



Implementation of Analytical Hierarchy Process and Best Worst Method in Supplier Selection

Nanang Alamsyah¹, Mohammad Rachman Waluyo², Muthia Zenzy Ariani³

^{1,2,3}Universitas Pembangunan Nasional Veteran Jakarta, Indonesia

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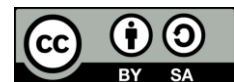
Analytical Hierarchy Process (AHP)

Best Worst Method (BWM)

ABSTRACT

The incompatibility of the quality of the goods sent and the delay in delivery cost the company money and created an unfavorable image in the eyes of the consumer. Both factors can be caused by errors in the supplier selection process of raw materials. The purpose of this research is to select the best supplier in the procurement process at the largest paper-producing company in Indonesia, which begins with determining the criteria that influence the selection of suppliers. The Analytical Hierarchy Process and the Best-Worst Method were used in this study. Based on 4 personnel in the procurement department, 8 criteria were found for selecting suppliers, with 3 alternative suppliers. The selected criteria are: certificate quality, defect rate, offer price, discounts, delivery time, order fulfillment, power response, and work history. The offer price is the most important variable with a weight of 29.3%. Supplier A was selected with a score of 66.78%, while Supplier C became the second alternative priority, and Supplier B became the third alternative priority.

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Corresponding Author:

Nanang Alamsyah,

Universitas Pembangunan Nasional Veteran Jakarta, Indonesia

Email: nanangalamsyah@gmail.com

1. INTRODUCTION

Suppliers are a key part of the supply chain and have an effect on how the production process goes. A factory requires raw materials from suppliers to control the production process. If the supplier is not responsible, this can cause various problems, and the company must make choices when choosing a supplier. Therefore, it is important to choose the right supplier in order to produce goods whose quality is always maintained [1]. The decision-making methods for selecting the right supplier are very diverse, one of which is the Analytical Hierarchy Process (AHP) method. According to research conducted [2], the AHP method is very suitable for multi-criteria decisions [3]. There are many criteria that can be used as decision-making parameters, namely consistent product quality, product availability, delivery time, and product quality [4]. The results obtained from this decision support system help companies make recommendations to determine the best supplier.

The AHP method in supplier selection can be combined with the Best Worst Method (BWM) [5]. This method is used to solve problems in multi-criteria decision making by taking into account several criteria to select the best and worst criteria and compare them with other criteria [6]. The developed AHP and BWM

methods have the advantage that BWM makes a structured comparison and AHP calculates weights using a hierarchy [7]. So that both methods can produce the same final result of reliable and accountable weighting because of the comprehensive calculation process. In the process of procuring goods, the procurement department often faces problems such as price changes, inappropriate prices, damaged goods, late deliveries, goods that do not match requests, missed communication with suppliers, and various other problems.

In the process of delivering a product, there are many factors that can cause it to be delivered at the wrong time. Factors that cannot be avoided by companies and suppliers because they occur naturally. After the product is received, it is checked by the user to ensure the quality of the product is in accordance with the standards set by the company. If there are products that are torn, bent, and dirty, a return process will be carried out to the supplier to get a new product. In the past 4 months, many defective products have been found. From the data obtained, the total number of defect products from October 2021 to January 2022 was 3.84%, 2.63%, 4.47%, and 4.89%, respectively. This causes a loss for the company because it has to carry out the return process, and the user also needs to sort the packaging to be distributed to several areas and stored for the following days.

Table 1. Packaging Delivery Time Data.

Plan	Realization	Note
27/09/21	28/09/21	1 day late
25/10/21	26/10/21	1 day late
29/11/21	29/11/21	On time
27/12/21	30/12/21	3 days late

The incompatibility of the quality of the goods sent and the delay in delivery resulted in the company suffering losses and creating an unfavorable image in the company's consumers' eyes [8]. Based on this, analysis is needed in selecting the best supplier for the packaging procurement process at PT. XYZ with destination to increase quality and so that companies can speed up the buying process because there is no need to negotiate and wait for replies from many suppliers. In addition, cooperation with the right suppliers can reduce the risks of loss, place orders on an ongoing basis, and ensure the smooth movement of goods in the supply chain by applying the Analytical Hierarchy Process (AHP) [9], and Best Worst Method (BWM). This research aims to select the best supplier in the procurement process at the largest paper-producing company in Indonesia.

2. RESEARCH METHODE

This study was carried out at PT. XYZ, which is one of the largest paper industry companies in Indonesia and produces various types of paper, with colored paper being the main product. Object study: this is packaging used to protect the big sheet that has been produced. Methods of data collection in research are observations, interviews, and questionnaires. As mentioned in Figure 1, research begins with observation for problem identification.

