Allocation of Maltodextrin Raw Material Orders by Fuzzy Analytic Network Process (FANP) and Goal Programming Methods (Study Case: PT. Neopangan Selaras Indonesia)

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Abstract. PT. Neopangan Selaras Indonesia is a food company that produces seasoning. One of the raw materials with the most frequent problems with delays and wrong allocation is maltodextrin, which is 72%. To determine the need for evaluation for each maltodextrin supplier using the Fuzzy Analytical Network Process (FANP) and Goal Programming methods. The existence of a method of merging these two studies. Determination of the proportion of the criteria and sub-criteria in the company by minimizing changes in each assessment. The FANP method in this study produced criteria and assessments of each supplier that could be considered in the allocation of the purchase of raw materials. The best supplier of weights was obtained by PT. Indo Asia Tirta Manunggal (0.4421). The Goal Programming method provides a solution by minimizing total costs by considering the price of each supplier, maximizing the purchase value by considering the weight generated. This method produces a solution that produces a total cost of 0.134%, increasing the purchase value of 1.143%.

Keywords: Fuzzy-ANP, Goal Programming, Order Allocation, Supplier Selection

1. Introduction

Competition in the industrial world, especially for each company is now classified as very tight, so companies need to make their strategies to defend from the competition. Quality, flexibility, product diversity, rapid response, and competition that occur mainly in the industrial field becomes important and the main thing for the company in obtaining customers [4]. Maintaining competition in the industrial world in a company is done by fulfilling all factors, such as obtaining raw materials at the right vendor, the production process following the plan so that it does not cause delays in shipping products to customers.

Ordering of raw materials is seen from suppliers who meet several requirements of the company itself, where suppliers are one of the most important parts of the company for the continuity of the business of a company. Supplier selection is a strategic activity especially if the supplier supplies an item that will be used for the long term as an important supplier [3]. The selection of suppliers in several companies must be carefully considered by the company itself and requires special analytical methods that can make it possible to minimize errors in selecting suppliers who will be used as the main raw material in the production process. Ordering of raw materials is one aspect of the company where careful planning must be done. Errors in allocating orders to suppliers can result in high costs due to the purchase of raw materials.
PT. Neopangan Selaras Indonesia is a company engaged in the food industry whose main focus is on the production of herbs. There are 4 main raw materials used by this company, namely Sugar, Salt, Monosodium Glutamate (MSG) and Maltodextrin. PT. Neopangan Selaras Indonesia has a make to order system where there are requests or orders from customers, the company will carry out the production process. This company applies a value that is the quality of the products produced must be following established standards, which means that the allocation of orders to each supplier must be done appropriately. At present, PT. Neopangan Selaras Indonesia does not yet have definite criteria and sub-criteria in selecting suppliers, where usually this company makes an order to several suppliers based on the availability of goods available at each supplier when the company makes an order. PT. Neopangan Selaras Indonesia also often experiences a budget increase tendency due to errors in the allocation of raw materials to each supplier. This research focuses on raw material Maltodextrin. Maltodextrin is a raw material that has a role as a sweetener or glucose chart with the physical form of white powder, which according to the company this raw material has the most delays for the 5 suppliers. 72% of the delay that often occurs in the raw material Maltodextrin.

This research was conducted by combining two methods, namely the Fuzzy Analytic Network Process (FANP) and Goal Programming. The combination of Fuzzy and ANP is one of the advantages in this study where FANP is used to identify the relationship between criteria by producing weights so that priorities can be identified in the selection of suppliers by minimizing subjective from the company itself. Methods that help produce allocations to each supplier based on the weights obtained and also the prices set by each supplier. This research will be assessed by 3 respondents who are considered to represent the company.

2. Methods

2.1. Data Collection
The data used during the research are as follows:

- **Primary Data**
  Data obtained directly by researchers following the problems of the company itself. The primary data contained in this study are interview data and questionnaire results to 3 respondents. The questionnaire in this study consisted of: criteria questionnaire, questionnaire linkages between sub criteria, paired comparison criteria and related sub criteria questionnaire, and paired supplier assessment questionnaire.

- **Secondary Data**
  Data obtained from books, research journals, lecture material, as well as historical data that support research. Secondary data used in this study consisted of: Dickson’s Vendor Selection Criteria, supplier capacity data, price data for maltodextrin raw materials, delay data on maltodextrin raw materials, and data request for maltodextrin raw materials.

