Determining the priority level of suppliers by using AHP and TOPSIS

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Abstract. The selection of suppliers by any company is important as a wise effort to get a smooth supply of raw materials to meet its needs from time to time. The selection and determination of sugar suppliers is important for PT MM as a syrup processing company that sometimes suffers from a shortage of sugar as raw material. This raw material is sometimes not available in sufficient quantities and causes disruption of production activities and failure to achieve production targets. While the company does not want to keep a stock of raw materials to meet the needs for a long time. This company prefers regular supply from time to time. Therefore the company must be selective in choosing the best actual suppliers that will become the company’s partners in the future. Selection is done by using five criteria, namely price, quality, delivery, service and warranty. The five criteria are then outlined in 14 sub-criteria. The company should select some of the right suppliers by trying to use available selection methods such as AHP methods and TOPSIS. AHP method can be implemented to determine the order of criteria used in supplier assessment, and TOPSIS to rank suppliers by using weighted criteria.

1. Introduction
The selection of suppliers for any industry is critical in obtaining a good supply of cheap and good quality raw materials at the right amount at the right time. In this context, the mainstay supplier is not easy to determine because each supplier generally has different strengths and weaknesses between each other. [1] One supplier, for example, can supply materials at low prices and good quality but unable to provide timely demand. The second supplier can meet the demand for the required materials but at a higher price. While other suppliers with great potential are often late in shipping materials. In this case the company should compare and then choose and decide the best suppliers before making the contract of procurement of raw materials [2]

To gain greater benefits, the company can pursue a procurement contract with multiple suppliers, but the company must determine how much supply each supplier will make. Collaboration with multiple suppliers would be better to gain more flexibility in getting raw materials in different situations. But in this case the company must use a supplier reference to be able to determine the procurement plan of the raw material by each supplier [3]

Selection of raw material suppliers (sugar) in PT MM can be done by studying the collaboration records and previous achievements of each alternate supplier. Decision makers in the company can learn the strengths and weaknesses of each suppliers, but are stuck on supplier selection issues in terms of advantages and disadvantages. Meanwhile, the company can bargain for greater benefits. In
the decision-making process, the company represented by a number of staff managers may differ in determining preferred suppliers. This can result in a lack of agreement that is acceptable to all team members. For example, disagreement between the purchasing department manager and the production department manager as well as the finance department manager.

Therefore, the first step that must be done is the agreement on the assessment criteria of suppliers. Thereafter it can be continued with the assessment of each supplier to obtain the order of suppliers according to the level of achievement. Each team member can propose criteria for his proposal to be selected and weighted according to his influence and importance. This can be done by using AHP so as to derive the hierarchical structure and its weight in the supplier assessment. [4]

The result of weighting and selection of criteria with AHP method is then used in supplier assessment by TOPSIS. The advantages and disadvantages of each supplier are assessed using the same criteria so that the sum of each score can be calculated as a basis for sorting their levels. [5]

2. Method

2.1. Suppliers
Locations of sugar suppliers to PT MM are outside the territory, on other islands, so delivery must be done by sea transportation. The supplier alternatives obtained from previous collaborations consist of 5 companies with identity codes P1, P2, P3, P4 and P5. All suppliers are considered capable of meeting PT MM demand. The supply of sugar can adequately meet the needs of PT MM, albeit with a delayed schedule that may disrupt the smoothness of PT MM production activities.

2.2. Selection Criteria
Five criteria used in this research are price, quality, delivery, service and warranty. The determination of the criteria used is obtained from discussions with the company management staff. While the sub criteria in accordance with the needs of PT MM is determined by the company's experts. The criteria and sub criteria used are presented below.

