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Automatic Task Machine (ATM) Design for Logistic Package Using Analytical Hierarchy Process (AHP) and Design for Manufacturing (DFM) Approaches

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ABSTRACT

The Automatic Task Machine (ATM) machine for logistics packages is a machine vision to measure the dimensions and other components in form load cell, which serves to measure the mass of an object. This machine design was development the addition of components such as insert card, screens, navigation buttons, receipt printers, automatic package doors and a storage room delivery mechanism. Method of Analytical Hierarchy Process (AHP) was chosen to determine the ATM design for the optimal logistics package for the best alternative decision. The questionnaires were made to get priority consumer needs, which it used for the initial design. The consumer needs questionnaire was based on several indicators, namely: ergonomics, measurement of dimensions and weight, package transmission and package storage. The next stage was selecting the optimal design using AHP, which involves Expert based on the indicator of a product. The highest indicator value obtained for the logistics package ATM is "dimension and weight" with a value of 5.22 and the optimal design choice was "alternative 3". The optimal design choice was analyzed using the Design for Manufacturing (DFM) approach to consider the cost of manufacturing product, which aims to minimize the cost of making ATMs for logistics packages.

KEY WORDS: *Automatic Task Machine (ATM), Dimensions, Mass, Analytical Hierarchy Process (AHP), Design for Manufacturing (DFM)*

1.0 INTRODUCTION

Freight forwarding services in Indonesia are a growing business, because the competition will increase over time. Currently, the courier and logistics service entrepreneurs are competing to offer their services. One of the challenges for the courier and logistics services is in terms of the variety of logistics sent. With the increasing variety of logistics, both in terms of size and type of material, the system for determining shipping rates varies as well.

The working principle of ATM for logistic packages starts from selecting the desires of consumers who want to send packages by determining the destination, type of shipment, and making payments on a self-service basis through the monitor screen using the navigation button on the ATM machine. The package (regular shape) is placed in the available package door will automatically open the door and the package is inserted automatically. The camera and sensor take digital images to measure dimensions (cm) and scales for mass measurement (kg) on the package. After taking the digital image and weighing it, the package will automatically go to the storage area with the help of a transmission system roller. Within a certain timeframe the courier service will pick up the package in the storage area of the goods (package), then the courier will send the consumer package according to the desired location. So that the ATM machine for this logistics package is expected to be able to accelerate and facilitate shipping service companies in serving consumers who do not have to queue at offices or shipping agents. The alternative design criteria for the ATM logistic package such as shape, size, material and dimensions of the elements were determined using the method AHP with the DFM approach to consider the ease of manufacturing the product design with the aim of minimizing costs.

In this paper the method of AHP was chosen to determine the optimal ATM logistics package design based on the questionnaire given to expert, to choose the best alternative decision. The AHP can describe decisions with doubtful levels of confidence by ranking alternative decisions and choosing the best one for complex problems by combining qualitative and quantitative factors in the overall evaluation of existing alternatives and giving a level of confidence in the answers to the questionnaire filled out by expert [1]. So, the AHP method is very suitable for use in decision making. That the results of the ATM logistic package design will be obtained the most optimal design choices based on the assessment experts.

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1.1 Design of ATM

The automatic machine measuring of mass and dimension can be illustrated in Figure 1.

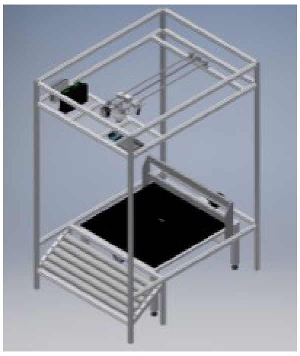


Figure 1: Automatic machine measuring of mass and dimension

1.1.1 Design of the Automatic Machine for Logistic Package

In this paper is design the several components, which function as information retrieval in the form of mass (kg) and dimensions (cm^3) of an object that is regular in shape. The working principle of automatic machine measuring of mass and dimension can read the mass information given from load cell. Simultaneously, the camera will take pictures of the light bias given by the sensor beam that moves along / in line with the camera and by using the laser triangulation method the area measurement image from the 2D image. Then the 2D image that has been taken will be processed using a computer algorithm to get the results 3D imagery to determine the volume of objects. The working principle for determining the dimensions of the object being measured is exactly the same as the working principle of a machine called machine vision [2].

