Material Handling Equipment Selection Using Analytical Hierarchy Process (AHP) Method

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ARTICLE INFO

Article history
Received 11 September 2022
Revised 11 October 2022
Accepted 25 October 2022

Keywords
AHP ;
Forklift ;
Criteria ;
Expert_Choice ;

ABSTRACT

This study discusses alternative decisions to choose a material handling equipment by considering various criteria according to PT. Semen Indonesia (Persero) needed. The purpose of this research is to obtain a decision regarding an effective and efficient forklift for handling goods at PT. Semen Indonesia (Persero), Tuban Factory. The method that will be used is the Analytical Hierarchy Process (AHP) to produce a decision regarding the forklift that is worth buying based on the weighting of the criteria for fuel, depreciation, and capacity using Expert Choice (EC) software. The results of this study are the ranking of forklift alternatives from the highest, namely the alternative type C forklift with a value of 0.607, the alternative type B forklift with a value of 0.218, and the alternative type A forklift with a value of 0.177. So it can be concluded that a good forklift to choose is a type C forklift which is a sit down counterbalance forklift with gas fuel, capacity of 5 tons and a residual value of Rp. 25,628,906.25

1. INTRODUCTION

Material handling is a process that includes operations such as moving, moving, storing, protecting, and controlling raw materials, semi-finished goods, and finished goods. In these various operations, a material handling equipment is needed that suits the needs so that materials or goods can be handled efficiently and safely. Material handling equipment have different characteristics based on the shape and size of the goods being carried. These tools can also take goods at once in large quantities. However, material handling equipment will depreciate, reducing the tool's function, one of which is the reduced carrying capacity. Therefore, there is a need for maintenance on the material handling tools used, which can impact the cost of equipment maintenance.

PT. Semen Indonesia Tbk. is a cement processing plant with the main raw materials for lime, clay, silica, and copper slag (B3 waste from refining iron) or usually use iron sand. Besides, to support the cement production, PT. Semen Indonesia Tbk. has a warehouse as a place to store spare parts which are located close to each plants. Currently, for warehouse operations, the company uses 4 forklifts with a capacity of 7 tons each, and currently it carrying capacity has decreased to 4 tons after being used for 7 years. Therefore, these problems allow the company to replace the shrinking forklift with a new type of forklift. The characteristics of the new forklift that are following the company's wishes are forklifts that have a good capacity but have a good residual value at the end of the forklift's economic life. This requirement is useful so that when a new forklift breaks down, the forklift still has a pretty good selling value. In addition, the company wants a forklift with the operator sitting in a sitting position while driving the forklift so that the operator can work in a relaxed manner. Therefore, to determine the forklift according to these characteristics, the authors conducted a study to select a new forklift using the Analytical Hierarchy Process (AHP) method. The AHP method is a method for finding solutions from the many criteria used. This method was chosen because this method can provide choices based on weighting the number of existing criteria.

2. LITERATUR REVIEW

Material handling is a process that includes operations such as moving, movement, storage protection, and control of raw materials, intermediate goods finished, as well as finished goods. This process is very important because all materials or products must be handled properly, such as

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maintaining the condition and quality of the product so that it can reach the final customer in a good and safe condition. Material handling also provides goods in the right quantity and condition, at the right time and place, positioned correctly, in the right order, and using the appropriate method to produce the right cost. Material handling has multiple goals.

Material Handling Objectives :

1. Minimize costs incurred when material handling is carried out
2. Minimize interruptions and even delays that may occur with
3. Provide the various materials needed at the right time and quantity
4. Increase productivity and effective capacity utilization
5. Maintain the safety of goods through repair work
6. Prevention of possible damage to the goods handled

Handling materials requires a tool so that the material being handled can be maintained safely and intact. Therefore, it is necessary to consider the characteristics of the goods being transported (material) and the origin and destination of the movement of the goods (move) so that it can be seen what material handling equipment is more suitable to use (Method).

