

DETERMINING THE SUITABLE MATERIAL HANDLING EQUIPMENT IN PT. XYZ.

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Abstract—Selection of appropriate material handling equipment for specific conditions is found to be a multi-criteria decision-making problem. The selection procedure is found to be unstructured, characterized by subject knowledge and requiring the application of an effective and efficient multi-criteria decision-making tool, such as the analytic hierarchy process (AHP). The AHP technique allows the problem to break down into smaller yet more detail parts for more natural selection understanding. This paper focuses on the application of AHP technique in selecting the suitable material handling equipment for maintenance activity in a specific environment. The importance of related criteria and alternative calculated using pairwise comparison matrices, checked with consistency ratio and the overall ranking of each alternative material handling equipment is then determined. The powered pallet is the most appropriate hand truck that meets the requirements in PT. XYZ environment with weight capacity having the most influence.

Keywords—AHP, Material Handling Equipment, Consistency Ratio, Attributes.

I. INTRODUCTION

The material, product or good will always flow within and across the facility such as a plant, warehouse, between buildings, a transportation or distribution spot to complete the function of its availability in that facility [1]. In any organization, be it big or small, involving manufacturing or construction type work, materials have to be handled as raw materials, work-in-process, or finished goods from the point of receipt and storage, through production processes and up to finished goods warehouse and dispatch points [2].

Selecting the proper MHE is a crucial task due to the considerable capital investment involved. At the same time, an efficient material handling system can reduce the operating cost and increase profit. Inaccurate selection of the MHE can interfere with the overall performance of the system and lead to unacceptable long lead times, and hence lead to substantial losses in productivity and competitiveness [3] which can cause an unacceptable amount of time if the MHE doesn't have enough reliability to be used on a long term because the longer it used it will be more vulnerable to be damaged [4]. Material handling can account for 30–75% of the total cost and efficient material handling can be primarily responsible for reducing a plant's operating cost by 15–30%. [5]. Because of these factors, the selection of MHE should be made intensively and carefully.

Past research focuses on selecting the appropriate MHE alternative using a variety of methods. Such as Onut et al. [6] used a fuzzy analytic network process to choose the most appropriate MHE. Due to the full range of equipment

available today, each having different characteristics and costs that differentiate from others, the determination of the right stuff for the designed manufacturing system is a very complicated decision [7].

Therefore, it is necessary to select the right material handling equipment to perform efficient machine maintenance activities. This paper presents a review of MHE selection problem which determines with multi-criteria decision making using analytical hierarchy process as a tool to solve MHE selection problem.

II. THEORETICAL REVIEW

A. Material Handling Equipment

Material handling equipment (MHE) is often called "the art and science of moving, packaging, and storing substances in any form" [8]. Furthermore, material handling is a system or combination of methods, facilities, labor, and equipment to move, pack and store items to meet specific objectives.

MHE is the most critical part of the current manufacturing system and increasingly plays an essential role in factory productivity [6]. The primary objective of MHS design — that of reducing production cost through efficient handling or, more specifically [5]

- 1 to increase the efficiency of material flow by ensuring the availability of materials when and where they are needed
- 2 to reduce material-handling cost
- 3 to improve the utilization of facilities
- 4 to improve safety and working conditions
- 5 to facilitate the manufacturing process
- 6 to increase productivity

B. Industrial Hand Trucks

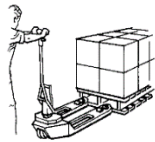
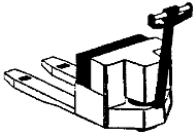
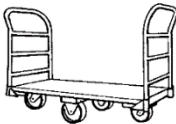
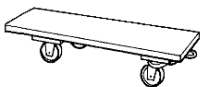
Industrial hand trucks generally consist of a cross-section to accommodate the load, equipped with wheels for moving and using the handle for operator convenience. The use of hand trucks can be found in all industrial circles [8]. Hand truck will suit if [9] :

1. The length and width of the load do not change
2. Load weight is not too high
3. Hand truck travel distance is relatively close

4. The field of travel is relatively good
5. Travel speed is not too high
6. No need to position the hand truck on difficult terrain

Maintenance activities to move the machine from the pump house of the product to a workshop that is 137 meters away requires proper MHE. For use in warehouses, manufacturing, shipping, and distribution, the types of industrial hand trucks [8] can be seen in Table I.