1.1.2 Volume of Image-Based Logistics Packages

Imaging is one of the choices in determining the volume of the logistics packages. This can be seen from the correctness of the image processing results, which have the largest percentage error, namely 0.04%. Imaging is a method for measuring dimensions that is widely developed today. It can be a solution for manual measurements that are influenced by the psychological condition of the measuring actor. Imaging is also widely developed together with the triangulation method as a method to determine the height of the logistical package captured by the camera in the form of an image. With a combination of image processing as an area measure and the triangulation method as a height measure, it can determine the volume of the logistic package [3].

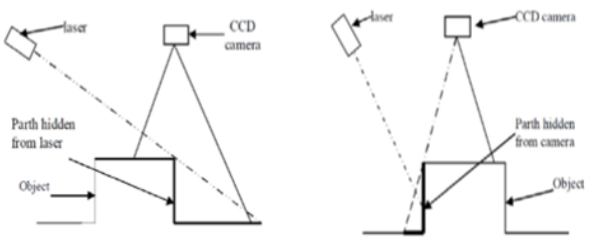
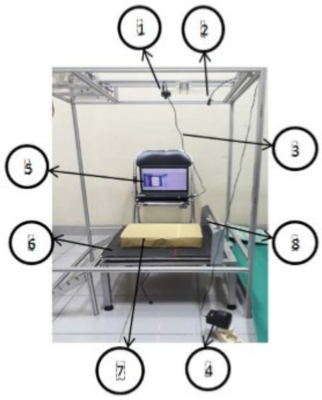


Figure 2: Laser shadows and camera shadows [4]

The example of component for volume of image-based logistics packages was developed in [3]. They developed a machine designed as depicted in Figure 3.

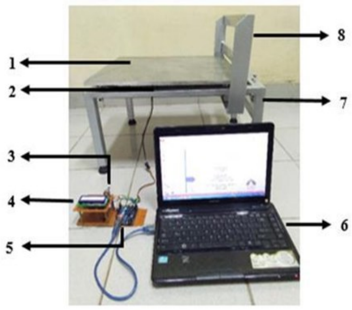


No	Nama
1	Imaging source DFM22BUC03-ML Color Board Camera
2	Laser garis
3	USB
4	Adaptor 3 volt TOSHIBA
5	Computer (PC)
6	Paket logistik
7	Based
8	Pendorong paket

Figure 3: Image of logistics packages machine [3]

1.1.3 Digital Scales on an Automatic Machine for Measuring Mass and Dimensions Based on Arduino

The Arduino Uno based digital scale designed using sensors load cell 50 kg and the HX711 module performed well in a load reading. Other supporters are the Arduino Uno and the HX711 module as an input signal amplifier, where the analog data obtained will be received by the ADC which will be converted into digital data. The digital data will be reprocessed by the Arduino programming language to display the results on the LCD in grams (gr). The example an automatic scale is seen in Figure 4. Based on the load cell test was performed the same load placement variations. The best position for placing the load on the making mass measurements was obtained in the middle of the base [5].



No	Nama
1	Base
2	Load cell 50 kg
3	Potensiometer
4	LCD 16X2
5	Arduino Uno
6	Laptop PC
7	Load cell
8	Pusher

Figure 4: An automatic scale [5]

1.1.4 Automatic control system on Automatic machine measuring of mass and dimension

A schematic design of a machine vision control system for measuring volume and weight has been obtained that can move a stepper motor to move the camera to the center position of the logistic package using a sliding shaft and downward as moving goods to reach storage and return to its original position made, then a machine vision control system has been assembled which is composed of several components such as Arduino, motor driver, stepper motor and power supply and has been running as desired [6].

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2.0 METHODS

The research method is carried out in several stages, the first is making a questionnaire to obtain data on consumer needs. Furthermore, the design of the modeling tool will be made with the selected design considerations. Then, the DFM (Design for Manufacturing) is adopted to minimize the cost of making ATMs for logistics packages. The DFM is a process of designing components by considering the processes that will be used in making these components to ensure that manufacturing costs are minimized [7,8].