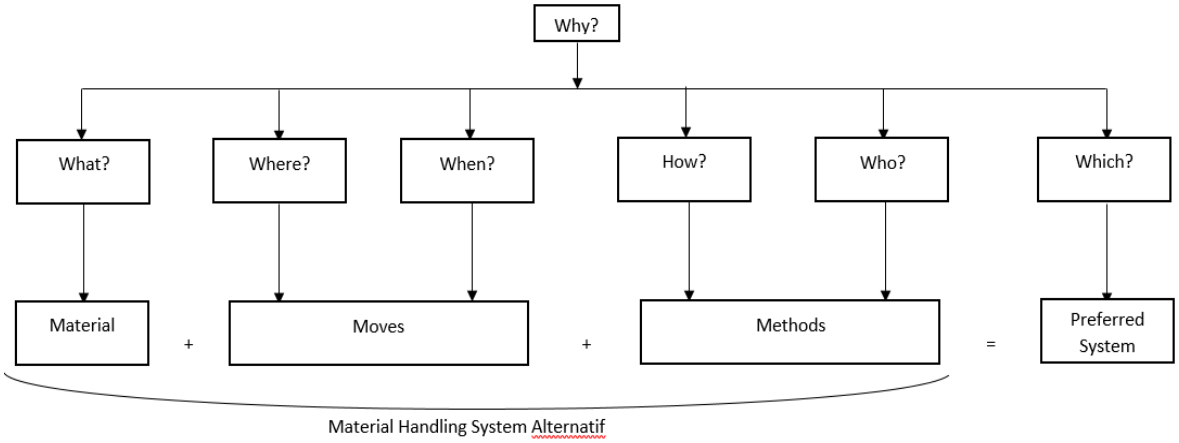

Figure 1. Material Handling Equation

Based on the Material Handling Equation (MHE) by considering the characteristics of the goods, movement of goods, criteria for the handling equipment desired by the company, and assumption that the size and function of the new forklift have the same size and function as the old forklift, the appropriate material handling tool to be used in this study is a sit counterbalance forklift. To choose an existing sit counterbalance forklift, we need a method that can provide a decision by considering several criteria to be used, namely the capacity of the forklift, the fuel required to move the forklift, and the depreciation of each forklift. The method is the Analytical Hierarchy Process (AHP) method. AHP is a decision-making system, so it can assist in determining the priorities of the various criteria used by analyzing the comparison between them.

The use of the AHP method has been carried out in research [5], in selecting heavy transportation equipment to assist undersea elevated tunnel construction activities. Similar research has also been conducted by [6], who chose a material confectionery tool in the form of fuel oil in the archipelago using the AHP method. The AHP method has also been used in research [7], which conducted an analysis of the factors for selecting material suppliers for construction business services using the fuzzy AHP method to process a questionnaire that can determine the weight of a factor, so that an interest priority is obtained. In this study [8], also used AHP to determine aircraft characteristics based on 3 criteria and 3 alternatives. Through research [9] which combines the AHP

and Time Motion Study (TMS) methods, it is hoped that you can find the most suitable waste collection tool for city conditions both qualitatively and quantitatively.

3. METHOD

AHP is a method of selecting a decision by describing a multi-criteria problem complex into a hierarchy (representation of a problem that is complex in a multi-level structure where the first level is the goal, which is followed by criteria level, sub-criteria, to the last level in the form of alternative choices [10]. Therefore, compared to other methods, AHP is more often considered a method solution to solve the problem. This condition because for the following reasons :

a. The hierarchical structure can group up to the most sub-criteria.
b. Considering the validity up to the inconsistency tolerance limit of various selected criteria and alternatives.
c. Considering durability in the form of sensitivity analysis output after decision-making.
d. Priority determination is based on a structured process, namely several criteria that have been decomposed beforehand

AHP Procedure

In the AHP method, there are several stages in problem-solving until it is obtained a decision, including :

a. Problem decomposition

Problem decomposition in **Figure 2** is the stage where a goal in making decisions is translated into a series of system-forming elements to achieve goals. In the AHP structure, problems are divided into simple clusters that represent different levels in the hierarchical structure.