TABLE I. TYPES OF INDUSTRIAL HANDLING TRUCK (IHT)

IHT Type	IHT Figure	IHT Definition
Manual Pallet		Hand truck with three wheels which has a platform in the form of a branch used to carry a pallet with a load on it. Be thrust by way of being pushed
Powered Pallet		Hand truck with three wheels which has a platform in the form of a branch used to carry a pallet with a load on it. Moves by motor
Floor Hand Truck		Hand truck with four wheels or more with a handle to push or pull
Dolly		Hand truck with four wheels with a flat platform because it has no handle, a load is used to push

C. Analytical Hierarchy Process

Analytic hierarchy process (AHP) is a theory of measurement through pairwise comparisons and relies on the assessment of experts to obtain a priority scale [10].

It can be complicated to choose an alternative to a range of other options, where many goals are essential to decision makers. AHP is a powerful tool for solving multi-criteria decision-making problems [9].

1) AHP Calculation

If there are as many objectives as m to compare, AHP performs the multi-objective decision-making process as follows:

- a) Develop the following pairwise ($m \times m$) A matrix for m

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mm} \end{bmatrix} \quad (1)$$

Where a_{ij} indicates how much more important the i -th objective than the j -goal, while making the appropriate MHE's decision. For all i and j , note that $a_{ii} = 1$ and $a_{ij} = 1 / a_{ji}$. Possible scoring values of a_{ij} in pairwise comparison matrices, together with appropriate interpretations. The intensity of interest is shown in Table II.

TABLE II. ASSESMENT OF A_{ij} VALUE

Value of a_{ij}	Description
1	Equal importance of i and j
3	Between equal and weak importance of i over j
5	Weak importance of i over j
7	Between weak and strong importance of i over j
9	Strong importance of i over j
2, 4, 6, 8	Between strong and demonstrated importance of i over j

- b) Divide each entry in column j of A by the number of entries in column j . This produces a new matrix, A_w , where the number of entries in each column will be 1.

$$A_w = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \cdots & \frac{a_{1m}}{\sum a_{im}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{a_{m1}}{\sum a_{i1}} & \frac{a_{m2}}{\sum a_{i2}} & \cdots & \frac{a_{mm}}{\sum a_{im}} \end{bmatrix} \quad (1)$$

- c) Calculate c_i as the average of entries in row i on A_w to generate column vector C .

$$C = \begin{bmatrix} c_1 \\ \vdots \\ c_m \end{bmatrix} = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} + \cdots + \frac{a_{1m}}{\sum a_{im}} \\ \vdots \\ \frac{a_{m1}}{\sum a_{i1}} + \cdots + \frac{a_{mm}}{\sum a_{im}} \end{bmatrix} \quad (3)$$

Where C_i represents the relative importance of the i -th goal.

- d) Check the consistency of the appraisal in the comparison matrix in pairs with the following sub-steps:

1) Calculate $A \cdot C$

2) Calculate λ_{max}

$$\lambda_{max} = \frac{1}{m} \sum_{i=1}^m \frac{x_i}{c_i} \quad (4)$$

where λ_{max} is the maximum eigenvalue of a pairwise comparison matrix.

- 3) Calculate Consistency Index (CI)

$$CI = \frac{\lambda_{max} - m}{m - 1} \quad (5)$$

TABLE III. RANDOM INDEX

m	2	3	4	5	6	7	8	9
RI	0	0,58	0,90	1,12	1,24	1,32	1,41	1,51

- 4) Compare the CI with the random index (RI) in Table III for the corresponding m (matrix size) to determine whether the consistency level is satisfactory. If the value of CI is found to be small enough, the decision maker's decision may be consistent enough to provide useful weighting estimates for various decision-making criteria [11].
- 5) If $CI / RI \leq 0.10$, the level of consistency is satisfactory. If $CI / RI > 0.10$, there is an inconsistency. In this case, AHP may not yield meaningful results. [12].
- 6) Compare the results of the eigenvalues (priority vectors) to each of the criteria and alternatives so that they can be ranked as comparable.