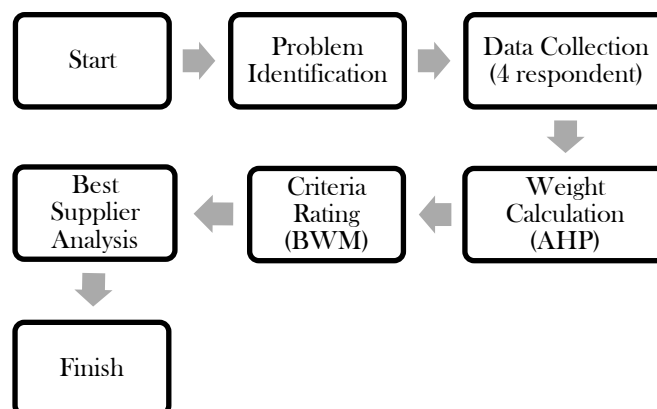


Figure 1. Processes of Research

Respondents from the distributed questionnaire (data collection), namely four procurement staff directly involved in the procurement process, packaged this. The methodology in this study combines AHP [10] and BWM methods for supplier selection [11].

2.1. Analytical Hierarchy Process (AHP)

AHP is a way to turn unstructured situations into a set of hierarchical parts by assigning subjective values and figuring out which variables are most important and have the most impact on the situation. The steps of AHP methods include [12]:

1. Interpret problems that occur and solve them before composing a hierarchy from those problems.
2. Determine the priority element.
3. Synthesis to get priority in the hierarchy.
4. Measuring consistency.
5. Calculating the Consistency Index (CI).

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

6. Calculating Consistency *Ratio* (CR).

$$CR = \frac{CI}{RCI} \quad (2)$$

7. Hierarchy consistency is checked. If the value of CR 0.1 then the data needs improvement, but if the value of CR 0.1 then the calculation results can be declared correct.

2.2. Best Worst Method (BWM)

The Best-Worst Method (BWM) is a new method used to solve problems by taking multi-criteria decisions [13]. In MCDM problems, a number of alternatives are evaluated, taking into account a number of criteria for choosing the best one. In BWM, criteria for best and worst conducted identification, formerly with maker decision. Then do comparisons in pairs. With other criteria [6], among two criteria (best and worst). According [13], the steps needed in the BWM method include:

1. Determining a set of criteria for a decision.
2. Determine the best criteria (most important or most desirable) and the worst criteria (least important or least desirable).
3. Determining preference criteria best above all criteria (vector best-to- other) others using values 1 to 9.
4. Using values 1 to 9, determine preference criteria that are best above all other criteria (vector best-to-other).
5. Find the optimal weight (w_1, w_2, \dots, w_n) to determine the optimal weight of the criteria so that the absolute difference is maximum $\left| \frac{w_b}{w_j} - a_{bj} \right|$ and $\left| \frac{w_j}{w_w} - a_{jw} \right|$ for all j is minimized.

3. RESULT AND ANALYSIS

Determination criteria for elections are conducted by looking for literature and adapting to problems that occur in the procurement process.

3.1. Processing Evaluation Criteria with AHP

Method AHP used for calculating weight from criteria as seen in Table 2. Result used for calculation next use method Best Worst Method (BWM) [6].

Table 2. Tabulation Results Weighting Criteria

Code	Criteria	K 1	K 2	K 3	K 4	K 5	K 6	K 7	K 8
K 1	Certificate Quality	1	1.414	0.230	0.408	1.414	2.378	1.278	0.639
K 2	Defect Rate	0.707	1	0.207	0.261	1.514	1.800	1.627	1.236
K 3	Offer Price	4.356	4.821	1	3.834	3.224	2.280	3.568	1.316
K 4	Discounts	2.449	3.834	0.261	1	1.316	2.280	2.280	1.316
K 5	Delivery Time	0.707	0.661	0.310	0.760	1	2.121	2.060	1.316
K 6	Order Fulfillment	0.420	0.556	0.439	0.439	0.471	1	0.408	0.568
K 7	Power Respond	0.783	0.615	0.280	0.439	0.485	2.449	1	0.173
K 8	Work History	1.565	0.809	0.760	0.760	0.760	1.760	3.663	1

TOTAL	11.988	13.708	3.487	7.900	10.184	16.069	15.882	7.664
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Following are the results recapitulation questionnaire evaluation criteria from fourth respondents who tabulated or combined. Next, normalize the matrix and calculate vector priority for weight criteria, as seen in Table 3.

Table 3. Weighting Criteria

Code	Weight	Λ max
K 1	0.094	1.131
K 2	0.094	1.283
K 3	0.293	1.021
K 4	0.159	1.256
K 5	0.103	1.049
K 6	0.058	0.935
K 7	0.068	1.081
K 8	0.131	1.005

After getting weight criteria, next data consistency is necessary tested, if no consistent so need repeat data. From result calculation, get that CR value 0.1 or 0.077 0.1 which means that results from evaluation weighting the character consistent and able accepted as seen on Table 4.

Table 4. Supplier Criteria Consistency

Lambda Max	
CI	0.109
RCI	1.410
CR	0.077

3.2. Processing Evaluation Criteria with BWM

The BWM method is used to get the value of the criteria that will be used for selecting the best supplier by comparing the best, worst, and other criteria so that the results obtained are in accordance with the needs of the consumer or company. Because the value is obtained from the results of the criteria questionnaire that has been processed by the AHP method, The priority vector values that have been obtained previously using the AHP method are then used to determine the best and worst criteria to be used in the BWM method, as seen in Table 5.

