Decision-making for supplier selection of supplement packaging

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Abstract. This research was conducted on manufacturers of various pharmaceutical products in Indonesia, especially multivitamins and over-the-counter medicines, and focused on packaging, which also plays a significant role. The company orders cardboard packaging from several suppliers. The problem is that there are still many cardboard packages with defects, such as stains on the information cover, faded writing, non-standard colors, illegible barcodes, and torn cardboard, resulting in a manual sorting process which results in wasted working time and disrupts production schedules. This research aims to select potential suppliers to reduce this problem by implementing the AHP method to determine weights and the MOORA method to determine priority choices from existing alternative suppliers. The results of the research, using the AHP method, obtained criteria weights, namely quality of 38%, delivery of 24%, cost of 21%, responsiveness of 10%, and flexibility of 7%, with the MOORA method the ranking results were obtained, namely first place Alternative 1, second place Alternative 2, and the third rank is Alternative 3. This shows that Alternative 1 is a priority supplier that can be recommended as the best supplier.

1 INTRODUCTION

This research was conducted at a pharmaceutical company in Indonesia that produces and markets various pharmaceutical products. The products produced are multivitamins and non-prescription medicines such as analgesics and allergy medicines. This company does not produce packaging materials such as cardboard, plastic tubes, aluminium tubes, plastic stoppers, aluminium foil, and other packaging but orders them from suppliers. Apart from ensuring that the products produced comply with predetermined standards, this company must also ensure that the quality of the product packaging meets the specified specifications. However, the problem is a mismatch between the material sent by the supplier and the specifications set by the company. During the sampling and packaging process, there were still packaging defects such as stains covering information, imperfect printing, faded writing, colors that did not match standards, illegible barcodes, and torn

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cartons. This results in frequent manual sorting processes which cause a waste of time, effort and energy, and materials being returned to suppliers. Rejecting activities takes up employee work time because the company carries out investigations and manual sorting, and the production process of a product does not comply with the predetermined schedule. This research focuses on cardboard packaging suppliers because cardboard packaging supplies are needed more than other types of packaging [1]. Cartons are secondary packaging, namely packaging that is not directly related to the product but is directly related to the primary packaging. The visual appearance of cardboard packaging is the attractiveness of a product which consists of text, color, shape, brand/logo and layout [2][3]. Very fatal defects, namely in text and inappropriate colors, can fade the product's authenticity.

Apart from that, it is more often found that the material sent by the supplier does not match the specifications set by the company. Thus, it is necessary to analyze suppliers for carton packaging so that there can be improvements and assessments from each supplier. Based on observations, material was found that did not comply with the quality set by the company. Reject data in 2021 can be seen in Table 1.

Table 1. Number of reject carton packaging.

Supplier	Number of Material Arrivals (pcs)	Number of Reject (pcs)	Total(%)
PT ARP	377601	3790	1,00
PT PBA	1353796	66220	4,89
PT DAI	3639844	183494	5,04

The large number of defective packaging can cause significant costs, rework activities such as sorting and investigation and the production process of a product not according to the predetermined schedule. This is caused by a mismatch between the Certificate of Analysis (CoA) and the incoming sample sent by the supplier. The AHP (Analytical Hierarchy Process) and MOORA (Multi-Objective Optimization by Ratio Analysis) methods were chosen to determine the ranking of recommended alternative suppliers. The AHP method is used to determine priority weight criteria, and the MOORA method is used to select suppliers. Able to decide on goals from contradictory criteria, where the requirements can be beneficial (benefit) or unprofitable (cost). Apart from that, MOORA can also easily separate an evaluation process's subjective elements into decision-weight criteria with several decision maker attributes[4][5].

Currently, many manufacturing and service companies do not have the best suppliers. This is because determining suppliers is based on intuition and relationships. However, it is not accompanied by rational and measurable evaluation criteria and methods. Thus, the importance of strong partnerships between companies and suppliers because it is associated with lower costs, good quality, innovation, helps companies achieve sustainable competitive advantages. So the company must find the right way to evaluate suppliers and choose the best among several suppliers to become partners in the supply chain [6][7].

2 Method

Suppliers are a group of organizations or individuals who have an interest in the success of a manufacturer compared to other [8][9] Suppliers intensively support the company's operational processes, usually in the form of unfinished raw materials, so the quality of the supplier can be seen from the final product which will later be sold by the company to customers [10]. Suppliers are one of the business partners who play an important role in ensuring the availability of supplies and the quality required by the company [11]. A company cannot compete with its competitors if its suppliers do not produce quality raw materials. thereby producing productivity and product quality that can provide consumer satisfaction . The supplier selection process begins with the need for suppliers, determining and formulating decision criteria, pre-qualification (initial screening and preparing a shortlist of potential suppliers from a list of suppliers), final supplier selection, and monitoring of selected suppliers, namely continuous assessment evaluation [11].

