional Material	- Utilizing materials with the main raw materials sourced and manufactured within the territory of the Republic of Indonesia constitutes at least 80% of the total material costs.	2

4.4. Indoor Health and Comfort (IHC)

The fifth category addressed in the assessment pertained to Indoor Health and Comfort (IHC), encompassing seven criteria related to environmental indicators for air quality, thermal conditions, visual comfort, and acoustic qualities. Within this category, MICE achieved a score of 10 out of a possible 10 points. A score of 2 was obtained for air quality, indicating compliance with SNI 03-6572-2001 standards for Ventilation Procedures and Air Conditioning Systems in Buildings, ensuring adequate air intake. Thermal comfort received a score of 1, reflecting generally satisfactory thermal conditions within the room, maintaining a temperature range of 24-27 °C and relative humidity of 60%. Visual comfort earned 1 point, aligning with illumination standards specified in SNI for Energy Conservation in Lighting Systems. The final point,

attributed to acoustic comfort, was based on adherence to sound level regulations outlined in SNI for Specifications of Sound Level and Buzzing Time in Buildings and Housing.

To further enhance indoor health and comfort, certain facilities should be provided within the building, including monitoring for CO2 and CO levels, as well as measurements of physical, chemical, and biological pollutants. Additionally, the establishment of non-smoking areas throughout the building is recommended, with designated smoking areas positioned at least 5 meters away from entrances. Details of the scores obtained within the IHC category are illustrated in Table 13 Indoor Health and Comfort (IHC).

4.5. Building Environment Management (BEM)

The sixth category addressed in the assessment pertained to Building Environment Management (BEM), comprising five criteria and yielding a score of 13 points. MICE achieved a score of 9 out of a possible 13 points. The BEM category is detailed in Table 14.

Table 13. Material Resource and Cycle (MRC)

Assessment Criteria	Requirement	Score
Outside View	- 75% of the active space area is oriented towards an exterior view, constrained by transparent openings along a straight line. - Utilizing materials derived from a recycling process accounts for at least 5% of the total material costs.	1
Environmental Tobacco Smoke Control	- Display signs stating, "No Smoking in all building areas" and prohibit the provision of designated smoking buildings or areas within the premises. If applicable, smoking areas outside the building should be located at least 5 meters away from entrances, outdoor air intakes, and window openings.	2
CO2 and CO Monitoring	- Rooms with a density exceeding 2.3 square meters per person are fitted with a CO2 sensor. This sensor regulates outdoor air ventilation to maintain CO2 concentrations below 1,000 ppm. It is positioned 1.5 meters above the floor near the return air grille or duct.	1
Chemical Pollutants	- Utilizing paints and coatings labeled or certified by GBC Indonesia for their low Volatile Organic Compounds (VOCs) content. - Utilizing composite wood products and laminating adhesive while avoiding the use of asbestos.	3
Thermal Comfort	- Set the general room thermal conditions to a temperature of 25^{0}C and a relative humidity of 60%.	1
Visual Comfort	- Utilizing lamps that provide room illumination levels in compliance with SNI 6197:2011 on Energy Conservation in Lighting Systems.	1
Acoustic Level	- Sound Level in the workspace based on SNI on Specifications of Sound Level and Buzzing Time in Buildings and Housing	1

Table 14. Building Environment Management (BEM)

Assessment Criteria	Requirement	Score
GP as a member of the project team	- Requires involvement of at least one GREENSHIP Professional (GP) certified expert, responsible for guiding the project until it receives a GREENSHIP certificate	1
Pollution of Construction Activity	-Implement a construction waste management plan that includes: -Establishing collection areas, separation, and recording systems for solid waste. -Differentiating records based on whether solid waste is disposed of in landfills, reused and recycled by third parties, or poses no risk of polluting drainage	2
Advanced Waste Management	- Processing building waste, both organic and non-organic, either independently or in partnership with third parties, to enhance value and minimize environmental impact.	2
Proper Commissioning	- Conducting testing and commissioning procedures as per GBCI instructions, which includes providing relevant training to enhance the functionality and performance of equipment and systems by plans and references.	3
Fit Out agreement	- Ensure a letter of agreement with the building tenant includes: (a) Utilization of certified wood for fit-out materials; (b) Execution of training conducted by the building management; and (c) Enforcement of indoor air quality (IAQ) management post-fit-out construction, implemented through a lease agreement.	1

4.6. Overall outcome of green building evaluation for MICE building

The outcomes of the green building evaluation for MICE Building at Mata Elang International Stadium are outlined in Table 15.

Table 15. Results of green building evaluation for MICE Building at Mata Elang International Stadium

Categories	Number of Criteria		Number of Indicators	
	Assessment	Max Score	Score	(%) of Max
1. Appropriate Site Development/ASD	8	17	8	47%
2. Energy Efficiency &Conservation /EEC -Incl. Bonus	7	26	21	81%
3. Water Conservation/WAC	8	21	17	81%
4. Material Resource and Cycle/MRC	7	14	12	86%
5. Indoor Health and Comfort/IHC	8	10	10	100%
6. Building Environment Management/BEM	8	13	9	69%
Total	46	101	77	76%

Scoring a total of 77 points, the MICE Building for the platinum level designation within the green building criteria. A comparison between the maximum attainable score and the assessment results is illustrated in Fig. 2.

Recommendations for enhancing the GREENSHIP rating were formulated through expert opinion collection. A set of questionnaires was distributed to 10 respondents, including building management and university architects. Based on the outcomes of the green building assessment, several recommendations were proposed:

a) Enhance energy control and monitoring systems.
b) Establish bicycle facilities to encourage non-motorized transportation.
c) Introduce additional vegetation to enhance the landscape.
d) Promote energy conservation practices and explore renewable energy sources.
e) Investigate the use of alternative water sources beyond groundwater.
f) Improve waste management practices.
g) Enhance thermal comfort through the integration of indoor vegetation.

Furthermore, aside from green building initiatives, the direction of building development is shifting towards smart buildings. Smart buildings employ Building Automation Systems (BAS) to automate various functions within the building, leveraging information technology and computer systems for control.

In summary, the Industrial Engineering Building attained a score of 77 out of a total of 101 points in the GREENSHIP assessment, earning a platinum rating.

4.7. Value engineering

Based on the 46 criteria in GREENSHIP, these criteria can be grouped into 5 groups as shown in Fig. 3 and Fig. 4, which are

1. Requirement Group
2. Given designs group
3. Energy Group
4. Passive design group
5. Create a design group

The initial cost of the building for MICE activities is IDR 5,057,670,000,000 with the details as shown in Table 16 and based on Pareto law where there is work that exceeds 20%, value engineering can be done.

Based on the price details in Table 16, mechanical and electrical work as well as structural work collectively exceed 20%. Given that mechanical and electrical work will primarily evolve as the building becomes operational, the focus of the author is on this aspect.

Based on Table 16, the initial costs from the breakdown of the largest costs are mechanical and electrical work of 30.6%, above 20% can be done by value engineering, and the most influential factor E 23 = Energy Efficiency Measures = 15 points so that the focus is on internal energy earned a platinum rating of GREENSHIP as green costs.