2.1 Questionnaire Making and Data Collection

The data collection was in the form of a consumer needs questionnaire. The consumer needs questionnaire was aimed to determine the preferences aspects the ATM logistic package, which based on the consumers need and favor. According to Ulrich [9], the minimum amount of data can be valid, if it is based on the opinion of a minimum of 10 to 50 people. The stages of collecting data on consumer needs are as follows:

1) Making a Questionnaire
   This initial questionnaire was made based on 4 aspects, namely:
   a) Aspects of ergonomic
   b) Aspects of measurement of dimensions and weight
   c) Aspects of transmission of the package
   d) Aspects of the package storage
   Initial questionnaires were made to get priority consumer needs, which were then used for initial design.
2) Determination of respondents as many as 10 people by distributing questionnaires was conducted in Pekanbaru City. Respondents were divided into 3 groups, namely:
   a) 4 people work as couriers.
   b) 5 courier service users.
   c) 1 person who works as a lecturer in Mechanical Engineering Department, Universitas Riau.
3) Assessment
   The assessment is carried out to get the highest percentage of each aspect. The assessment uses a rating scale to get the results of the questionnaire.
   a = Very Like (score 4)
   b = Like (score 3)
   c = Dislike (score 2)
   d = Not like (score 1)

$$Persentase = \frac{Total\ score}{Ideal\ score}\ x\ 100\%$$

Total score = total score of 1 to 4 rating scale,
Ideal score = Highest value X Number of Respondents

2.2 Automatic Task Machine (ATM) Design

The ATM for logistics packages is designed using the Autodesk Inventor, based on the priority of each aspect that has been obtained, including designing the components of the ATM for the logistic package. The ATM design for logistic packages is divided into 4 main parts, the first part is ergonomic, the second part is measuring dimensions and weight, the third part is package transmission and the fourth part is storage for the logistics package.

2.3 Design Selection Using the AHP Method

After obtaining consumer needs, then the most optimal alternative is selected using AHP, which involves expert on the selection of alternatives. The AHP method is used to determine the optimal design of the ATM for the logistics package, the steps are as follows:

1) Create a hierarchical structure of the questionnaire.
   Create an ATM hierarchical structure for logistic packages based on the 4 questionnaire results criteria as follows:
   a) Ergonomic
   b) Measurement of dimensions and weight
   c) Transmission the package
   d) Storage the package

The hierarchical structure of ATM package logistics can be seen in Figure 5.

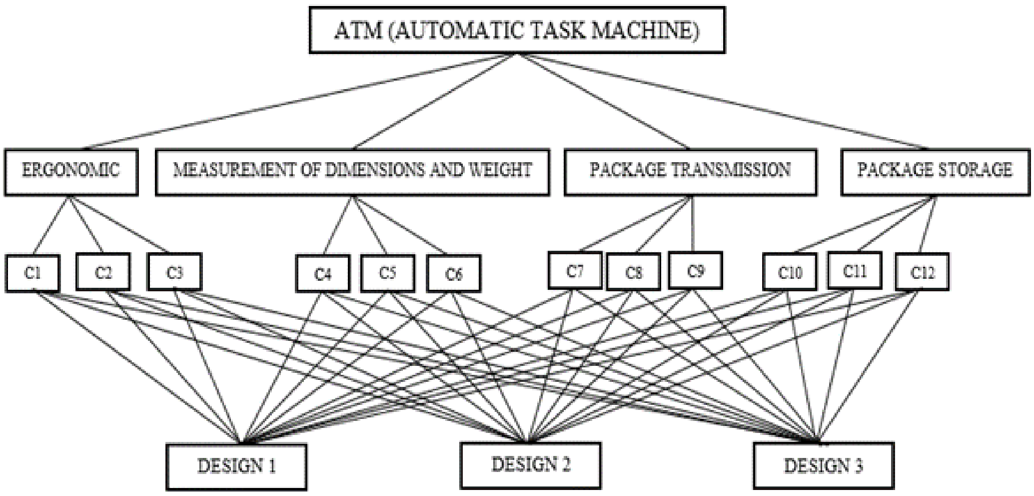

Figure 5: Hierarchical structure of ATM for Logistics package

Information;
C1 : P x L x T (150 x 130 x 150) cm
C2 : P x L x T (130 x 120 x 150) cm
C3 : P x L x T (124 x 60 x 150) cm
C4 : Camera and sensor in stationary position and package in stationary position C5