- **P. Price Criteria**, covering 3 sub criteria:
  - a. Conformity of price level with quality level (P1)
  - b. Ability to give a discount on a specific order (P2)
  - c. Unpunctual payment and redemption (P3)

- **Q. Quality criteria**, covering 3 sub criteria:
  - a. The suitability of sugar quality to the prevailing standard (Q1)
  - b. Delivery of sugar without defects (Q2)
  - c. Consistency in quality fulfillment (Q3)

- **D. Delivery criteria (Shipping)**, covering 3 sub-criteria:
  - a. Ability to deliver sugar according to the approved date (D1)
  - b. Ability in terms of transportation handling (D2)
  - c. The accuracy / suitability of quantity in delivery (D3)

- **S. Service criteria**, covering 3 sub criteria:
  - a. Ease of contact (S1)
  - b. Ability to provide clear and easy information (S2)
  - c. Speed in response to customer demand (S3)

- **W. Warranty criteria**, covering 2 sub-criteria:
  - a. Supplier's willingness to replace defective sugars (W1)
  - b. Speed of response in replacement of defective sugars (W2)

The total number of criteria is 5 and the sub-criterion is 14. Based on the results of the discussion, the relative positions of criteria and sub criteria can be arranged in hierarchical form as shown in figure 1.

2.3. Questionnaires
This research uses 2 questionnaires. The first questionnaire was used to collect data on the importance of each criteria and sub-criteria. The second questionnaire was used to collect data on the level of conformity (perception) of each supplier alternative.
2.4. Respondents
Respondents as many as 7 person are the member of decision makers in the company consisting of
president director, director, and five management staff represented by marketing managers, public
relations managers, production managers, financial managers and accounting managers. In this case
the respondents are considered as members of the assessment team.

Figure 1. Hierarchy of criteria and sub-criteria for sugar supplier selection

3. Result and Discussion
The results of research consist of two parts. The first part is the result of the implementation of
Analytic Hierarchy Process (AHP) method and the second part is the result of the application of The
Order Preference Technique by Equal to Ideal Solution (TOPSIS).

3.1. Implementation of Analytic Hierarchy Process (AHP)
The AHP implemented in three simple consecutive steps: [6]
1) Computation of the vector of criteria weights.
2) Computation of the matrix of option scores.
3) Ranking the option.

After the data recapitulation, then consistency test, validity test and reliability test conducted on the
answers of all respondents. The consistency test of the respondent's answer for each question is done
by calculating CR (Consistency Ratio).

The weighting average for each criteria and sub-criteria is calculated using the geometric mean as
shown in table 1 which is considered as the result of group assessment of the values given by the
members of the assessment team.

| Criteria | Price | Quality | Delivery | Service | Warranty |
|----------|-------|---------|----------|---------|----------|
| Price    | 1     | 0,1436  | 0,1412   | 0,1519  | 0,1652   |
| Quality  | 6,9633| 1       | 6,5831   | 5,8326  | 6,1270   |
| Delivery | 7,0815| 0,1519  | 1        | 0,2051  | 0,1573   |
| Service  | 6,5831| 0,1714  | 4,8768   | 1       | 5,5654   |
| Warranty | 6,0529| 0,1632  | 6,3584   | 0,1797  | 1        |
| Total    | 27,6808| 1,6302 | 18,9595  | 7,3692  | 13,0149  |

The data in each cell in table 1 is divided by the sum of each columns and yields the normalization
matrix. The sum of values in each column after normalization is 1 as shown in table 2

The weighted average of each criterion is obtained by summing data from each row in table 2 (the
normalization matrix) and dividing it by the number of available criteria. The calculation results are
shown in table 3.
Table 2. Matrix normalization criteria for interest level (at Level 2)

| Criteria | Price | Quality | Delivery | Service | Warranty |
|----------|-------|---------|----------|---------|----------|
| Price    | 0.0361| 0.0881  | 0.0074   | 0.0206  | 0.0127   |
| Quality  | 0.2516| 0.6134  | 0.3472   | 0.7915  | 0.4708   |
| Delivery | 0.2558| 0.0932  | 0.0527   | 0.0278  | 0.0121   |
| Service  | 0.2378| 0.1052  | 0.2572   | 0.1357  | 0.4276   |
| Warranty | 0.2187| 0.1001  | 0.3354   | 0.0244  | 0.0768   |
| Total    | 1     | 1       | 1        | 1       | 1        |