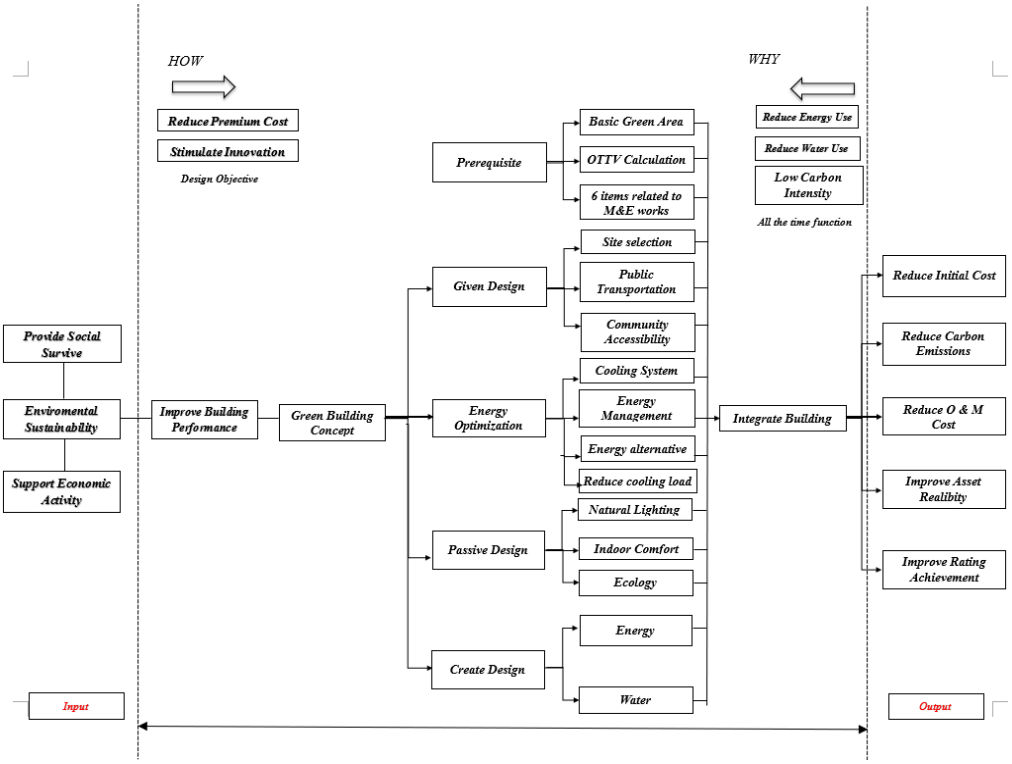

Figure 3. FAST Diagram before value engineering

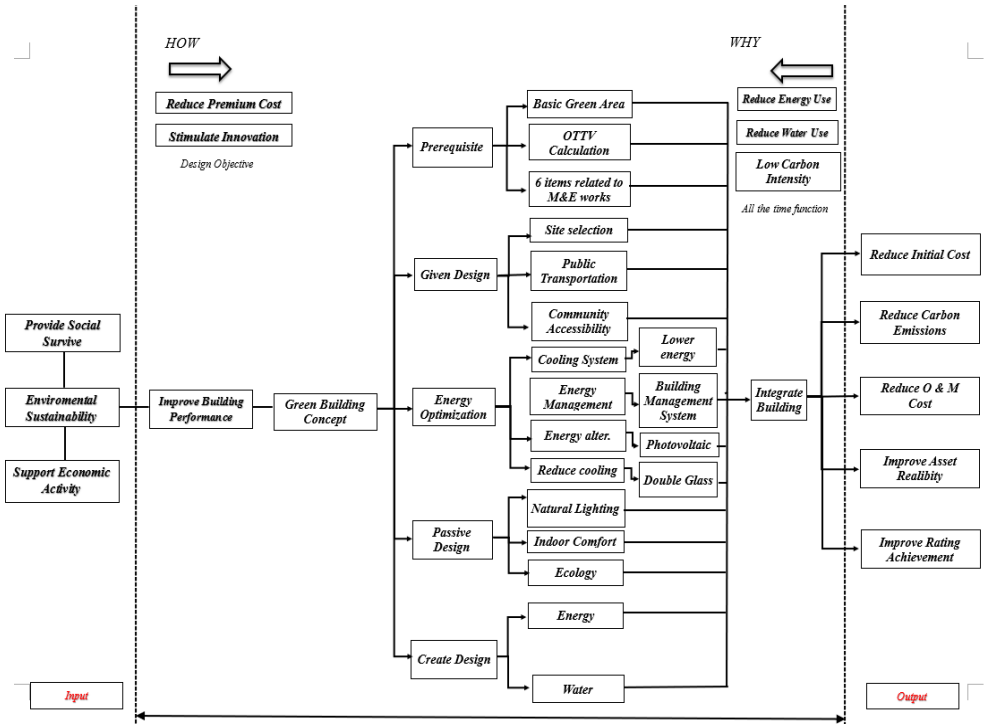

Figure 4. FAST Diagram after value engineering

Table 16. Initial Cost of MICE Building

Works Description	Initial Cost IDR	%
Preliminaries	536,964,000,000	10.6%
Project Site Preparation & Vacuuming System	46,000,000,000	0.9%
Basement Foundation & Piling Works	575,470,000,000	11.4%
Structural Works	1,338,265,000,000	26.5%
Architectural Works & Finishes	800,208,000,000	15.8%
MEP Services	1,546,565,000,000	30.6%
External & Infrastructure Works	178,043,000,000	3.5%
Other Packages	36,155,000,000	0.7%
Total	5,057,670,000,000	100.0%

The total additional cost to make the energy-related green costs IDR 379,036,191,458 = 7.494% as shown in Table 17 with cost breakdown as shown in Table 18.

Table 17. Total additional green costs

Work Description	Initial Cost IDR	Worth to Green Building IDR
Preliminaries	536,964,000,000	536,964,000,000
Project Site Preparation & Vacuuming System	46,000,000,000	46,000,000,000
Basement Foundation & Piling Works	575,470,000,000	575,470,000,000
Structural Works	1,338,265,000,000	1,338,265,000,000
Architectural Works & Finishes	800,208,000,000	907,953,638,400
MEP Services	1,546,565,000,000	1,817,855,553,058
External & Infrastructure Works	178,043,000,000	178,043,000,000
Other Packages	36,155,000,000	36,155,000,000
Total Investment	5,057,670,000,000	5,436,706,191,458
Total Additional Cost		7.494%

Table 18. Cost breakdown of additional cost before value engineering

Work Description	Initial Cost IDR	Worth to Green Building IDR
Preliminaries	536,964,000,000	536,964,000,000
Project Site Preparation & Vacuuming System	46,000,000,000	46,000,000,000
Basement Foundation & Piling Works	575,470,000,000	575,470,000,000
Structural Works	1,338,265,000,000	1,338,265,000,000
Architectural Works & Finishes	800,208,000,000	800,208,000,000
Glass replacement on Building Envelope		107,745,638,400
MEP Services	1,546,565,000,000	1,546,565,000,000
Additional cost on Chiller		60,522,553,058
Additional cost on BMS		154,224,000,000
Additional Cost on PV		56,544,000,000
External & Infrastructure Works	178,043,000,000	178,043,000,000
Other Packages	36,155,000,000	36,155,000,000
Total Investment	5,057,670,000,000	5,436,706,191,458

From the value engineering stage, this research uses the Function Analysis System in analyzing energy optimization. Energy optimization is carried out on a) the air conditioning system that will be used because the energy cost of a building is the highest from the air conditioning machine, b) the AC load which will be evaluated from the load of the glass envelope building as Overall Thermal Transfer Value (OTTV), c) other energy besides AC which requires energy management d) alternative energy sources as renewable energy.

Regarding energy optimization, an analysis was carried out on the causes of the cooling load, capacity, and partial load of the chiller used to cool the room, building management systems, and alternative energy sources to reduce additional costs. with details of additional cost reductions to IDR 237,173,388,379 as shown in Table 19.