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C5 : Camera and sensor moving translation and package in a stationary position
C6 : Camera and sensor is stationary and package rotates clockwise
C7 : Transmission the package to storage room using belt conveyor and lift
C8 : Transmission the package to storage room using conveyor belt
C9 : Transmission the package to storage room using roller bearing
C10: System per room uses a roller bearing base
C11: A room that uses a sheet plate base
C12: A room that uses a roller bearing base.

The hierarchical structure consists of 4 levels, level 1 is the main goal/objective, namely the optimal design, level 2 is the indicator/criterion that affects the optimal design, level 3 is the sub-indicator/criteria and level 4 is an alternative design. Making a questionnaire based on the hierarchical structure that has been made previously, this questionnaire aims to obtain a level of importance in selecting designs by comparing interests 1 with other interests based on the comparison priority scale in Table 1.

Table 1: Comparison priority scale [10]

Importance Scale	Definition	Information
1	Just as important	The two elements have the same effect
3	A little bit more important	Experience and judgment are slightly in favor of one element
5	More important	Experience and judgment are very partial to one element
7	Very important	One element is very liked and practically very real dominance over his partner
9	Absolutes are more important	One element is shown to be absolutely preferable to its partner
2,4,6,8	Middle value	Awarded if there is doubt of assessment
The opposite	Aij = 1 / Aij	If an activity i gets a number when compared to activity j, then j has the opposite value when compared to i

2) Distributing questionnaires to experts. In distributing questionnaires, 3 experts were chosen to be respondents. Respondents were selected based on fields related to the research topic, namely the expedition field of *TIKI*, *JNE* and *Lingga Cargo*, in this case the researcher gave a questionnaire to each freight forwarder.

Table 2: Comparison matrix [11]

	A_1	A_2	...	A_n
A_1	a_{11}	a_{12}	...	A_{1n}
A_2	a_{21}	a_{22}	...	A_{2n}
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
A_n	a_{n1}	a_{n2}	...	a_{nn}

3) Create a matrix of normalization results
After the pairwise comparison matrix for each expert, a matrix of the normalization results of the three experts is created. Each column is summed and then divided by the total required experts. An example of a matrix of normalization results can be seen in Table 3.

Table 3: Matrix of normalization results

	A_1	A_2	A_3	A_n
A_1	$(a_{11}+b_{11}+c_n)/3$	$(a_{12}+b_{12}+c_n)/3$	$(a_{13}+b_{32}+c_n)/3$	A_{1n}
A_2	.	.	...	A_{2n}
.	.	.	.	.
.	.	.	.	.
A_n	a_{n1}	a_{n2}	...	a_{nn}

4) Creating the pair-wise comparison matrix. After the questionnaire is filled in by the expert, a pair-wise comparison matrix is made from the results of the questionnaire. An example of a comparison matrix in pairs can be seen in Table 2.

5) Next, calculate the eigenvector and eigenvalues to get the weight and value max. With n = $4^{1/n}$

$$Eigenvector\ C\ (Weight) = \begin{Bmatrix} \dfrac{\frac{(C11*C12*C13*C14)1}{n}}{Sum\ C} \\ \dfrac{\frac{(C21*C22*C23*C24)1}{n}}{Sum\ C} \\ \dfrac{\frac{(C31*C32*C33*C34)1}{n}}{Sum\ C} \\ \dfrac{\frac{(C41*C42*C43*C44)1}{n}}{Sum\ C} \end{Bmatrix} \quad (1)$$

Where is the value "*Sum C*" is:

$$Sum\ C = \frac{(c11*c12*c13*c14)1}{n} + \frac{(c21*c22*c23*c24)1}{n} + \frac{(c31*c32*c33*c34)1}{n} + \frac{(c41*c42*c43*c44)1}{n} \quad (2)$$