Analytical Hierarchy Process (AHP) is a cumulative technique developed for cases with various analysis levels [10]. The AHP method is a practical way to handle various functional relationships in a complex network cumulatively. This method uses pairwise comparisons, calculates weighting factors, and analyzes them to produce relative priorities among existing alternatives [12][13]. The advantage of AHP lies in its holistic design, which uses logic and considerations based on intuition, quantitative data, and qualitative preferences. Apart from that, the advantage of AHP also lies in its hierarchical structure, which organizes it from top to bottom, starting from the most important to the alternative level to choose which one is the best. Each problem can be formulated as a hierarchical decision problem. The elements at each level are compared to the elements at the level below. Multi Objective Optimization by Ratio Analysis (MOORA) is a method that can be used to assist the decision-making process. This research combines AHP and MOORA because both are able to provide objectivity in producing decisions[14].

The MOORA method was first developed by Brauers who applied it in a multi-criteria decision-making process. One of the advantages of this method is high flexibility and a good level of selectivity. This is because MOORA can determine objectives from contradictory criteria, where the criteria can be beneficial (benefit) or unprofitable (cost). Apart from that, MOORA can easily separate the subjective elements of an evaluation process into decision-weight criteria with several decision-maker attributes [15][16]. Multi-Objective Optimization by Ratio Analysis (MOORA) is a method that can assist the decision-making process. The MOORA method was first developed by Brauers, who applied it in a multi-criteria decision-making process. One of the advantages of this method is high flexibility and a good level of selectivity. This is because MOORA can determine objectives from contradictory criteria, where the criteria can be beneficial (benefit) or unprofitable (cost). Apart from that, MOORA also can easily separate the subjective elements of an evaluation process into decision weight criteria which have several decision maker attributes. The MOORA method performs ranking by comparing the value of each criterion for each alternative by looking at their respective weights to obtain the ideal alternative. In ranking, the MOORA method has several steps, namely [17][18]. Formation of decision-making:

$$X = \begin{pmatrix} X_{01} & \dots & X_{0j} & \dots & X_{0n} \\ \dots & \dots & \dots & \dots & \dots \\ X_{ij} & \dots & X_{ij} & \dots & X_{nj} \\ & & (1) & & \\ \dots & \dots & \dots & \dots & \dots \\ X_{n1} & \dots & X_{mj} & \dots & X_{mn} \end{pmatrix} \qquad i = m,0\ ; j \tag{1}$$

M = number of alternative; n = number of criteria; X_{ij}= number of performs alternative i against j; X_{0j}= optimum value of j criteria.

Normalization of decision making matrix for all criteria:

$$X^*_{ij} - X_{ij}/\sqrt{\left[\sum_{i=1}^{m} X^2_{ij}\right]} \tag{2}$$

xij = alternative matrix with j criteria; i = 1, 2, 3, ..., n is the initialization of a sequence of criteria or attributes;
j = 1, 2, 3, ... , m is an alternative sequence initialization; X^*_{ij} = Alternative Normalization Matrix j with criteria i

Determine the normalization matrix weight:

$$\sum_{j=1}^{n} wj = 1 \quad (3)$$

Determine the max-max and min-max:

$$Yi = \sum_{j=1}^{g} wj * Xij - \sum_{j=g+1}^{n} \mathrm{Wj} * \mathrm{Wij} \quad (4)$$

i = 1,2,3, ..., g are criteria or maximized attribute
j = g+1, g+2, g+3, ..., n are minimized criteria or attributes
y*j = Results normalization matrix maximize reduction and minimize alternative j

The alternative with the largest Yi value produces the best alternative in order thus generate rankings: ranking or ranking. Total maximum value (benefit attribute) in a decision matrix can results in the value of yi being positive or negative. At this stage it is carried out ranking of the yi values, where The highest yi value is the marker the best alternative, while Alternative with the lowest yi value is the alternative worst.

3 Results and Discussion

3.1 Identification and Preparation Criteria

These criteria consist of quality, cost, delivery, flexibility and responsiveness. These criteria can be used to assess the three suppliers, PT ARP, PT PBA, and PT DAI. The following is a hierarchy created based on the criteria and alternatives in Fig. 1.