Table 19. Cost breakdown of additional cost after value engineering

Work Descriptions	Initial Cost IDR	Worth to Green Building IDR
Preliminaries	536,964,000,000	536,964,000,000
Project Site Preparation & Vacuuming System	46,000,000,000	46,000,000,000
Basement Foundation & Piling Works	575,470,000,000	575,470,000,000
Structural Works	1,338,265,000,000	1,338,265,000,000
Architectural Works & Finishes	800,208,000,000	800,208,000,000
Glass replacement on Building Envelope		107,745,638,400
MEP Services	1,546,565,000,000	1,546,565,000,000
Additional cost on Chiller		33,073,749,979
Additional cost on BMS		61,200,000,000
Additional Cost on PV		35,154,000,000
External & Infrastructure Works	178,043,000,000	178,043,000,000
Other Packages	36,155,000,000	36,155,000,000
Total Investment	5,057,670,000,000	5,294,843,388,379
Total additional cost		4.689%

Economic benefits, According to Knight Frank 2023, rental prices for green buildings are 34% higher than those for conventional buildings. This increase leads to higher profits for green building companies, subsequently raising the value of these buildings.

Environmental benefits include reducing energy consumption, conserving resources to expand availability, preventing energy crises, lowering CO2 emissions, mitigating global warming, and combatting the effects of climate change.

5. Conclusion

The most influential factor in getting green certification is energy. The design of this building must be improved to meet EEC2 prerequisites with improvements to the OTTV, cooling loads from the air conditioning, and lighting installations. Decreasing the value of OTTV from the national standard of 35 W/M² to 21.06 W/M² there is an additional cost of IDR 107,745,638,400, - by modifying the building envelope as in Table 17. The total energy consumption of buildings decreased from Kwh/year from 43,222,692.07 to 29,110,483.10 or energy-saving 14,112,208.96. The points achieved because of savings from the total energy consumption of 11 points, 32.65% of energy-saving minus 10% = 22.65% divided by 2%. With the additional point achieved because of savings from the total energy consumption of 11 points the total points criteria achieved will be 77 or platinum rating and with the conversion of 1 kwh = 0.891 kg and energy savings of 14,112,208.96 kwh/year, there is a reduction in CO2 emissions of 12,573,978.82 kg. With Pareto's law, mechanical and electrical work that is more than 20% of the weight of the initial budget is feasible for value engineering. With FAST diagrams for energy optimization, the total additional cost to make the energy-related green costs IDR 379,036,191,458 = 7.494% can be reduced to IDR 237,173,388,379 = 4.689%. The additional cost can be returned in 3 years and 2 months.

Recommendations for future research on the Green Building Score utilizing the GREENSHIP Rating System and the Value Engineering approach include:

a) Exploring additional aspects of green building certification beyond the current focus.
b) Applying the Value Engineering method to other case studies to evaluate its effectiveness and benefits in different contexts.
c) Investigating the long-term impacts of Value Engineering on the performance and sustainability of green buildings.
d) Assessing the cost-benefit analysis of Value Engineering in various phases of construction projects.
e) Comparing the GREENSHIP Rating System with other green building certification systems to identify potential improvements and best practices.

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Effect of Temperature Variation PWHT Dissimilar Welding Low Carbon Steel ASTM A36 with ASTM A240 Type 316L

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Abstract

ASTM A36 low carbon steel is steel commonly used in construction, and the austenitic stainless steel 316L series is stainless steel with good corrosion resistance. Joining two dissimilar metals is unavoidable because it can provide good mechanical properties and resist corrosion at a low cost. This study studied the effect of variations in post-welding heating process temperature (PWHT) on mechanical properties and microstructure by shield metal arc welding (SMAW) low carbon steel ASTM A36 with ASTM A240 type 316L with a thickness of 6 mm with a single V connection and using an E308L-electrode. 16. The PWHT process was carried out to improve the weld results with variations in heating temperatures of 400, 600, and 900˚C with a holding time of 1 hour with 15% dromos quenching media. Testing mechanical properties includes hardness test using micro Vickers method on low carbon steel base metal, HAZ, weld metal, HAZ, and stainless steel base metal and impact test using Charpy method. Optical microscopes were used to study the microstructure of the area of the base metal, HAZ, and weld metal viewed using a laser scanning microscope. The test results show that the highest average hardness value in the weld metal area is in the specimen without PWHT with a value of 124.96 HV and samples with a PWHT temperature of 400˚C on the weld metal 121.63 HV and the lowest in the PWHT specimen 900˚C 76.17 HV. in the HAZ 316L area. The hardness value of the weld metal without PWHT and PWHT indicates that the hardness value is higher than the two-parent metals. While the impact test with PWHT specimens at 400˚C had higher impact energy than specimens without PWHT by 6.50%, and the lowest was 16.26% at the optimum temperature of 900˚C, the shape of the samples showed ductile cracks.

Keywords: Welding of dissimilar metals, post-welding heat treatment, SMAW welding, impact test

1. Introduction

The connection of materials with the welding method is a method of joining similar or different metals that has been widely applied. One of the challenges in the field of welding is the welding of different metals. This challenge is more difficult than similar welding due to differences in hardness, toughness, and physical and chemical composition of the parent metal [1, 2]. In today's industrial world, welding applications for dissimilar metals have been widely used, such as in marine, automotive, and power plants. Changes in microstructure and compositional gradients can affect changes in the physical properties and chemical compositions of welded joints of dissimilar metals [3]. Accordingly, large industries are now maximizing the properties of materials and compositions to obtain high-quality products at low operating costs by using dissimilar metal joint to obtain high-quality products [3, 4, 5].

Post-welding heating (PWHT) aims to eliminate residual stresses, make the grains finer, increase corrosion resistance, and reduce hardness to obtain plastic and tensile mechanical properties [3, 6]. Residual stress in the weld is affected by heat input, and this can lead to embrittlement, decreased weld strength, and low corrosion resistance [6, 7]. Heat treatment to remove residual stresses is mostly carried out below the critical temperature and n in the crucial temperature [6]. In recent years, several experiments have been carried out on the effect of PWHT on welds [3, 6, 7]. Variation of holding time 1 hour, 2 hours, and 3 hours temperature 550˚C PWHT process welding different metals ST 37 and AISI 304, the value of hardness without PWHT was higher after PWHT 168.22 HVN and 157.03 [8]. Another study describes variations in temperature of 450˚C and 1100˚C with different holding times. The highest hardness value of 238.5 HV was obtained from PWHT welding specimens of 450˚C for 4 hours having good weld quality [9].

Setiawan et al. studied the effect of temperature variations of 450, 550, and 650˚C for 3 hours of PWHT process on toughness and corrosion resistance of ASTM 252 material. That the optimum value of toughness is achieved at a temperature of 550˚C [10]. Sadeghi et al. observed the effect of temperature variations at 480, 560, 620˚C, and 680˚C PWHT of different metal joints of A537CL1 pressure vessel steel and A321 austenite steel,

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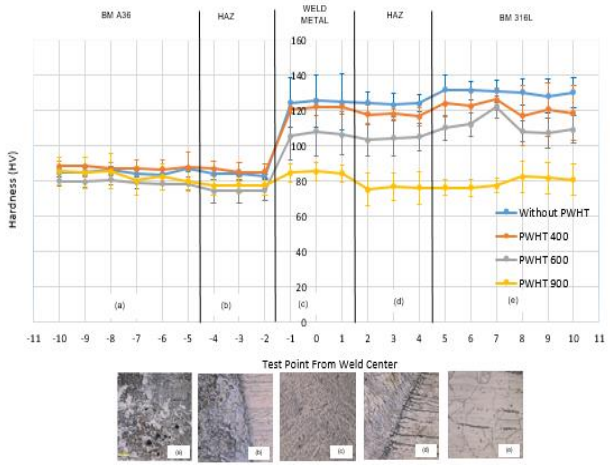
Table 1. Chemical composition of weld metal and electrode (%wt)

Element	C	Ni	Cr	Mo	Mn	Si	P	S	Cu	Fe
316L	0.03	10-14	16-18	2-3	2	0.75	0.045	0.03	-	Bal.
A36	0.26	-	-	-	-	0.04	0.04	0.05	-	Bal.
E308L-16	0.04	9-11	18-21	0.75	0.5-2.5	-	-	-	-	Bal.

they found that PWHT had no significant effect on the microstructure at other joint areas and the value of hardness and tensile strength decreased [6]. Based on those research, this paper aims to evaluate the effect of temperature variations of PWHT 400, 600, and 900˚C on the mechanical properties of hardness, impact, and microstructure tests of welded metal joints of different metals ASTM A36 and ASTM A240 type 316L using filler metal.