6) Calculating value weight (W)
Weight (W) is the weight of each criterion which can be obtained by the equation:

$$W = \frac{line\ average}{average\ number\ of\ rows} \quad (3)$$

7) Consistency Test
The Consistency Ratio test (CR) was done to assess the consistency of the answering of the experts, if the CR value is > 0.1 then the distribution of the questionnaires must be repeated, the consistency test is obtained by the equation [1]:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

$$\lambda_{\max} = [(c_{11} + c_{21} + c_{n1})(c_{12} + c_{22} + c_{n2})(c_{13} + c_{23} + c_{n3}) \ldots] \begin{Bmatrix} W1 \\ W2 \\ W3 \\ W4 \\ W5 \\ W6 \end{Bmatrix}$$

$$CR = \frac{CI}{IR} \quad (5)$$

Information:
n = *Number of Elements* *CI = Consistency Index*
IR = *Random Index* *CR = Consistency Ratio*

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Score of the random index can be seen in Table 4.

Table 4: Score Random Index [12]

n	1	2	3	4	5	6	7	8	9	10	11
IR	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

8) The best alternative is chosen based on value weigh t (W) which has been obtained from the calculation result.

2.4 The DFM Analysis on the ATM for Logistic Package Design Alternative

1. Design alternatives 1
   In the ATM design alternative 1 is depicted in Figure 6. The design of logistics package consists of 25 components and the total production cost is IDR. 13,591,200.

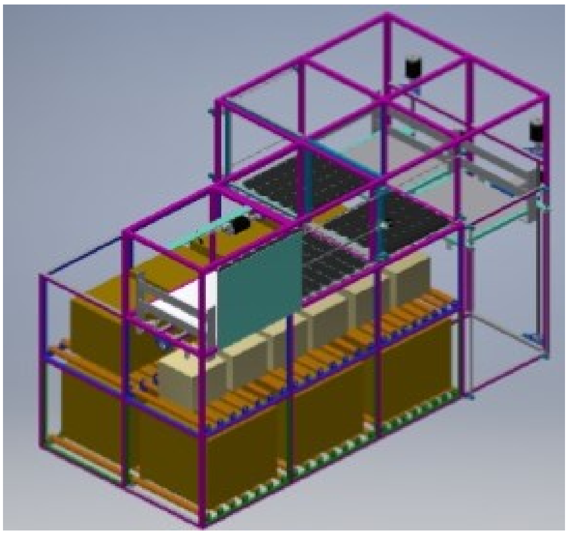

Figure 6: Design alternatives 1

2. Design alternatives 2
   The ATM design alternative 2 can be seen in Figure 7. The design of logistic package consists of 19 components and the total production cost is IDR. 7,256,400.

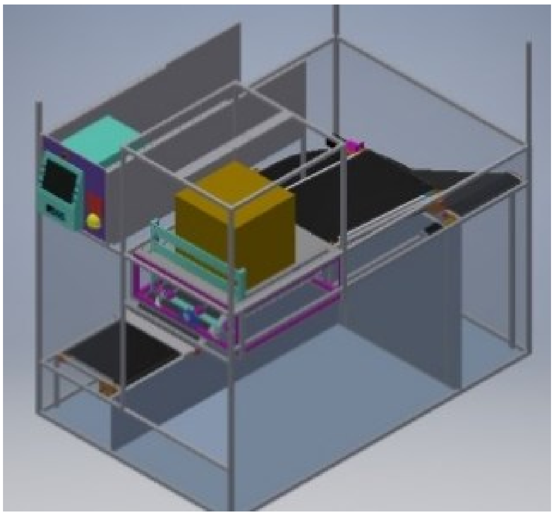

Figure 7: Design alternatives 2

3. Design alternatives 3
   The ATM design alternative 3 can be seen in Figure 8. The design of logistic package consists of 23 components and the total production cost is IDR. 6,777,000.