Table 3. Average weighting for sugar supplier criteria

| Criteria | Price | Quality | Delivery | Service | Warranty | Average |
|----------|-------|---------|----------|---------|----------|---------|
| Price    | 0.0361| 0.0881  | 0.0074   | 0.0206  | 0.0127   | 0.0330  |
| Quality  | 0.2516| 0.6134  | 0.3472   | 0.7915  | 0.4708   | 0.4949  |
| Delivery | 0.2558| 0.0932  | 0.0527   | 0.0278  | 0.0121   | 0.0883  |
| Service  | 0.2378| 0.1052  | 0.2572   | 0.1357  | 0.4276   | 0.2327  |
| Warranty | 0.2187| 0.1001  | 0.3354   | 0.0244  | 0.0768   | 0.1511  |
| Total    | 1     | 1       | 1        | 1       | 1        | 1       |

The calculation of the consistency ratio uses the following formulas:

\[ CR = (\text{Weighted Average Calculation Matrix}) \times (\text{Vector Weight of each row}) \]

\[ CR = \begin{bmatrix} 0.0361 & 0.0881 & 0.0074 & 0.0206 & 0.0127 & 0.0330 \\ 0.2516 & 0.6134 & 0.3472 & 0.7915 & 0.4708 & 0.4949 \\ 0.2558 & 0.0932 & 0.0527 & 0.0278 & 0.0121 & 0.0883 \\ 0.2378 & 0.1052 & 0.2572 & 0.1357 & 0.4276 & 0.2327 \\ 0.2187 & 0.1001 & 0.3354 & 0.0244 & 0.0768 & 0.1511 \end{bmatrix} \times \begin{bmatrix} 25,0046 \\ 14,1995 \\ 20,7934 \\ 14,9873 \\ 25,0046 \end{bmatrix} = 5,0000, 5,0000, 5,0000, 5,0000, 5,0000

\[ \lambda_{max} = \frac{25,0046}{5} = 5,0009 \] (1)

\[ CI = \frac{5,0009 - 5}{5-1} = 0,0002 \] (2)

\[ CR = \frac{CI}{\text{Random Consistency Index}} \]

The Random Index (RI) for \( n = 14 \) is 1.57 (the value obtained from the Table Random Index). With the value of \( CR \leq 0.1 \) then the respondent's answer is consistent.

The results of the calculation of the geometric mean of sub-criteria represented in table 4, and the result of the average weighting of the sub-criteria is presented in table 5.

a. Average entry (\( \lambda_{max} \))

\[ \lambda_{max} = \frac{198,7934}{14} = 14,1995 \] (4)
c. Consistency Index (CI)

\[
CI = \frac{\lambda_{max} - n}{n - 1}
\]

\[
CR = \frac{CI}{\frac{1}{n-1}}
\]

(5)

With the value of \( CR \leq 0.1 \) then the respondent's answer is consistent.