2. Research Method

This study uses an experimental method, A36 low carbon steel plate material with 316L stainless steel plate with a thickness of 6 mm, single V connection. SMAW welding current 70 A with reverse polarity with a 0.59 kJ/mm heat input. Electrodes E308L-16 and 2.6 mm in diameter. The chemical composition of the base metal and electrodes is shown in Table 1. After welding the specimen in the Non-Destructive Test, the next step is to make a specimen size 6 mm x 11 mm x 55mm. Mechanical properties are tested in two parts of the specimen, namely, without PWHT and PWHT. PWHT samples with temperatures of 400˚C, 600˚C, and 900˚C using a Thermo Scientific furnace, holding time of 1 hour, and quenching media of 15% dromus. The specimens were then prepared for hardness and impact tests. Samples for microstructure were first sanded with grit 400, 800, 1000, 1500, 2000, and 5000. Then, carbon steel parts were etched with 2% nital, and weld metal parts and stainless steel parent metal were etched with glycergia etching reagent. (10 ml HNO3, 20 ml HCL, and 30 ml glycerin). Hardness test on the second part of the base metal, HAZ, and weld metal using the Vickers method Mitec type 402MVDS-Y, load 0.5 Kgf and dwell time 10 seconds. The impact test specimen with a standard sub-size size of 55 mm x 10 mm x 55 mm refers to the ASTM E23 standard with the Charpy impact test method, and the machine used Impact Testing type MJB-W300B with a load of 300J.



(a) BM A36,(b) HAZ A36, (c) Weld Metal, (d) HAZ 316L, (d) BM 316L

Figure 1. The distribution of hardness of the weld metal E308L-16 and the microstructure without treatment

3. Results and Discussion

3.1. Hardness

This study aims to analyze the hardness profile and microstructural changes in welded joints between austenitic stainless steel and low carbon steel after post-weld heat treatment (PWHT). The hardness test profile looks like Fig. 1. The results indicate that the hardness profile distribution of the welding metal differs from that of the filler metal E308L-16. Hardness tests using the Vickers microhardness method show an increase in hardness from the base metal to the weld metal for both specimens without PWHT and with PWHT. The highest weld metal hardness in the sample without PWHT was 124.96 HV, while the lowest weld metal hardness in the 900˚C PWHT specimen was 85.01 HV.

The distribution of hardness values in each treatment shows that the average hardness value of the weld specimen without PWHT is higher than that of the treated samples in all test areas. Changes in PWHT temperature resulted in hardness degradation in the base metal, heat-affected zone (HAZ), and weld metal. Based on the hardness profile graph, the weld metal shows a higher hardness value than the base metal and HAZ. The increase in weld metal hardness is associated with a smoother microstructure and the absence of chromium carbide formation. Research conducted by [12, 13] also indicates that PWHT affects the hardness distribution and microstructure in welded joints between austenitic stainless steel and low-carbon steel. The findings are consistent with our results, where PWHT at high temperatures (900˚C) results in a decrease in hardness due to grain enlargement and carbide dissolution. Additionally, another study by [15] found that PWHT on low-carbon steel and stainless steel welded joints results in significant hardness variation. High-temperature PWHT increases strength but decreases hardness due to microstructural changes, including grain enlargement.

Further, the research by [11] on the effect of delta ferrite on the mechanical properties of dissimilar ferritic-austenitic stainless steel welds supports our findings. Delta ferrite in the weld metal can influence hardness and mechanical properties. The presence of delta ferrite is beneficial in preventing hot cracking during welding, but excessive delta ferrite can lead to brittleness and decreased toughness. Our study found no chromium carbide formation, which aligns with the beneficial effects of delta ferrite in maintaining weld metal integrity.

3.2. Impact

Figure 2 shows the average results of the Charpy V-notch impact test with welding metal E308L-16, and Figure 3 shows the impact test fracture. The test was carried out on the weld metal area at room temperature. This figure shows that the highest impact after the post-welding heating process on the 400˚C PWHT specimen was 1.31 joules/mm^2, or an increase of 6.5% from the specimen

without PWHT. The lowest impact values were in the 600 Cand 900˚C PWHT specimens by 6.5% and 16.26% of the samples without PWHT. In general, the purpose of the post-welding heating process is to expect the value of toughness, flexibility, and impact energy to increase with the increase in post-welding heating temperature. The amount of ferrite phase in the weld metal can affect the decrease in the impact energy value. This is because the temperature and time of the post-welding heating process will jeopardize the ferrite delta phase transformation [7]. The fracture shape of the specimen was without heat treatment, and after PWHT, it showed a ductile fracture. The decrease in the toughness of the weld metal can be influenced by inclusions [14].

3.3 Microstructure

Macro-observation of the welding of different metals with *filler metal* E308L-16 after etching with glysergia aims to reveal some differences between carbon steel and stainless steel with weld metal. The difference between the weld metal, A36 low carbon steel base metal, and 316L base metal, the HAZ area adjacent to the weld metal, is visible. In addition to this area, there is still a hot area between the weld metal and the HAZ area, called the welding boundary (*fusion line*), as shown in Fig. 4.