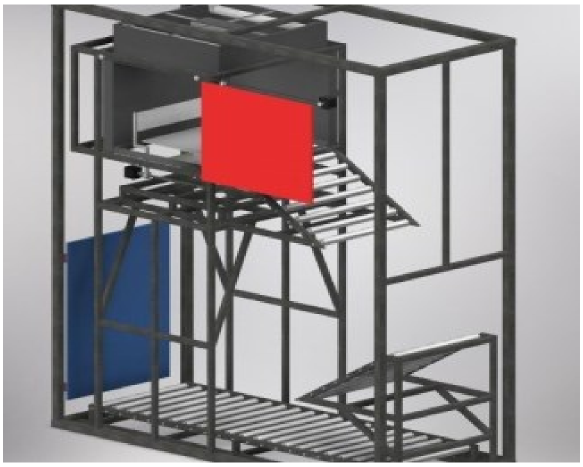

Figure 8: Design alternatives 3

3.0 RESULT AND DISCUSSION

3.1 Results of the Consumer Needs's Questionnaire

From the calculation results, the priority needs of each consumer are obtained which can be seen in Table 5.

Table 5: Priority needs of consumers

NO	ASPECT	PRIORITY	WEIGHT(%)
1	*Ergonomic*	Medium sized ATM	87.5
2	Measurementdimensions and weight	Using cameras, sensors and load cells for dimensions and weight measurements	92.5
3	Packet transmission	Using a transmission system to transmit the package from the dimensions and weight measurement point to the final storage area of the package.	90
4	Package storage	Using the transmission system base at the end of the package storage area to make it easier for the courier to pick up the packages that are at the end of the package storage.	87.5

3.1.1 Rating of Weight Expert Against Criterias

After processing the data, the weight values were obtained as can be seen in Table 6.

Table 6: The weighted value of criteria on ATM for logistic package

Criteria	*Weight*
Ergonomic	0.06
Measurementdimensions and weight	0.69
Packet transmission	0.19
Package storage	0.07

From the weight gain in Table 6, it can be seen that the criteria of weight for the ATM logistic package was the highest for the dimension and weight measurement (0.69) and the lowest for *Ergonomic* (0.6).

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3.1.2 Rating of weight expert against criteria with sub-criteria

At this stage, data processing was carried out to obtain the weight value of the sub-criteria against the criteria. From the value obtained, it was known that the most influential sub-criteria on the criteria for logistic package ATM using the AHP method. From data processing, the weight value can be seen in Table 7.

Table 7: The weighted value of against criteria with Sub criteria on ATM for logistic package

Criteria vs Subcriteria	*Weight*	CR
Ergonomic		
PxLxT (150x130x150) cm	0.106	
PxLxT (130x120x150) cm	0.602	0.1
PxLxT (124x60x150) cm	0.292	
Measurementdimensions and weight		
Camera & sensors are stationary and package is stationary	0.127	
Camera & sensor moves translation and package in stationary position	0.275	0.06
Camera & sensor is stationary and package rotates clockwise	0.598	
Packet transmission		
Transmission of packages to storage rooms using conveyor belts and package lifts	0.112	
Transmission of packages to the storage room using a conveyor belt	0.289	0.08
Package transmission to storage room using roller bearings	0.599	
Package storage		
The per chamber system uses roller bearings	0.259	
A room that uses a plate base	0.136	0.1
Room using roller bearing bases	0.605	

Table 8: The weighted value of criteria with sub criteria against designs of alternative on ATM for logistic package

Sub criteria	*Weight* Alternative 1	Alternative 2	Alternative 3
Ergonomic			
PxLxT (150x130x150) cm	0.626	0.233	0.141
PxLxT (130x120x150) cm	0.452	0.429	0.189
PxLxT (124x60x150) cm	0.153	0.153	0.694
Measurementdimensions and weight			
Camera & sensors are stationary and package is stationary	0.590	0.177	0.233
Camera & sensor moves translation and package in stationary position	0.249	0.641	0.110
Camera & sensor is stationary and package rotates clockwise	0.132	0.180	0.688
Packet transmission			
Transmission of packages to storage rooms using conveyor belts and package lifts	0.611	0.200	0.189
Transmission of packages to the storage room using a conveyor belt	0.300	0.641	0.059
Package transmission to storage room using roller bearings	0.239	0.152	0.609
Package storage			
The per chamber system uses roller bearings	0.571	0.119	0.310
A room that uses a plate base	0.146	0.657	0.198
Room using roller bearing bases	0.289	0.114	0.596

3.1.3 Rating weight *Expert* against sub-criteria with alternatives design

At this stage, data processing was carried out to obtain the weight value of the alternatives against the sub-criteria. From the values obtained, it was known the alternative that most influences the sub-criteria for ATM logistic packages using the AHP method. From data processing, the weight value can be seen in Table 8.