**Table 4.** Geometric mean of sub criteria weight (Level 3)

| S1 | S2 | S3 | W1 | W2 |
|----|----|----|----|----|
| P1 | 0.0194 | 0.0052 | 0.061 | 0.0072 | 0.0069 | 0.0061 | 0.0103 | 0.0914 | 0.0111 | 0.0672 | 0.084 | 0.0066 | 0.0295 | 0.0617 | 0.0334 |
| P2 | 0.0817 | 0.0218 | 0.0656 | 0.0075 | 0.0076 | 0.0072 | 0.0126 | 0.0948 | 0.0073 | 0.0581 | 0.0781 | 0.0068 | 0.0515 | 0.048 | 0.0392 |
| P3 | 0.006 | 0.0063 | 0.0189 | 0.0062 | 0.0069 | 0.0064 | 0.0128 | 0.0583 | 0.01 | 0.0672 | 0.0762 | 0.0066 | 0.0515 | 0.044 | 0.0267 |
| P4 | 0.0817 | 0.0874 | 0.0921 | 0.0303 | 0.0103 | 0.014 | 0.0147 | 0.0781 | 0.0121 | 0.0921 | 0.0914 | 0.0806 | 0.0445 | 0.0611 | 0.0511 |
| P5 | 0.0753 | 0.1198 | 0.1145 | 0.1235 | 0.0419 | 0.0585 | 0.0223 | 0.0583 | 0.0158 | 0.0778 | 0.0881 | 0.0097 | 0.0479 | 0.0456 | 0.0672 |
| P6 | 0.1066 | 0.1011 | 0.0991 | 0.0978 | 0.0241 | 0.0337 | 0.0166 | 0.0675 | 0.078 | 0.0002 | 0.0004 | 0.0078 | 0.0445 | 0.0611 | 0.0614 |
| P7 | 0.1356 | 0.1242 | 0.1064 | 0.1477 | 0.1354 | 0.1454 | 0.0719 | 0.1149 | 0.1512 | 0.1157 | 0.102 | 0.0886 | 0.0878 | 0.0723 | 0.1085 |
| P8 | 0.0038 | 0.0041 | 0.0059 | 0.007 | 0.013 | 0.009 | 0.0113 | 0.0181 | 0.0088 | 0.0398 | 0.0069 | 0.008 | 0.0554 | 0.0657 | 0.0183 |
| P9 | 0.1105 | 0.1889 | 0.1201 | 0.1589 | 0.1685 | 0.2442 | 0.0302 | 0.1311 | 0.0636 | 0.0075 | 0.0081 | 0.0915 | 0.0618 | 0.0673 | 0.1038 |
| P10 | 0.0048 | 0.0063 | 0.0047 | 0.0055 | 0.0009 | 0.0056 | 0.0104 | 0.0076 | 0.1412 | 0.1467 | 0.1316 | 0.0107 | 0.0268 | 0.0468 | 0.0217 |
| P11 | 0.0305 | 0.0045 | 0.0054 | 0.0008 | 0.0064 | 0.01 | 0.0072 | 0.0013 | 0.0512 | 0.1517 | 0.0249 | 0.0194 | 0.0641 | 0.0456 | 0.0277 |
| P12 | 0.144 | 0.1579 | 0.1421 | 0.175 | 0.2147 | 0.214 | 0.1454 | 0.1121 | 0.0343 | 0.1453 | 0.1571 | 0.0494 | 0.0235 | 0.0256 | 0.1436 |
| P13 | 0.1174 | 0.0755 | 0.0065 | 0.1217 | 0.1567 | 0.1352 | 0.1466 | 0.0583 | 0.1839 | 0.1116 | 0.0948 | 0.0375 | 0.1789 | 0.1463 | 0.1406 |
| P14 | 0.0666 | 0.0961 | 0.0991 | 0.1052 | 0.195 | 0.1168 | 0.2111 | 0.0583 | 0.2003 | 0.0759 | 0.0904 | 0.4088 | 0.2595 | 0.2122 | 0.1568 |

Based on the result of average criteria weight in table 3 and average sub-criteria weight in table 5, the order of criteria and sub-criteria can be obtained as shown in table 6 and table 7.

**Table 6.** The order of criteria by importance level

| Rank | Criteria | Weight | Description |
|------|----------|--------|-------------|
| 1    | Q        | 0.4949 | Quality     |
| 2    | S        | 0.2327 | Service     |
| 3    | W        | 0.1511 | Warranty    |
| 4    | D        | 0.0883 | Delivery    |
| 5    | P        | 0.0330 | Price       |
Table 7. The order of sub-criteria by importance level