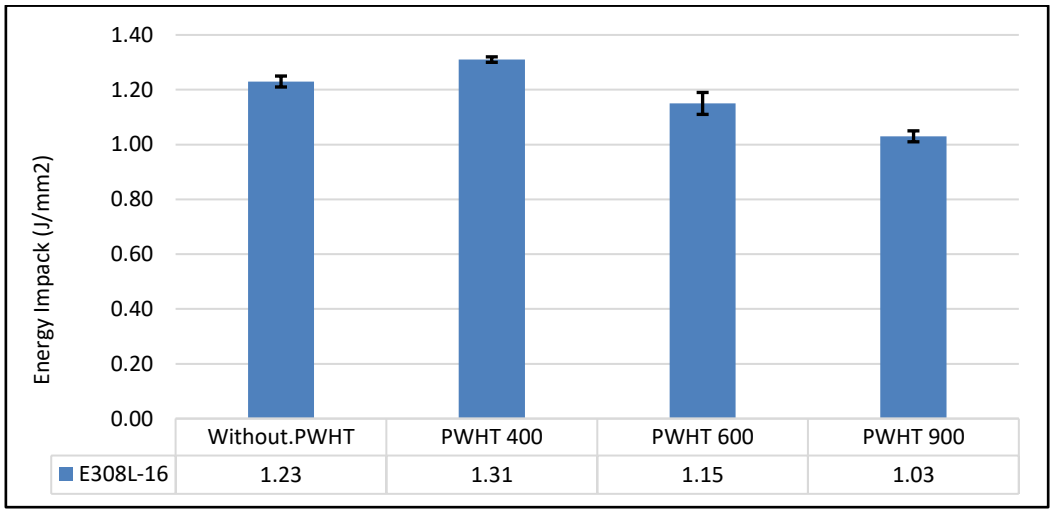


Figure 2. Impact Strength of weld metal E308L-16

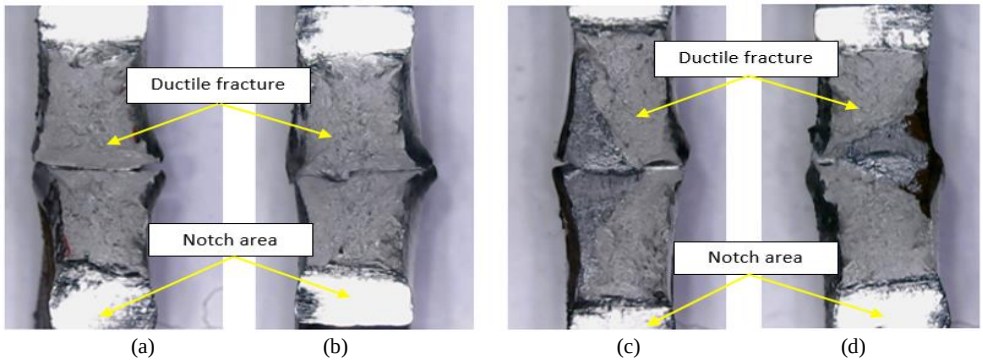


Figure 3. Impact test fracture (a) without PWHT, (b) PWHT 400˚C, (c) PWHT 600˚C and (d) PWHT 900˚C

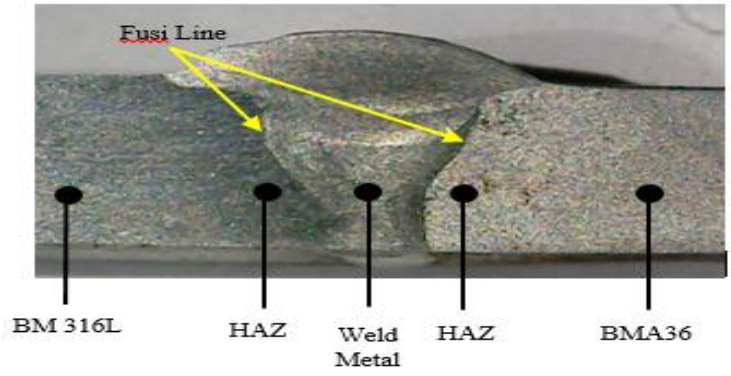


Figure 4. Dissimilar metal welding macrostructure

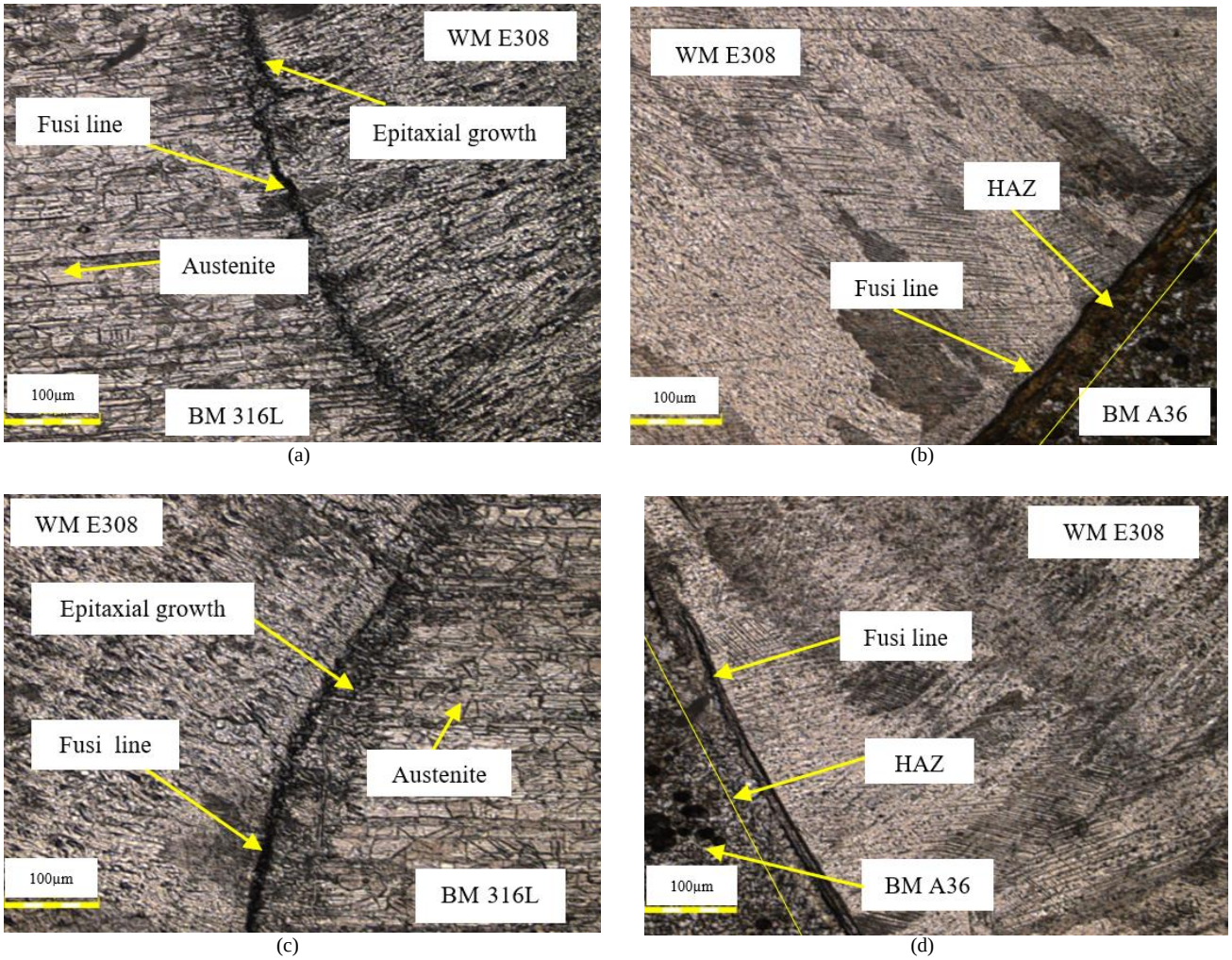


Figure 5. Microstructure of the weld metal surface of stainless steel and low carbon steel, (a) HAZ area 316 and WM E308L-16 without PWHT, (b) area HAZ A36 and WM E308L-16 without PWHT, (c) area HAZ 316 and WM E308L-16 PWHT 400 and (d) HAZ area A36 and WM E308L-16 PW

The results of observing the microstructure of the welding of different metals are shown in Fig. 5. The difference between the parent metals for carbon steel is visible. Low-grade, stainless steel, and weld metal. Figures 5 (a) and 5 (c) show the welding surface between the weld metal and 316L stainless steel base metal. The surfaces of these two parts show similarities because the chemical composition of chromium and nickel contains a small ratio, and epitaxial growth of the weld metal fuses with the parent metal is also visible. While Fig.s 5 (b) and (d) show the weld surface of the weld metal with A36 low carbon steel, showing significant differences due to the different chemical compositions. The results of metallographic observations in Fig. 5 show that the heat treatment sample with a temperature of 400˚C does not show any influence on the joint weld zone. This is because the post-weld heat treatment temperature is below the critical temperature, so there is no phase change [7]. The phase changes that occur during the welding process and post-weld heat treatment (PWHT) significantly influence the mechanical properties of welded joints. In the welding of austenitic stainless steel and low-carbon steel, the primary phase transformations that may occur include the martensitic transformation in the heat-affected zone (HAZ) of the carbon steel and the formation of delta ferrite and austenite in the stainless steel.