3.1.4 Alternative Options

From the results of data processing, the alternative weight percentage value for ATM logistic packages can be seen in Figure 9.

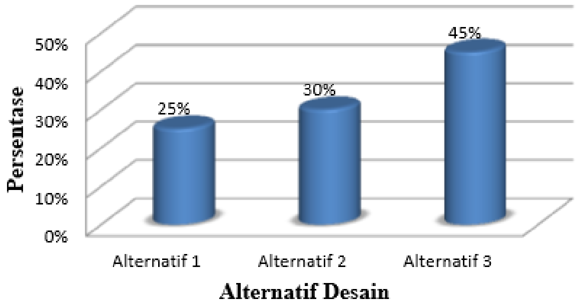

Figure 9: Percentage on design alternatives of ATM for logistic package

Table 9: Manufacturing costs for design of the alternative 3

No.	material	total	Unit price	Total
1.	Iron Hollo 30x30x30x30	1 stick	90000	90000
2.	Iron Hollo 20x20x20x20	1 stick	65000	65000
3.	Steel shaft	3 sticks	104000	312000
4.	Steel pipe	2 sticks	135000	270000
5.	2mm aluminum plate	2 sheets	420,000	840,000
6.	Duraluminium plate	1 sheet (50x50x1)	120,000	120,000
7.	*Load cell*	1 piece	315,000	315,000
8.	Cameras and sensors	1 piece	1,350,000	1,350,000
9.	*Linear bearing*	4 pieces	19,000	76,000
10.	Stapper motor	4 pieces	150,000	600,000
11.	*Bearings*	70 pieces	15,000	1,050,000
12.	Wheels	3 pieces	26,000	78,000
13.	*Fulley*	2 pieces	40,000	80,000
14.	*v-belt*	1 piece	49,000	49,000
15.	Monitor screen	1 piece	540,000	540,000
16.	Navigation Keys	1 piece	150,000	150,000
17.	*Card Insert*	1 piece	127,000	127,000
18.	BT C58BT receipt printer	1 piece	605,000	605,000
19.	Safe door hinges	2 pieces	30,000	60,000
	Total			**6,777,000**

In Figure 9 shows the alternative 3 that revealed the highest percentage value, namely 45%. This value was influenced by the first highest criteria, namely measurement of dimensions and weight with a value of 68.98%. The second highest was the transmission package with a value of 18.52%. Then, each has the highest sub-criteria, which affects, namely the camera and sensor sub-criteria in a stationary position and the package rotates clockwise with a value of 0.413 for the dimensions and weight measurement criteria.

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The sub-criteria for the transmission of the package to the storage space using roller bearing with value of 0.114 for the package transmission criteria. Therefore, the design of alternative 3 was as the optimal on ATM for logistic package. The DFM analysis on alternative design of ATM for logistics package was preferred the design alternative 3. The manufacturing cost of the ATM for logistics package for alternative 3 was the lowest cost of IDR. 6,777,000 that was compared to design of the alternative 1 and 2.

4.0 CONCLUSION

This paper is proposed to design of the automatic machine for logistic package using the AHP and DFM approaches. The conclusions is obtained from this study: first, the indicators of design that affect the selection of ATM design for logistics packages was obtained based on criteria from the highest to the lowest, namely: measurement of dimensions and weight of 68.98%, package transmission of 18.52% and package storage of 6.65% and ergonomics 5.85%. Second, the ATM design for the most optimal logistics package is in design alternative 3 with a percentage value of 45%. Third, the DFM analysis makes it easy to define design alternative options that are easy to create. The lowest cost of making a logistic package of the ATM is shown in the design alternative 3 of IDR. 6,777,000. That is cheapest than the design of alternative 1 and alternative 2.

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