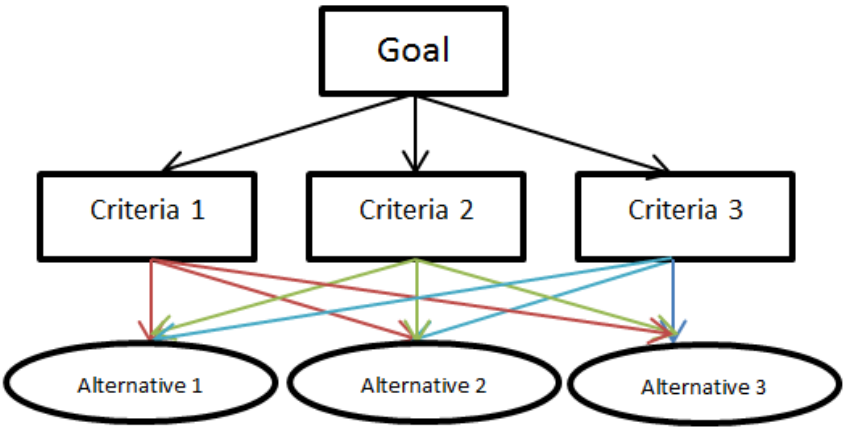

Figure 2. Problem Decomposition

b. Rating/weighting

Assessment/weighting is used to compare elements/criteria, with an assessment or pairwise comparison (weighting) on each element based on the level of importance evaluated by comparison pairs on a 9-point scale (fundamental scale of Saaty) like **Table 1**.

Table 1. Fundamental Scale of Saaty

Value (IaJb; KcId)	Explanation
1	Two factors are equally important
3	One factor is a little more important
5	One strong factor is more important

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7	One very strong factor is more important
9	One factor is absolutely more important
2,4,6,8	Advanced value

a,b = (1,2,3,…n = number criteria)

c,d = (1,2,3,…m = number alternative)

c. Matrix Preparation and Consistency Test

After the weighting process or filling out the questionnaire, the next stage is compiling a paired matrix to normalize the weights for each element in each hierarchy. This stage can be done either manually or with tools such as Microsoft Excel and Expert Choice software.

The paired matrix in **Table 2** consists of n matrices (n is the number of criteria in the hierarchical level), where each matrix consists of m rows and m columns (m is the number of alternatives).

Table 2. Criteria Pairwise Comparison Matrix

	i	**criteria**			
j		**1**	**2**	**…**	**n**
criteria	**1**	1	i1j2	…	i1jn
	2	i2j1	1	…	i2jn
	…	…	…	…	…
	n	inj1	inj2	…	injn = 1

In pairwise comparison matrices, consistency can be determined using a consistency ratio (CR) measure

$$CR = \frac{CI}{RI} \quad (1)$$

$$CI = \frac{\lambda\, max - n}{n-1} \quad (2)$$

CI = Consistency Index

λ max = Eigenvalue

n = Matric Dimension

RI = Random Indeks

Table 3. Random Index Value

n	1	2	3	4	5	6	7	8	9	10
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

The comparison matrix is acceptable if the resulting consistency ratio is < 0.10. Meanwhile, if the CR matrix is high, it indicates that the considerations entered are inconsistent and unreliable, and the considerations must be raised again [13].

d. Priority setting on each hierarchy

Each criterion and alternative has been paired comparisons (pairwise comparisons), then the results of the comparisons are processed to determine the ranking of alternatives from all alternatives. Comparison of these criteria based on assessment form to obtain a weight of the criteria, which calculated through the mathematical equation to get an alternative priority.

e. The synthesis of priorities

The synthesis of priority is obtained from multiplying the local priority (alternative priority of one of the criteria) with the priority located at the top level and adding it to each element in the level that is affected by the criteria. The result is a composite (global priority) that can be used to make decisions.

f. Decision making/decision

Decision-making is a process where a decision will be taken or determined about the best alternative based on alternative global priorities.

4. RESULT AND DISCUSSION

Hierarchical Structure

Based on observations, literature studies, and interviews with a number of people who are considered experienced as well as interviews with the company as an agency that has a certain desire for its new forklift, it is obtained 3 levels (hierarchies) with variables or elements at each level.

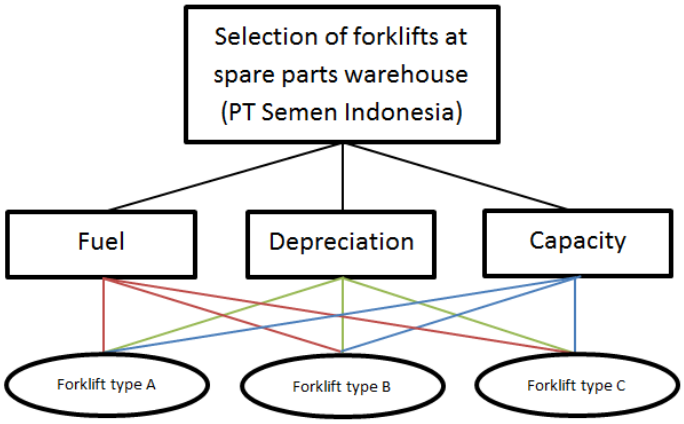

Figure 3. AHP Hierarchical Structure

a. The main purpose (Goal)
Selection of forklifts at spare part warehouse (PT Semen Indonesia)

b. Criteria
This level is the first level of the hierarchy structure which consists of several criteria [14].