For carbon steel, the transformation from austenite to martensite can increase hardness but reduce toughness. In contrast, the formation of delta ferrite in stainless steel can provide stability against hot cracking but may lead to brittleness if the delta ferrite content is excessive. When PWHT is conducted at temperatures lower than the critical temperature (e.g., 400˚C), there are no significant phase changes in the microstructure, and thus, the mechanical properties remain relatively unchanged. However, higher PWHT temperatures, such as 900˚C, can cause microstructural alterations, including carbide dissolution and grain growth, leading to a decrease in hardness, as observed in your research findings. Relevant studies, such as the [15], reveal that high-temperature PWHT can decrease hardness and strength due to the phase changes and microstructural transformations that occur. Additionally, the study on the [11] highlights that the delta ferrite formed during dissimilar welding can impact mechanical properties, particularly in maintaining joint integrity against hot cracking. However, it must be carefully controlled to avoid reducing toughness.

4. Conclusion

Conclusions obtained in this research are as follows:

- The hardness decreases with increasing heat treatment temperature. The hardness value decreased in the PWHT 900˚C specimen by 31.97% of the untreated sample, and the hardness of the weld metal was higher than the two-parent metals.
- The highest impact test value was on specimens with PWHT 400˚C at 6.5 %, and the lowest was on samples of PWHT 900˚C with a reduction in the value of 16.26% from samples without PWHT.
- The macrostructure shows the difference between the metal parts of the two-parent metals, haz area, weld metal, and fusion line. The chemical composition ratio of chromium and nickel is the same, showing the similarity between the base metal and the parent metal.
- Researchers suggest researching corrosion resistance in the HAZ area of A36 base metal with welded metal.

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Analysis of Thermal Comfort of Office Buildings (Case Study: Hasanuddin University Rectorate Building)

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Abstract

Thermal comfort is one of the fundamental aspects of indoor environmental quality, and it is closely related to occupant satisfaction and energy use in buildings. The purpose of this research was to analyze the thermal conditions of the student affairs rooms (Interest & Talent Room and Student Meeting room) at the second floor and the academic and education rooms (Academic Meeting room, Academic Registration room, and Head of Education and Evaluation room) at the seventh floor of Hasanuddin University rectorate building. This study used a quantitative method using a survey where the researcher asked several respondents about the level of thermal comfort of the room occupants when the volume of air conditioner (AC) is increased gradually every day at 18ºC, 22ºC, and 27ºC. In addition, measurements were conducted using HOBO from 08.00 – 17.00 to obtain data in the form of air temperature, humidity, and air velocity in the room. At the same time, respondents were asked to fill out a questionnaire asking the level of comfort felt by the room occupants at that time. The results showed that the average air temperature at 18º C is 24.62ºC, humidity is 63.108%, and air velocity is 0.144 m/s. At a temperature of 22º C, the average air temperature is 24.78ºC, humidity is 60.684%, and the air velocity is 0.142 m/s. At a temperature of 27º C, the average air temperature is 25.97ºC, humidity is 64.022%, and the air velocity is 0.127 m/s. The results showed that the respondents felt ‚cold‘ when the volume was at 18ºC, felt 'comfortable' when the volume was at 22ºC, and felt neutral when the volume was at 27ºC. In the end, temperatures of 22ºC and 27ºC can be used as a reference in the use of air conditioning temperatures in the room.

Keywords: Thermal comfort, rectorate building, temperature, humidity, air velocity

1. Introduction

Thermal comfort is one of the fundamental aspects of indoor environmental quality, and it is closely related to occupant satisfaction and energy use in buildings. Maintaining thermal comfort for building occupants is the main goal of HVAC (Heating, Ventilation, and Air Conditioning), design engineers, architects, and buildings because humans need comfortable room air (thermal comfort) to perform activities optimally [1]. Generally, the comfort of a room depends on two factors. They are an environmental factor and individual factors caused by the user itself [2]. Thermal comfort is defined as a feeling in the human mind that expresses satisfaction with its thermal environment [3].

The requirement for a 'comfortable temperature' is a thermal condition of the air in the space, which 'does not disturb' the body [4]. The terms of thermal comfort range from cold/cool/slightly cool/neutral/ slightly warm/warm/hot [5]. Thermal comfort is needed by humans so that they can carry out activities smoothly, whether at home, school, or office. A comfortable work environment is needed by workers to be able to work optimally and productively. Therefore, the work environment must be handled or designed in such a way that it becomes conducive for workers to carry out activities in a safe and comfortable atmosphere [6].

According to Szokolay in [7] comfort depends on climatic variables (sun or radiation, air temperature, humidity, and wind speed) and several individual factors such as clothing, acclimatization, age, gender, level of obesity, health level, type of food and drinks consumed, and skin color. Typically, an office was designed to be a room that should be filled by working people. These workers certainly have positions and roles. The Office grew even more along with the needs that came from a formal human profession. Then, people started to build spaces and facilities in it [8]. Therefore, thermal comfort in office space needs to be considered properly.

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Two approaches can be taken to meet room thermal comfort standards; through the use of active devices and passive designs [9]. AC is an active device that can be used to provide comfort and benefits during activities. In fact, air conditioners can make a room more airtight [10]. The function of the air conditioner is as a regulator (coolant/heater) of the desired room temperature to create comfortable air conditions. In the workplace, AC is also a way to increase work productivity [11]. However, using too much air conditioner will consume much energy [12]. This research was conducted to analyze the thermal conditions of the room. This research was conducted in the rectorate building of Hasanuddin University on the second and seventh floors, representing the Hasanuddin University rectorate. The second floor represents the bottom four floors, and the seventh floor represents the top four floors.

According to standard [13], buildings must provide the following thermal environment.

- Cool and comfortable, between effective temperature 20.5° C – 22.8° C
- Optimal comfort, between the effective temperature of 22.8° C – 25.8° C
- Warm and comfortable, between the effective temperature of 25.8° C – 27.1° C

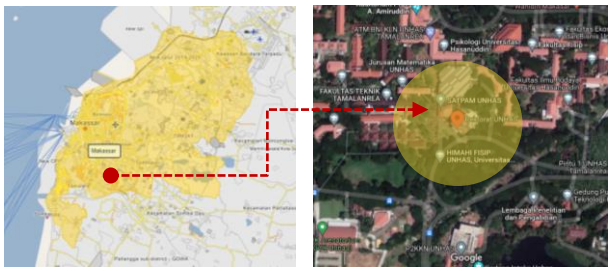
For tropical areas, the recommended relative humidity is between 40% ~ 50%, but for a room with a dense number of people such as a meeting room, the relative humidity is still allowed in the range of 55% ~ 60%. In order to maintain comfortable conditions, the velocity of the air over the head should not be greater than 0.25 m/s and preferably less than 0.15 m/s.

2. Research Method

The research method used was quantitative research with survey methods. This method was used to find detailed information on the thermal conditions of the Hasanuddin University rectorate building so that the data obtained are accurate and reliable. The informants were 37 rectorate employees working in the room.

2.1. Research sites

The research location was in the rectorate of Hasanuddin University on Jl. Perintis Kemerdekaan No. KM 10, Tamalanrea Indah, Tamalanrea district, Makassar City, as shown in Fig. 1. The Hasanuddin University Rectorate, as shown in Fig. 2, consists of 8 floors, and the top floor is the floor occupied by the UNHAS Chancellor. The rectorate building area is 10,208.66 m^2. The sample location of the study was on the second floor, which has a floor area of 1,376.24 m^2, and the seventh floor (academic and educational) with an area of 1,020.96 m^2.