D. Advantages and Disadvantages of AHP

Like other analytical method, AHP also has advantages and disadvantages in its analysis system [13]. Advantages of this method are : Makes the problem broad and unstructured into a flexible and easy to understand model, Solves complex problems through systems approach and deductive integration, Can be used on system elements that are mutually free and require no linear relationship, Represents natural thinking that tends to group system elements to different levels of each level containing similar aspects, Provides measurement scales and methods for prioritization, Considers the logical consistency in the assessment used to determine priorities, Leads to an overall estimate of how desired each alternative

While it has advantages, AHP also has its disadvantages which is: AHP model dependence on the primary input, The primary data is the perception of an expert so that in this case involves the subjectivity of the expert and the model also becomes meaningless if the expert gives a wrong assessment, This AHP method is only a mathematical method without any statistical test, so there is no confidence limit from the correctness of the model

E. Geometric Mean

Geometric mean or commonly called geomean is often used to evaluate data that includes several levels, and sometimes to assess ratios, percentages, or other data sets that have their own range [14].

$$\sqrt[n]{X_1 X_2 \dots X_n} \quad (6)$$

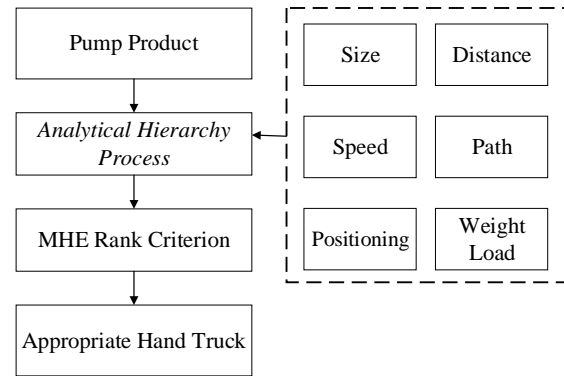
Where X_1, X_2 , etc. represent individual data points and n is the total number of data points used in the calculation. Geomean is also generally used in research that requires respondents to give weight to a thing that is multi-participant.

III. RESULT AND DISCUSSION

A. Conceptual Model

Conceptual Model is the details of activities undertaken by the authors to achieve the objectives in this study. Conceptual model in this research can be seen in Fig. 1.

Fig. 1. Conceptual Model



The object to be carried using MHE is the pump product. AHP method is then used to select the proper MHE with its supporting criteria that are size, distance, speed, path, positioning, and weight load. After doing data processing, the rank of the most influential standards will be shown, and lastly, the most appropriate MHE is determined.

B. Hierarchy of Problem Solving

Easier understanding for AHP method problem solving is presented as a flowing chart below.

Fig. 2. Problem Solving Hierarchy

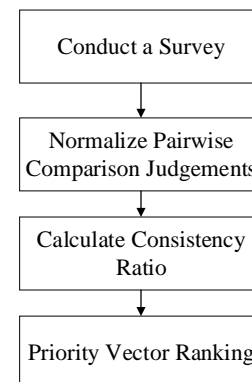


Fig. 2 explained how all steps are needed to make a conclusion based on AHP method.

C. Determining the Respondents

Pairwise comparison judgements is needed to show the importance of each matrix of criteria obtained from the assessment of people who have the problem about the relative importance of the elements with respect to the overall goal [12]. People who are close to using and repairing the pump machine, after all, this MHE will be used for maintenance activity for pump product. As many as twelve people including machine operator, maintenance staff, and people who have higher rank of maintenance activities are then selected to conduct a survey which contains a comparison of the criteria that determine an MHE.

D. AHP Calculation

1) Geomean Calculation

The geomean calculation is done by recapitulating the results of questionnaires about the comparison of criteria and alternatives that exist. Respondents were asked to

compare the requirements of a right hand truck [9]. These criteria are size, distance, speed, positioning, path, and weight. The result of standards comparison was seen in Table IV.