Table 5. Vector Best-to-Others & Others-to-Worst.

Best to Others	Offer Price	Others to Worst	Order Fulfilment
K1	5	K1	4
K2	6	K2	3
K3	1	K3	8
K4	2	K4	7

It was found that the best criterion is the bid price and the worst criterion is order fulfillment. Next, determine the best-to-other (BO) and other-to-worst (OW) vectors. The BWM method is calculated using the Microsoft Excel application and data from the previously calculated weight calculation criteria using the AHP method. To get optimal weight, use the score vector criteria from the AHP method.

$$\text{Weight Best-to-Other} = \left| \frac{w_b}{w_j} - a_{bj} \right| = \left| \frac{0,094}{1} - 5 \right| = 4,906$$

$$\text{Weight Other-to-Worst} = \left| \frac{w_j}{w_w} - a_{jw} \right| = \left| \frac{1}{0,094} - 4 \right| = 6,638$$

$$\text{W center} = \frac{\text{Weight Best-to-Other} + \text{Weight Other-to-Worst}}{2} = \frac{4,906 + 6,638}{2} = 5,772$$

Then enter the value of W center in the solver with Microsoft Excel so that we get optimal weights per criteria and KSI values; for more detail, see Table 6. Solver is used to find the optimal value of a dataset so that the value obtained is the optimal weight for each of the criteria. The obtained KSI value, ξ is 0.0664. This value is used to obtain the CR, and the CI value used is 4.47.

$$CR = \frac{\xi}{\text{Consistency Index}} = \frac{0,0664}{4,47} = 0,0149$$

Obtained CR value worth 0.0149 or $CR \leq 0.1$ which can be interpreted that calculation or the data consistent.

Table 6. BWM Optimal Weight

Code	Weight Best-to-Other	Weight Other-to-Worst	W Center	Optimal Weight
K 1	4.906	6.638	5.772	0.0797
K 2	5.906	7.638	6.772	0.0664
K 3	0.707	4.587	2.647	0.3321
K 4	1.841	0.711	1.276	0.1992
K 5	3.897	4.709	4.303	0.0996
K 6	7.942	16.241	12.092	0.0332
K 7	6.932	12.706	9.819	0.0569
K 8	2.869	1.634	2.251	0.1328

3.3. Processing Evaluation Supplier with AHP

Calculation evaluation suppliers used to determine score vector priority for each supplier on each criterion, so that suppliers with the highest score on each of the criteria that will be scored from the results calculation criteria with the BWM method will get the highest score, as shown on Tables 7, 8, and 9 [14]

Table 7. Recapitulation Supplier Weight

Criteria	PT. A	PT. B	PT. C
K1	0.467	0.133	0.400
K2	0.561	0.133	0.307
K3	0.427	0.142	0.431
K4	0.567	0.158	0.276
K5	0.534	0.124	0.343
K6	0.567	0.126	0.307
K7	0.574	0.118	0.307
K8	0.489	0.109	0.402

Table 8. Final Results of AHP and BWM Calculations.

Criteria	PT. A	PT. B	PT. C
K1	PT. A	PT. B	PT. C
K2	0.0797	-	-
K3	0.0664	-	-
K4	-	-	0.3321
K5	0.1992	-	-
K6	0.0996	-	-
K7	0.0332	-	-
K8	0.0569	-	-
Total	0.6678	0	0.3321

The value from each supplier is added up, and the supplier with the highest score is the best. After calculating the evaluation weight supplier on each criterion, the weight or score vector priority supplier could be recapitulated as follows: From the table above, we see that PT. A has the highest score on the criteria of certificate quality, level defects, piece price, accuracy time delivery, fulfillment order, power response, and history work. PT. B did not receive the highest score on any of the criteria. While PT. C has the highest score on the price offer criteria. After being selected as the supplier's winner, or the one who scored highest on each criterion, suppliers selected the weight criteria from the BWM method. Following are the results from the calculation of AHP and BWM.

Table 9. Table Supplier Priority.

Alternative	Weight	Priority
PT. A	0.6678	I
PT. C	0.3321	II
PT. B	0	III

4. CONCLUSIOON

Based on data processing and analysis that has been carried out by researchers can be concluded that (1) there are 8 criteria that are used as the initial design to evaluate suppliers. The weight of the criteria assessment with the highest level of importance to the lowest level of importance is obtained, namely the bid price criterion of 0.293, the price discount criterion of 0.159, the performance history criterion of 0.131, the delivery timeliness criterion of 0.103, the quality certificate criterion of 0.094, the responsiveness criterion of 0.068, and the order fulfillment criteria is 0.058. (2) The final result of the value of data processing with the BWM and AHP methods, it was found that the Supplier A has the most potential and meets the criteria because it has the highest optimal weight of 0.6678. While the weight of Supplier B is 0 and weight Supplier C of 0.3321. So it can be concluded that Supplier A can be used as a priority supplier to cooperate or carry out a sustainable contract in the packaging procurement process at PT. XYZ.

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