| Rank | Sub-criteria | Weight    | Description                                           |
|------|--------------|-----------|-------------------------------------------------------|
| 1    | W2           | 0.1568    | Speed of response in replacement of defective sugars  |
| 2    | S3           | 0.1436    | Speed in response to customer demand                  |
| 3    | W1           | 0.1406    | Supplier’s willingness to replace defective sugars    |
| 4    | D1           | 0.1085    | Ability to deliver sugar according to the approved date|
| 5    | D3           | 0.1038    | The accuracy / suitability of quantity in delivery    |
| 6    | Q2           | 0.0672    | Delivery of sugar without defects                     |
| 7    | Q3           | 0.0614    | Consistency in quality fulfillment                    |
| 8    | Q1           | 0.0511    | Suitability of pure sugar to applicable standards      |
| 9    | P2           | 0.0392    | Ability to give a discount on a specific order         |
| 10   | P1           | 0.0334    | Conformity of price level with quality level          |
| 11   | S2           | 0.0277    | Ability to provide clear and easy information         |
| 12   | P3           | 0.0267    | Unpunctual payment and redemption                      |
| 13   | S1           | 0.0217    | Ease of contact                                       |
| 14   | D2           | 0.0183    | Ability in terms of transportation handling           |

3.2. The application of The Order Preference Technique by Similarity with Ideal Solution (TOPSIS)

The procedure of TOPSIS application for the problem of decision making with interval data can be explained in the following steps. [7][8]

3.2.1. Construction of decision matrix and criteria weighting. Weighting was done by all member of the decision makers for all selection sub criteria. The results of the weighting for the first supplier are presented in table 8 below.

Table 8. Weighting result of sub criteria of selection for one supplier (P1)

| Member of DM* | P1 | P2 | P3 | Q1 | Q2 | Q3 | D1 | D2 | D3 | S1 | S2 | S3 | W1 | W2 | Y |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| 1             | 2  | 2  | 2  | 3  | 3  | 3  | 2  | 2  | 2  | 2  | 3  | 3  | 3  | 2  | 34|
| 2             | 4  | 3  | 4  | 4  | 4  | 4  | 3  | 4  | 4  | 3  | 5  | 4  | 5  | 5  | 56|
| 3             | 2  | 2  | 2  | 3  | 2  | 3  | 2  | 3  | 3  | 2  | 3  | 3  | 3  | 3  | 36|
| 4             | 3  | 4  | 3  | 4  | 4  | 3  | 3  | 4  | 4  | 3  | 4  | 3  | 3  | 3  | 49|
| 5             | 3  | 2  | 3  | 2  | 3  | 2  | 3  | 3  | 2  | 3  | 2  | 3  | 1  | 34|
| 6             | 3  | 4  | 3  | 4  | 3  | 3  | 4  | 3  | 4  | 3  | 4  | 4  | 3  | 3  | 49|
| 7             | 2  | 2  | 2  | 3  | 3  | 3  | 3  | 3  | 2  | 3  | 3  | 3  | 1  | 36|

* DM : Decision Maker

In the same way, construction of decision matrix and weighting sub criteria is performed for all the other suppliers.

3.2.2. Calculation of the normalized decision matrix. Formation of the matrix R as a normalized decision matrix. Any normalization of the $r_{ij}$ value can be done by calculating using equation (7).

$$r_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}^2} \text{ for } i = 1, 2, 3 \ldots m \text{ and } j = 1, 2, 3 \ldots n$$  \hspace{1cm} (7)

Where $r_{ij}$ is the normalized matriks [i][j] and $x_{ij}$ is decision matriks [i][j]
3.2.3. Calculation of the weighted normalized interval decision matrix. Any normalization of the \( r_{ij} \) value can be done by calculating using equation (8).

\[
Y_{ij} = w_i \cdot r_{ij} \text{ for } i = 1, 2, 3 \ldots m \quad j = 1, 2, 3, \ldots n (8)
\]