TABLE IV. CRITERIA'S GEOMEAN

Criteria	Geomean	Criteria
Size	1.865	Distance
Size	1.357	Speed
Size	1.654	Positioning
Size	0.496	Path
Size	1.032	Weight
Distance	0.532	Speed
Distance	0.941	Positioning
Distance	1.097	Path
Distance	0.574	Weight
Speed	1.824	Positioning
Speed	1.023	Path
Speed	0.731	Weight
Positioning	1.264	Path
Positioning	0.817	Weight
Path	0.55	Weight

Respondents asked about the best alternative that is suited to each of the above criteria. The result can be seen in Table V. The other options include manual-handed pallet, powered pallet, floor hand truck, and dolly.

TABLE V. ALTERNATIVES GEOMEAN

	Alternative	Geomean	Alternative
Size	Manual Pallet	1.07	Powered Pallet
	Manual Pallet	1.663	Floor Hand Truck
	Manual Pallet	2.948	Dolly
	Powered Pallet	2.879	Floor Hand Truck
	Powered Pallet	3.312	Dolly
	Floor Hand Truck	1.201	Dolly
Distance	Manual Pallet	0.652	Powered Pallet
	Manual Pallet	1.339	Floor Hand Truck
	Manual Pallet	3.164	Dolly
	Powered Pallet	1.455	Floor Hand Truck
	Powered Pallet	3.883	Dolly
	Floor Hand Truck	1.587	Dolly
Speed	Manual Pallet	0.264	Powered Pallet
	Manual Pallet	0.739	Floor Hand Truck
	Manual Pallet	1.040	Dolly
	Powered Pallet	2.725	Floor Hand Truck
	Powered Pallet	4.887	Dolly
	Floor Hand Truck	1.219	Dolly

TABLE VI. ALTERNATIVES GEOMEAN (CONT.)

	Alternative	Geomean	Alternative
Positioning	Manual Pallet	3.205	Powered Pallet
	Manual Pallet	2.221	Floor Hand Truck
	Manual Pallet	0.309	Dolly
	Powered Pallet	1.367	Floor Hand Truck
	Powered Pallet	0.493	Dolly
	Floor Hand Truck	0.215	Dolly
Path	Manual Pallet	0.744	Powered Pallet
	Manual Pallet	1.843	Floor Hand Truck
	Manual Pallet	1.482	Dolly
	Powered Pallet	2.018	Floor Hand Truck
	Powered Pallet	3.250	Dolly
	Floor Hand Truck	0.613	Dolly
Weight	Manual Pallet	0.800	Powered Pallet
	Manual Pallet	2.428	Floor Hand Truck
	Manual Pallet	1.924	Dolly
	Powered Pallet	2.093	Floor Hand Truck
	Powered Pallet	2.842	Dolly
	Floor Hand Truck	1.640	Dolly

Comparison between alternatives performed using criteria as its differentiator. Each option is then compared with one another to get its values. The values are used to analyze each alternative

The higher the geomean value means the left-hand criterion is more important than the right-handed standard, otherwise the lower the geomean value means the right-hand rule is more important than the left-handed standard.

2) Priority Vector

Priority vector is calculated using the formula on the AHP Method. It is used to rank criteria and alternative based on each term. Consistency Ratio (CR) is then used to measure whether the research is proper enough to continue.

The Table includes information such as Priority vector, λ_{max} , Consistency Index, Random Index which found in Table III, and Consistency Ratio. The results can be seen in Table VII - Table XIII.

TABLE VII. CRITERIA PRIORITY VECTOR

Criteria	Priority Vector	λ_{max}	CI	RI	CR
Size	0.190	6.27	0.054	1.24	0.044
Distance	0.119				
Speed	0.179				
Positioning	0.137				
Path	0.166				
Weight	0.209				

Since the value of $CR = 0.044 < 10\%$, then the calculation is consistent. The research may proceed.