This research was carried out by distributing pairwise comparison questionnaires between criteria and alternatives. The paired comparison assessment scale consists of a scale of 1 - 9. Assessments were carried out by respondents for each level depicted in Fig. 1.

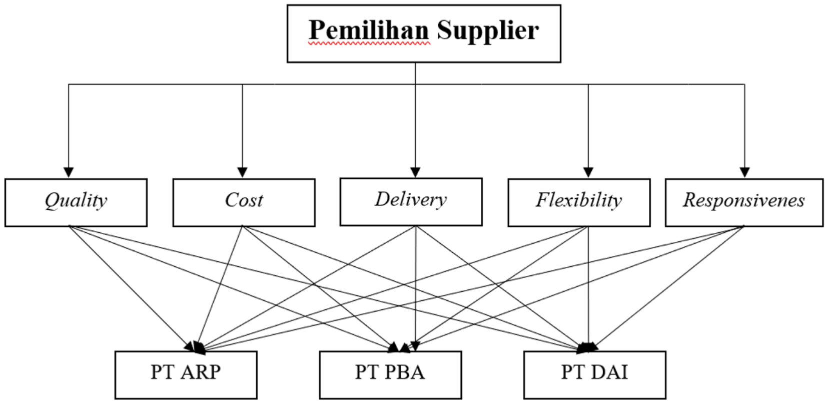

Fig. 1. Hierarchy structure.

3.2 Data Processing with AHP

3.2.1 Geometric Mean

The Analytical Hierarchy Process (AHP) method only requires one answer in the comparison matrix. So, the results of the pairwise comparison questionnaire from 5 respondents were averaged using the geometric mean with the following formula: P= √(n&X1 x X2 x X3x…x Xn…)

An example of geometric mean calculation from Table 2 between quality and cost criteria is as follows:

Table 2. *Geometric mean* Each Criterion

Criteria	Quality	Cost	Delivery	Flexibility	Responsiveness
Quality	1	1.53	1.48	5.52	4.83
Cost	0.65	1	1.05	2.85	1.63
Delivery	0.68	0.95	1	3.74	2.81
Flexibility	0.18	0.35	0.21	1	0.68
Responsiveness	0.21	0.61	0.36	1.48	1
Total	2.72	4.44	4.10	14.59	10.95

P= √(5&0.33 x 3 x 5 x 5 x 0.33) = 1.53
In the same way, geometric mean results will be obtained for each criterion at each level.

3.2.2 Normalization Matrix

Matrix normalization is obtained by dividing each geometric mean value for each column by the sum of the values . An example of calculation between quality criteria can be seen in Table 3.

Table 3. Normalization Matrix Each Criteria

Criteria	Quality	Cost	Delivery	Flexibility	Responsiveness
Quality	0.37	0.34	0.36	0.38	0.44
Cost	0.24	0.23	0.26	0.20	0.15
Delivery	0.25	0.21	0.24	0.26	0.26
Flexibility	0.07	0.08	0.05	0.07	0.06
Responsiveness	0.08	0.14	0.09	0.10	0.09
Total	1.00	1.00	1.00	1.00	1.00

Normalization = (Results of geometric mean) / (∑ each column geometric mean) = 1/2.72= 0.37

In the same way, normalization results will be obtained for each criterion at each level.

3.2.3 Priority Vector

The priority vector calculation is obtained from the results of matrix normalization for each criterion. The results are then added up and averaged for each row. An example of calculation from Table 4 priority vector for quality criteria is as seen in Table 4.

Table 4. Priority Vectors Each Criteria.

Criteria	Amount	Mean
Quality	1.89	0.38
Cost	1.07	0.21
Delivery	1.22	0.24
Flexibility	0.33	0.07
Responsiveness	0.49	0.10
Total		1.00

Priority Vector = (∑Normalize each row) / (∑matrix elements)

= (0.37+0.34+0.36+0.38+0.44)/5 = 1.89/5 = 0.38

Other priority vectors are obtained in the same way.

3.2.4 Consistency Test

In the consistency test, the first thing to do is calculate the eigenvector. The eigenvector is obtained by multiplying the pairwise comparison matrix of the geometric mean with the weight vector. An example of calculations from Table 5 for quality criteria is as follows:

Table 5. Eigen Vector Each Criteria.