(a) (b)

Figure 1. (a) Makassar City Map (b) Location Map of Hasanuddin University Rectorate Building

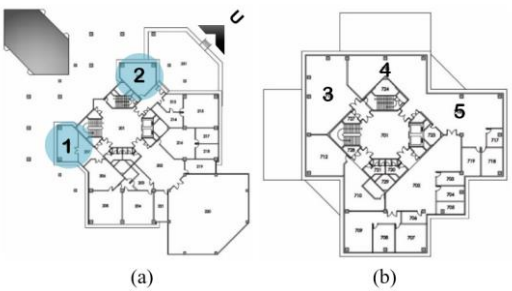
Figure 2. Rectorate building facade

2.2. Population and sample

The population in this study were employees of the rectorate building, especially employees in the second-floor fields (student affairs) and seventh-floor (academic and education), head of interest and talent room, student Meeting room, Academic Meeting room, registration (academic) room and Head of Education and Evaluation room. The four rooms represent the rectorate. The population was the generalization area consisting of objects/subjects that have certain quantities and characteristics determined by the researcher to be studied and then draw conclusions [14]. While the samples taken include questionnaires of respondents about air temperature, humidity, and air velocity in the room.

2.3. Data collection

Data collection was conducted in the form of primary data and secondary data. Primary data is a source of direct data obtained by researchers. While secondary data is data obtained by researchers from existing sources, such as through books, research journals, and articles related to



(a) (b)

Figure 3. (a) The floor plan of the student affairs on the second floor (1) head of interest and talent room (2) student meeting room (b) The floor plan of academics and education on the seventh floor (3) academic meeting room (4) registration (academic) room (5) Head of Education and Evaluation room

research. In this research, data collection was conducted using research instruments such as the Hobo thermal measuring instrument to obtain statistical data in the form of temperature, humidity, and air velocity measurements which were carried out every Monday to Friday from 08.00 - 17.00 WITA. This study measures the value of several variables using a Likert scale to find out about the thermal conditions, behavior, and activities of room occupants.

a. Data Analysis

The data analysis technique was descriptive analysis. This analysis is used to describe the characteristics of respondents and research variables. After the data in the form of air temperature, humidity, and air velocity were obtained, the data were tabulated, and a table or graph was made. Data analysis was performed using MS Excel spreadsheet software and the Statistical Package for Social Sciences (SPSS). Spreadsheets were used to calculate the average values of the thermal environment variables and to produce tables showing microclimatic conditions [15]. SPSS version 22 was used to analyze the validity and reliability of the questionnaire.

The measurement data were analyzed statistically to determine differences in air temperature, humidity, and wind flow speed at each measurement point. In addition, statistical tests were carried out to ensure the validity and consistency of the questionnaire.

3. Discussion and Results

3.1. General description of respondents

The number of respondents in the study were 17 people on the 2nd floor and 20 people on the 7th floor, making it 37 respondents in total. The respondents consist of 17 men (45.9%) and 20 women (54.1%). The age of the respondents started with 7 people (18.9%) aged 21-34 years, 25 people (67.6%) aged 35-54 years, and 5 people (13.5%) aged > 55 years. In the room occupancy variable, from a total of 37 respondents, 33 respondents (89.2%) answered 5x a week, 1 respondent (2.7%) answered 1-4x a week, and 3 respondents (8.1%) answered 1-4x in 4 weeks. In the type of clothing variable, 30 respondents (81.1%) answered "long-sleeved shirt, long pants", 6 respondents (16.2%) chose "long-sleeved light shirt, long pants" and 1 respondent (2.7%) answered “sweater/jacket”.

Table 1. Respondent data and measurement time at Hasanuddin University rectorate

No	Room	Total of Respondents	Measuring Time
1	Head of Interest and Talent room	5	08:00 – 17:00
2	Student Meeting room	12	08:00 – 17:00
3	Academic Meeting room	6	08:00 – 17:00
4	Registration (academic) room	7	08:00 – 17:00
5	Head of Education & Evaluation room	7	08:00 – 17:00
	TOTAL	37	

3.2. Student affairs

The room measured using HOBO is a room in the student affairs area on the second floor of the rectorate. It consists of the Head of Interest & Talent room and the Student Meeting room.

The room for the Head of Interest and Talent (a) has an area of 39.6 m^2 witha length of 8.25 m and a width of 4.80 m. While Student Meeting room (b) has an area of 52.58 m^2 with a length of 8.40 m and a width of 6.26 m. This room is in the form of a pentagon because it has five sides to the room. In addition, these two rooms are heading towards the west of the building.

3.3. Academics and education

The room measured using HOBO is a room located in the academic & education on the seventh floor of the rectorate. It consists of Academic Meeting room, Registration (Academic) room and Head of Education & Evaluation room.

(a) (b)

Figure 4. (a) Head of interest and talent room (b) Student meeting room

(a) (b)

(c)

Figure 5. (a) Academic meeting room (b) registration (academic) room (c) Head of Education and Evaluation room

The academic Meeting room has an area of 119.52 m^2, while The Academic Registration room has an area of 100.26 m^2 and has openings to the north and west of the building. The Head of Education & Evaluation room division has an area of 126.36 m^2 and has an opening or window to the north of the building. The type of opening or window in this room is a glass window that can be opened by sliding the glass.

3.4. Result of average thermal condition at temperatures 18ºC, 22 C, and 27 C

3.4.1. Temperature (ºC)

The average value of air temperature in the study room can be seen in Fig. 6. As shown in Fig. 6, the average air temperature at 18º C is 24.62ºC with the following description. The Head of Interest & Talent room is 25.9ºC, the Student Meeting room is 24.1ºC, the Academic Meeting room is 23.24ºC, the Registration (academic) room is 25.25ºC, and the Education & Evaluation room is 24.61ºC. The average temperature at 22ºC is 24.78ºC, where the Head of Interest & Talent room is 25.08ºC, the Student Meeting room is 24.65ºC, the Academic Meeting room is 26.17ºC, the Registration (academic) room is 24.26ºC, the Education & evaluation room is 23.74ºC. The temperature of 27ºC is 25.97ºC, where the Head of Interest & Talent room is 25.81ºC, the Student Meeting room is 25.04ºC, the Academic Meeting room is 26.59ºC, Registration (academic) room is 26.3ºC, and the Education & evaluation room is 26.11ºC.

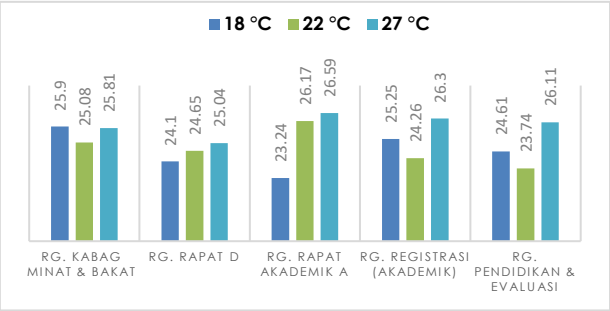


Figure 6. The average value of air temperature in the study room

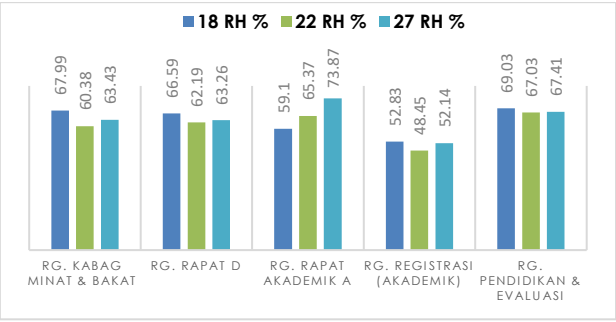


Figure 7. The average value of air humidity in the study room

3.4.2. Humidity (RH %)

The average value of air humidity in the research room can be seen in Fig. 7. As shown in Fig. 7, the average humidity at 18ºC is 63.108% with the following description; the Head of Interest & Talent room is 67.99%, the Student Meeting room is 66.59%, the Academic Meeting room is 59.1%, the Registration (academic) room is 52.83%, and the Education & Evaluation room is 69.03%. The average temperature at 22ºC is 60.684 %, where the Head of Interest & Talent room is 60.38 %, the Student Meeting room is 62.19%, the Academic Meeting room is 65.37%, the Registration (academic) room is 48.45 %, the Education & Evaluation room is 67.03%. While, the temperature of 27º C is 64.022%, consisting of the Head of Interest & Talent room is 63.43%, the Student Meeting room is 63.26%, the Academic Meeting room is 73.87%, the Registration (academic) room is 52.14%, and the Education & Evaluation room is 67.41%.