The criteria are: fuel, depreciation, and capacity.

1. Fuel

The criteria for fuel/energy are chosen by considering environmental friendliness. This is because the forklifts used previously were diesel engined forklifts which were not environmentally friendly so they produced a lot of exhaust gas. Therefore, this criterion was chosen so that forklifts with energy that are more environmentally friendly can be found.

2. Depreciation

The depreciation criterion was chosen because through the calculation of depreciation, it can be seen the book value at the end of the economic life of the forklift (salvage value). By

knowing the residual value, the company will know the selling value of the forklift when the forklift's service life has expired. So that depreciation will be taken into consideration in the selection of forklifts.

3. Capacity

The capacity criteria were chosen because the company of course wants a forklift that is able to carry more goods in one trip

c. Alternatives

Based on the results of Material Handling Equipment (MHE), the material handling tools that are in accordance with the conditions and needs of the company are forklifts with sit down counterbalance forklifts.

Forklift alternatives

The following are various types of sit-down counterbalance forklifts that will be used as alternative choices:

a. Sit down counterbalance forklift A type

Forklift Specifications:

1. Forklift Type: Electric forklift
2. Purchase price: Rp. 100,000,000
3. Economic life: 8 years
4. Capacity: 3 tons
5. Fork height max: 5 meters
6. Service weight: 5,130 kg
7. Nominal voltage: 48v
8. Rated drive power: 11 kW
9. Residual value: Rp. 10,011,291.5”

b. Sit down counterbalance forklift B type

Forklift Specifications:

1. Forklift Type: Diesel forklifts
2. Purchase price: Rp. 100,524,060
3. Economic life: 8 years
4. Capacity: 3.5 tons
5. Maximum lifting height: 6500 mm
6. Fork length: 920 mm
7. Minimum lifting height: 80 mm
8. Residual value: Rp. 10,063,756.68

c. Sit down counterbalance forklift C type

Forklift Specifications:

1. Forklift Type: LPG forklifts
2. Purchase price: Rp. 256,000,000
3. Economic life: 8 years
4. Capacity: 5 tons
5. Fork height: 6m
6. Weight: 500 kg
7. Residual value: Rp. 25,628,906.25

Weighting and Consistency Test

Based on the criteria and alternatives that have been compiled into a hierarchical structure, the level of each hierarchy can be seen. The elements/elements at each level of the hierarchy are then compared with paired assessments or weighting. To determine this weighting, the authors conducted interviews with the company through an online interview process. The weighting is based on the Saaty fundamental scale shown in **Table 3.1**. Then do the calculation of the consistency test manually with **Equation 1**. Because the number of criteria (n) is 3, the RI value that will be used in the calculation of the consistency test is 0.58 base on **Table 3.3**. The following is a weighting matrix of criteria using expert choice software:

a. Pairwise Comparison Key Criteria

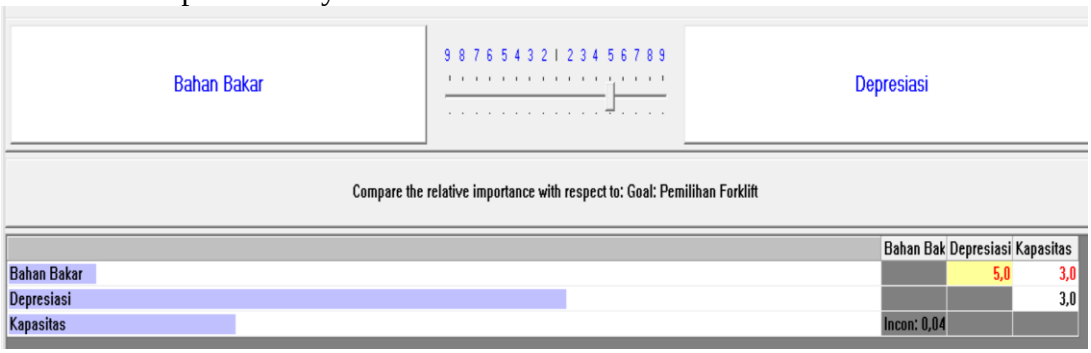

Figure 4 Pairwise Comparison Matrix of Main Criteria

In the figure, it can be seen that the CI (consistency index) is 0.04. So then the consistency test of the weighting is:

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0{,}04}{0{,}58}$$

$$CR = 0{,}06$$

Because the value of CR < 0.1, then this weighting is acceptable

b. Pairwise Comparison of Fuel/Energy Criteria

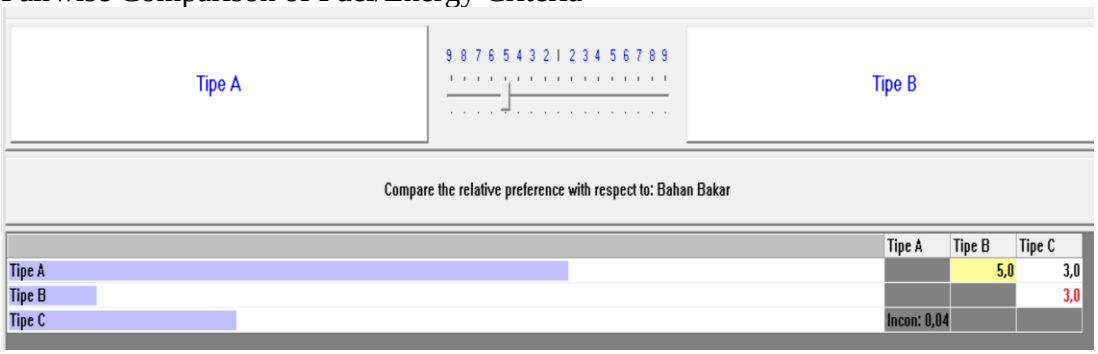

Figure 5. Pairwise Comparison Matrix of Fuel Criteria

In the figure, it can be seen that the CI (consistency index) is 0.04. So then the consistency test of the weighting is:

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$$CR = \frac{CI}{RI}$$

$$CR = \frac{0{,}04}{0{,}58}$$

$$CR = 0{,}06$$

Because the value of CR < 0.1, then this weighting is acceptable

c. Pairwise Comparison of Depreciation Criteria

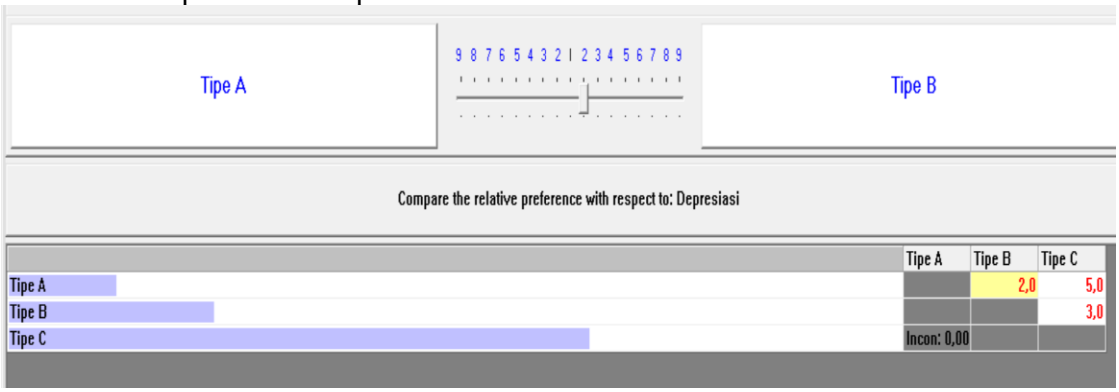

Figure 6. Pairwise Comparison Matrix of Depreciation Criteria

In the figure, it can be seen that the CI (consistency index) is 0.00. So then the consistency test of the weighting is:

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0{,}00}{0{,}58}$$

$$CR = 0$$

Because the value of CR < 0.1, this weighting is acceptable.