TABLE VIII. SIZE PRIORITY VECTOR

Alternatif	Priority Vector	λ_{max}	CI	RI	CR
Manual Pallet	0.338	4.036	0.012	0.90	0.013
Powered Pallet	0.384				
Floor Hand Truck	0.159				
Dolly	0.119				

Since the value of $CR = 0.013 < 10\%$, then the calculation is consistent. The research may proceed.

TABLE IX. DISTANCE PRIORITY VECTOR

Alternatif	Priority Vector	λ_{max}	CI	RI	CR
Manual Pallet	0.290	4.037	0.012	0.90	0.013
Powered Pallet	0.386				
Floor Hand Truck	0.216				
Dolly	0.108				

Since the value of $CR = 0.013 < 10\%$, then the calculation is consistent. The research may proceed.

TABLE X. SPEED PRIORITY VECTOR

Alternatif	Priority Vector	λ_{max}	CI	RI	CR
Manual Pallet	0.138	4.014	0.005	0.90	0.005
Powered Pallet	0.548				
Floor Hand Truck	0.182				
Dolly	0.131				

Since the value of $CR = 0.005 < 10\%$, then the calculation is consistent. The research may proceed.

TABLE XI. POSITIONING PRIORITY VECTOR

Alternatif	Priority Vector	λ_{max}	CI	RI	CR
Manual Pallet	0.263	4.237	0.079	0.90	0.088
Powered Pallet	0.150				
Floor Hand Truck	0.102				
Dolly	0.485				

Since the value of $CR = 0.088 < 10\%$, then the calculation is consistent. The research may proceed.

TABLE XII. PATH PRIORITY VECTOR

Alternatif	Priority Vector	λ_{max}	CI	RI	CR
Manual Pallet	0.273	4.082	0.027	0.90	0.030
Powered Pallet	0.398				
Floor Hand Truck	0.149				
Dolly	0.180				

Since the value of $CR = 0.030 < 10\%$, then the calculation is consistent. The research may proceed.

TABLE XIII. WEIGHT PRIORITY VECTOR

Alternatif	Priority Vector	λ_{max}	CI	RI	CR
Manual Pallet	0.319	4.046	0.015	0.90	0.017
Powered Pallet	0.375				
Floor Hand Truck	0.174				
Dolly	0.133				

Since the value of $CR = 0.017 < 10\%$, then the calculation is consistent. The research may proceed.

3) Comparison of Priority Vector (Eigen Value)

The following Table XIII is the result of the priority vector comparison of each of the criteria and the alternatives derived from the normalized geomean questionnaire data. It is a recapitulation of priority vector the calculated in Table VII - Table XIII.

TABLE XIV. EIGEN VALUE COMPARISON

	Eigen Value	Manual Pallet	Powered Pallet	Floor Hand Truck	Dolly
Size	0.190	0.338	0.384	0.159	0.119
Distance	0.119	0.290	0.386	0.216	0.108
Speed	0.179	0.138	0.548	0.182	0.131
Positioning	0.137	0.263	0.150	0.102	0.485
Path	0.166	0.273	0.398	0.149	0.180
Weight	0.209	0.319	0.375	0.174	0.133
Total		0.271	0.382	0.164	0.183

Recapitulation of the priority vector of each criterion and alternative so that it can be solved by multiplying the matrix between the eigenvalue with the priority vector of all options. In Table XIV we can see the values of the priority vectors of each criterion and the alternatives. Weight with a value of 0.209 becomes the most important criterion for selecting the right-hand truck followed by size, speed, path, positioning, and distance.

IV. CONCLUSIONS

Based on questionnaires filled by academic experts and field, obtained the right-hand truck for maintenance activities of pump products. In Table XIII we can see the values of the priority vectors of each criterion and the alternatives. Load capacity with a value of 0.209 becomes the most important criterion for selecting the right-hand truck on the maintenance activities of the pump product followed by platform width, velocity, travel path, position setting, and mileage. After doing the matrix multiplication, the powered pallet obtained as the most appropriate hand truck with the highest priority vector value worth 0.382 for the maintenance activity of the pump product followed by the manual pallet, dolly, and floor hand truck.

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