3.4.3. Air velocity (m/s)

The average air velocity value in the research room can be seen in Fig. 8. As shown in Fig. 8, the average air velocity at 18ºC is 0.144 m/s with the following description: the Head of Interest & Talent room is 0.099 m/s, the Student Meeting room is 0.077 m/s, the Academic Meeting room is 0.191 m/s, the Registration (academic) room is 0.141 m/s, and the Education & Evaluation room is 0.214 m/s. The average temperature at 22ºC is 0.142 m/s, where the Head of Interest & Talent room is 0.130 m/s, the Student Meeting room is 0.078 m/s, the Academic Meeting room is 0.195 m/s, the Registration (academic) room is 0.160 m/s, the Education & Evaluation room is 0.147 m/s. While the average temperature at 27ºC is 0.127 m/s, consisting of the Head of Interest & Talent room is 0.109 m/s, the Student Meeting room is 0.081 m/s, the Academic Meeting room is 0.220 m/s, the Registration (academic) room is 0.109 m/s, and the Education & Evaluation room IS 0.117 m/s.

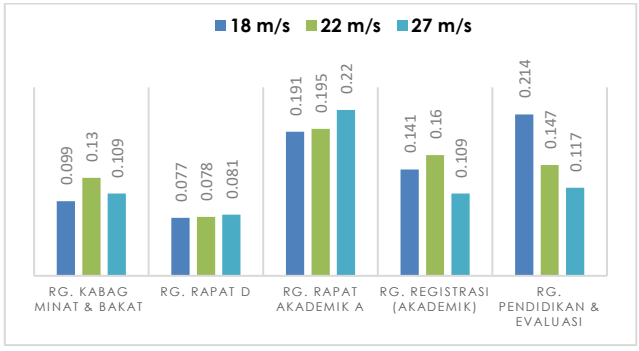


Figure 8. The average value of air velocity in the research room

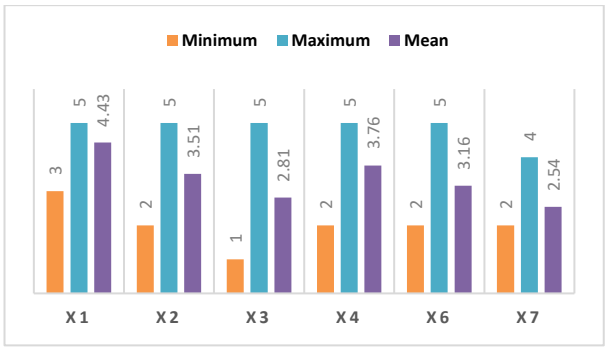


Figure 9. The average results of respondents' answers at a temperature of 18ºC

3.5. Average results of perceptions on temperature 18ºC, 22ºC, and 27ºC

3.5.1. Temperature of 18º C

From Fig. 9, the results of the average respondents at a temperature of 18ºC state that the room felt (X1) "Very cold" and respondents felt (X2) "Uncomfortable" so they wanted a change in the temperature to be (X3) "warmer" in the room. The thermal conditions at that room temperature were also (X4) "Neutral – Unacceptable" for the respondents.

3.5.2. Temperature of 22ºC

From Fig. 10, the results of the average respondents at a temperature of 22ºC stated that the room felt (X1) "Cold", respondents felt (X2) "Comfortable" so they were (X3) "Neutral" to temperature change. When it was 22ºC, the thermal condition at that room temperature was also (X4) "Acceptable" for the respondents.

3.5.3. Temperature of 27ºC

From Fig. 11, the results of the average respondents at a temperature of 27ºC stated that respondents felt (X1) "Neutral" to changes in temperature. When the temperature is at 27ºC, the thermal condition of the room was still (X4) "acceptable".

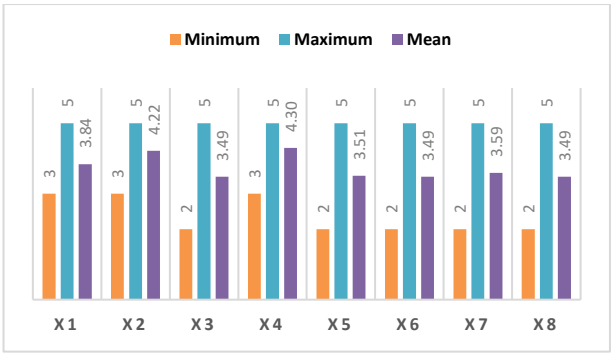


Figure 10. The average results of respondents' answers at a temperature of 22ºC

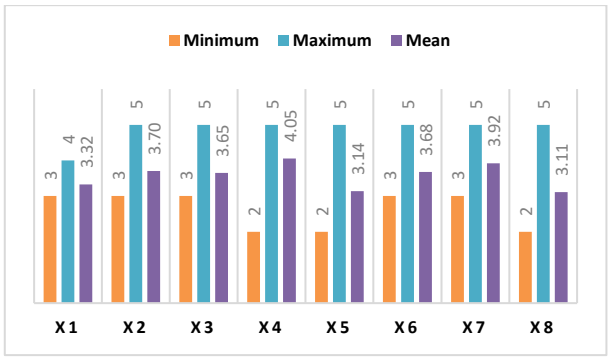


Figure 11. The average results of respondents' answers at a temperature of 27ºC

4. Conclusion

Based on the results of data measurements, the natural thermal conditions of the room using HOBO-Temp/RH/Light/External conducted from 08.00 - 16.00 Central Indonesia Time, the highest average temperature in all measured rooms is in the range of 27 C - 30ºC. From these results, it can be concluded that the room does not meet the categories in the ASHRAE and SNI thermal comfort standards in the building. Using air conditioning in the room is a good solution to help create a room so that it can be cooler and more comfortable when used by room occupants, who were the rectorate staff of Hasanuddin University.

Based on the results of research conducted by the author by measuring five rooms using HOBO-Temp/RH/Light/External, when the temperature is at 18ºC, the average value of the room temperature is 24.62ºC, the humidity is 63,108, and the air velocity is 0.144 m/s. When the temperature is at 22º C, the average value of the room is 24.78ºC, the humidity is 60.684, and the air velocity is 0.142 m/s. While the temperature is at 27ºC, the room temperature is 25.97ºC, the humidity is 64.022, and the air velocity is 0.127 m/s. Although the temperatures of 18º C and 22ºC are not much different, room occupants feel more "comfortable" in the room if the AC temperature is set at 22ºC.

Based on the results of the questionnaire, the perception of room occupants towards the room when the temperature is at 18ºC is that the average respondent's answer felt very cold in the room. Besides, they felt a dry sensation which made them uncomfortable. At a temperature of 22ºC, the respondents said that they were comfortable or could accept the current thermal conditions with a damp sensation that was still tolerable. Meanwhile, for a temperature of 27ºC, the respondents answered neutral, so the temperatures of 22ºC and 27ºC can be used as a reference in the use of air conditioning temperatures in the room.

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