d. Pairwise Comparison of Capacity Criteria

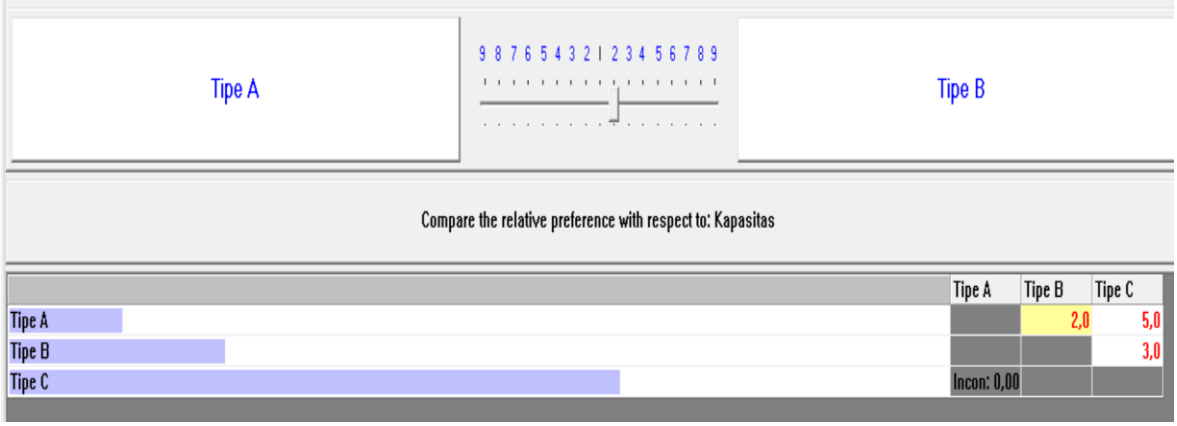

Figure 7. Pairwise Comparison Matrix of Capacity Criteria

In the figure, it can be seen that the CI (consistency index) is 0.00. So then the consistency test of the weighting is:

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0{,}00}{0{,}58}$$

$$CR = 0$$

Because the value of CR < 0.1, then this weighting is acceptable.

Processing Results

Based on the pairwise comparison assessment (weighting) against each criterion, alternative assessments can be seen based on the existing criteria. The assessment of these criteria can be seen as follows:

Table 4. Alternative Values in Each Criterion

Criteria	**A Type**	**B Type**	**C Type**
Fuel	0,637	0,122	0,122
Depresiation	0,105	0,230	0,230
Capacity	0,258	0,648	0,648

Based on the priorities of the assessments of the data processing results above, it can also be seen that alternative priorities globally are used to determine decisions in the selection of forklifts.

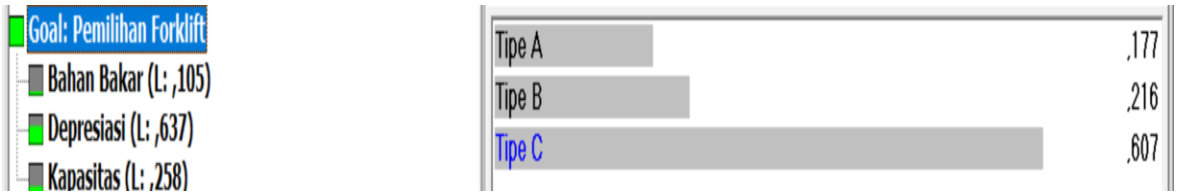

Figure 8. Global Alternative Priorities

The figure shows that the alternative value of forklift with the highest is the alternative C type forklift with a value of 0.607, the alternative B type forklift with a value of 0.216, and the alternative A type forklift with a value of 0.177. So, it can be seen that the chosen forklift alternative is the C-type forklift.

5. CONCLUSION

Based on the results of data processing using the Analytical Hierarchy Process (AHP) method with the help of Expert Choice software, the global priority value of each forklift alternative can be seen. Forklift priority sequences from highest to lowest include the alternative C type forklift with a value of 0.07, the alternative B type forklift with a value of 0.216, then the alternative A type forklift with a value of 0.177. Based on this priority value, it can be concluded that the forklift alternative selected based on fuel, depreciation, and capacity criteria is C type forklift. This C type forklift is a sit-down counterbalance type forklift with a price of Rp. 256,000,000. This forklift is LPG fueled with 5 tons capacity.

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