3.2.4. Determination of the positive ideal solutions.

\[ A^+ = (Y^+_1, Y^+_2, Y^+_3, \ldots, Y^+_n) \]

\[ A^+ = \{ \max Y_{ij} | j \in J \}, \{ \min Y_{ij} | j \in J' \}, i=1,2,\ldots,m \} = \{ Y^+_1, Y^+_2, Y^+_3, \ldots, Y^+_n \} \]

\[
\begin{align*}
Y^+_1 & = \max \{ 0.0144; 0.0147; 0.0149; 0.0153; 0.0153 \} = 0.0153 \\
Y^+_2 & = \max \{ 0.0116; 0.0174; 0.0178; 0.0178 \} = 0.0178 \\
Y^+_3 & = \max \{ 0.0114; 0.0119; 0.0121; 0.0121 \} = 0.0122 \\
Y^+_4 & = \max \{ 0.0225; 0.0226; 0.0226; 0.0233; 0.0230 \} = 0.0233 \\
Y^+_5 & = \max \{ 0.0293; 0.0301; 0.0299; 0.0305; 0.0305 \} = 0.0305 \\
Y^+_6 & = \max \{ 0.0270; 0.0274; 0.0277; 0.0277 \} = 0.0277 \\
Y^+_7 & = \max \{ 0.0464; 0.0483; 0.0485; 0.0497; 0.0496 \} = 0.0497 \\
Y^+_8 & = \max \{ 0.0080; 0.0082; 0.0080; 0.0084; 0.0084 \} = 0.0084 \\
Y^+_9 & = \max \{ 0.0457; 0.0444; 0.0473; 0.0473 \} = 0.0473 \\
Y^+_{10} & = \max \{ 0.0093; 0.0096; 0.0099; 0.0099; 0.0099 \} = 0.0099 \\
Y^+_{11} & = \max \{ 0.0123; 0.0123; 0.0125; 0.0125; 0.0123 \} = 0.0125 \\
Y^+_{12} & = \max \{ 0.0631; 0.0635; 0.0642; 0.0655; 0.0649 \} = 0.0655 \\
Y^+_{13} & = \max \{ 0.0624; 0.0623; 0.0627; 0.0640; 0.0630 \} = 0.0640 \\
Y^+_{14} & = \max \{ 0.0674; 0.0698; 0.0702; 0.0714; 0.0717 \} = 0.0717 \\
\end{align*}
\]

3.2.5. Calculation of the relative closeness to the positive ideal solution. The distance between Alternative \( A_i \) with the ideal solution can be calculated by the equation (10):

\[
D_i^+ = \sqrt{\sum_{j=1}^{n} (Y_{ij} - Y^+_i)^2} \quad \text{for } i=1,2,3,\ldots,m
\]

3.2.6. Determination of preference values for each alternative.

\[
V_i = \frac{D_i^+}{D^+_i + D^+_i} \quad \text{for } i=1,2,3,\ldots,m
\]

3.2.7. Ranking the order of preference or selecting the alternative closest to 1. The ranking of sugar suppliers according to the order of preference is presented in table 9 below.
Table 9. Priority level of sugar supplier

| Level | Supplier | Preference | Value   |
|-------|----------|------------|---------|
| 1     | P4       | $V_4$      | 0.99665 |
| 2     | P5       | $V_5$      | 0.98742 |
| 3     | P3       | $V_3$      | 0.97229 |
| 4     | P2       | $V_2$      | 0.95519 |
| 5     | P1       | $V_1$      | 0.93655 |

4. Conclusion
The order of the five criteria for selection of sugar suppliers according to the greatest weight is Quality, Service, Warranty, Delivery, and Price. The five main sub criteria with the greatest weight are the speed of response in replacing the defective sugars, the speed in response to customer demand, the willingness of the supplier to replace the damaged sugars, the ability to deliver sugar according to the approved date, and the accuracy or suitability of quantity in delivery.

According to TOPSIS application, the priority level of suppliers based on preference values ranging from the best are P4, P5, P3, P2 and P1. Thus the company can choose the fourth supplier as the best sugar supplier, followed by the fifth and third supplier.

Finally the results of this study indicate that the use of AHP method and TOPSIS is appropriate and good for sugar supplier selection.

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