Criteria	Quality	Cost	Delivery	Flexibility	Responsiveness	Amount	Mean	Weight
Quality	0.05	0.02	0.02	0.0018	0.004	0.094	0.019	0.10
Cost	0.03	0.01	0.02	0.0009	0.001	0.061	0.012	0.06
Delivery	0.03	0.01	0.01	0.0012	0.002	0.062	0.012	0.06
Flexibility	0.01	0.00	0.00	0.0003	0.001	0.017	0.003	0.02
Responsiveness	0.01	0.01	0.01	0.0005	0.001	0.024	0.005	0.03

Weight = Geometric mean x weight vector

= (1 x0.019) + (1.53x0.012) + (1.48x0.012) + (5.52x 0.003) + (4.83x0.005) = 0.10

Other eigenvectors are obtained in the same way.
The next step is to calculate λ max.

$$\lambda \text{ maks} = \frac{\sum\left(\frac{Weight}{Weigh\ vector}\right)}{\sum\ matriks\ elemen} = \frac{5.19 + 4.49 + 5.04 + 5.01 + 5.40}{5} = 5.03$$

$$\text{CI} = \frac{(\lambda \text{ maks} - \text{n})}{n-1} = \frac{5.03}{5-1} = 0.01 \text{ CR} = \frac{CI}{IR} = \frac{0.01}{1.12} = 0.01$$

The CR value is less than 10% from the data processing results, which means it is consistent.

3.3 Data Processing with Multi-Objective Optimization based on Ratio Analysis (MOORA)

Table 6. Criteria weight.

Criteria	Weigh
Quality	0.44
Cost	0.15
Delivery	0.26
Flexibility	0.06
Responsiveness	0.09

Next, the system will perform the ranking process using the MOORA method. The system was tested using input data in this study, as shown in Table 7. In Table 3, alternatives are coded with the provisions that 1 represents Supplier 1, 2 represents Supplier 2, 3 represents Supplier 3. Rating Scale: Not Important (1); Less Important (2); Important (3) Very Important (4).

Table 7. Supplier assessment.

Criteria	Alternative		
	1	**2**	**3**
Quality	4	4	1
Cost	3	3	2
Delivery	3	3	2
Flexibility	3	2	1
Responsiveness	3	2	2

Calculation using the MOORA method:
Decision matrix:

$$\begin{pmatrix} 4 & 3 & 3 & 3 & 3 \\ 4 & 3 & 3 & 2 & 2 \\ 1 & 2 & 2 & 1 & 2 \end{pmatrix}$$

Normalization and normalization matrices are weighted based on the type of criteria :

$$Xij = \frac{Xij}{\sqrt{[\sum_{i}^{m} X_{ij}^2}}$$

$$\begin{pmatrix} 0.69 & 0.63 & 0,63 & 0.81 & 0.72 \\ 0.69 & 0.63 & 0.63 & 0.45 & 0.48 \\ 0.18 & 0.43 & 0.43 & 0.27 & 0.48 \end{pmatrix}$$

Weighted matrix normalization :

$$X = \begin{pmatrix} 0.69 & 0.63 & 0,63 & 0.81 & 0.72 \\ 0.69 & 0.63 & 0.63 & 0.45 & 0.48 \\ 0.18 & 0.43 & 0.43 & 0.27 & 0.48 \end{pmatrix}$$

$$Yi = \sum_{j=1}^{g} wjXij * - \sum_{j=g+1}^{n} \text{Wj Wij} *$$

The recapitulation results of supplier selection calculations can be seen in Table 8.

Table 8. Recapitulation of normalization calculation results weighted matrix for each supplier.

Supplier	Recapitulation	Value	Rank
Supplier 1	(0.69 x 0,44) + (0.63 x 0.26) + (0.81 x 0.06) + (0.72 x 0.09) – (0.63 x 0.15)	0.4859	1
Supplier 2	(0.69 x 0,44) + (0.63 x 0.26) + (0.45 x 0.06) + (0.48 x 0.09) – (0.63 x 0.15)	0.4431	2
Supplier 3	(0.18 x 0,44) + (0.43 x 0.26) + (0.27 x 0.06) + (0.48 x 0.09) – (0.43 x 0.15)	0.1921	3

4 Conclusion

1. In the analysis of supplier selection using the Analytical Hierarchy Process (AHP) method, the results of the importance levels of the criteria were obtained sequentially, namely quality at 44%, delivery at 15%, cost at 26%, responsiveness at 6%, and flexibility at 9%. So, it can be concluded that quality criteria are the most crucial supplier selection requirement.
2. Based on data processing results, rankings were obtained for the three suppliers: rank 1 for supplier 1 was 48.59%, Supplier 2 was ranked 2 with 44.31% and rank 3 for supplier 3 was 9.21%. Thus, supplier 1 is the recommended supplier to be selected as the sole supplier.

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