2.2. Fuzzy Analytical Network Process (FANP) Methods
The steps in this research are as follows [2]:

- Determine the criteria and sub-criteria following company conditions in the selection of maltodextrin suppliers. Determination of the criteria is based on Dickson's Vendor Selection Criteria [1].
Tabel 1. Criteria and Sub-Criteria Used

| Criteria                      | Sub-Criteria                                      |
|-------------------------------|---------------------------------------------------|
| Quality (K)                   | Age of Material                                   |
|                               | Material Function                                 |
|                               | Material Compliance with Specifications           |
|                               | Accuracy of Order Quantity                        |
| Delivery (P)                  | Accuracy of Delivery Time                         |
|                               | Availability of Material                          |
|                               | Past Performance                                  |
| Performance History (SP)      | Flexibility to change the number of orders        |
|                               | Fulfillment in the cooperation agreement          |
|                               | Response Speed                                    |
| Warranties and Claim Policies (G) | Ease of contact                                  |
|                               | Service time                                      |
|                               | Ease of Replacing Reject items                    |
|                               | Discounts and Bonuses                             |
| Price (H)                     | Payment Method                                    |
|                               | Product Prices                                    |
|                               | Communication Skills                              |
| Communication system (SK)     | The Speed of Information Exchange                 |
|                               | Flexibility in Sharing                            |
| Management and Organization (MO) | Ability to follow Procedures                     |

- Describe the ANP structure model in which there are several clusters according to the relationship of company conditions in the selection of suppliers obtained from questionnaire data collection 3 and filling in pairwise comparisons with scale [5].
- Convert the resulting value on questionnaires 4 and 5 into the Triangular Fuzzy Number scale.
- Calculate the geometric mean by combining several values of each respondent into one unit in each upper boundary (l), middle boundary (m), and lower limit (u). The geometric average is calculated using the formula:
  \[ w_i = \sqrt[n]{\frac{w_{n-2} \cdot w_{n-1} \cdot w_n}{w_{n-3}}}, \quad (1) \]
- Calculate defuzzification by combining all of the averages to get a single value from the upper limit (l), middle limit (m), and lower limit (u).
  \[ F_{ij} = \frac{l_{ij} + m_{ij} + u_{ij}}{3}, \quad (2) \]
- Calculate and make a normalization matrix and priority vectors. The normalization matrix is obtained from the previous defuzzification value which will be normalized dividing the cell value by the total column in that cell. Priority Vector Calculations are carried out with the following formula:
  \[ VP = \frac{\text{Number of Rows}}{n}, \quad (3) \]
- Perform consistency test calculations, where this data will be said to be consistent if the value produced is less than 10%, conversely, if the value of this test is produced more than 10%, it is necessary to retrieve the data. There are two calculations of consistency test, namely Consistency Index and Consistency Ratio with the following formula:
  \[ CI = \frac{\lambda_{\text{max}} - n}{n - 1}, \quad (4) \]
  \[ CR = \frac{CI}{RI}, \quad (5) \]
• Making Supermatrix in 3 steps.

Unweighted Supermatrix is a supermatrix made from a recapitulation of priority vector values that have been calculated by existing comparisons. Weighted Supermatrix is a multiplication supermatrix between the unweighted supermatrix and cluster matrix, the final result of each column being 1. Limit Supermatrix is a weighted supermatrix multiplication supermatrix by itself, in which several iterations are carried out until the matrix is stable and the results obtained for each row have the same value and the total column is 1.

2.3. Mathematical Model with Goal Programming Method

The Mathematical Model is made following the conditions of the company, where by formulating the goals to be achieved first. Where the objective function to be considered as a proposal is as follows:

- Minimize the Total Cost of Purchasing Raw Materials
- Maximizing the Value of Purchasing Maltodextrin
- Minimize the Total Cost of Purchasing & Maximizing the Value of Purchasing

**Indices**

\[ i = \text{Supplier Index, } i = 1,2,...,n \]

**Parameter**

\[ B_i = \text{Raw Material Costs from suppliers } -i \]
\[ V_i = \text{Valuation Weight from supplier } -i \]
\[ D = \text{Demand} \]
\[ G_i = \text{Capacity from supplier } -i \]

**Decision Variable**

\[ k_i = \text{The order quantity for suppliers } -i \]
\[ l_i = \text{Decision variable whether raw material will be ordered or not at the supplier } -i \]
  1, there are ordering raw materials at the supplier -i
  0, there is no ordering of raw materials at the supplier -i

**Goals Function**

\[ \text{Min } Z_1 = \sum_{i=1}^{n} B_i \cdot k_i \quad \text{; with } i = 1,2,...,n \]  \hspace{1cm} (6)
\[ \text{Max } Z_2 = \sum_{i=1}^{n} V_i \cdot k_i \quad \text{; with } i = 1,2,...,n \]  \hspace{1cm} (7)

**Limit Function**

- The Total order is equal to the total demand

\[ \sum_{i=1}^{n} k_i = D \quad \text{; with } i = 1,2,...,n \]  \hspace{1cm} (8)

- The Order Allocation for each supplier does not exceed the supply capacity limit of the supplier

\[ \sum_{i=1}^{n} k_i \leq G_i \cdot l_i \quad \text{; with } i = 1,2,...,n \]  \hspace{1cm} (9)

- Minimum suppliers are distributed with 2 suppliers

\[ n_{\text{min}} \leq \sum_{i=1}^{n} l_i \leq n_{\text{max}} \quad \text{; with } i = 1,2,...,n \]  \hspace{1cm} (10)

- \[ k_i \geq 0, \quad i = 1,2,3 \]

\[ k_i : \text{integer} \]
Mathematical model combining the two conditions above by function number 3, the mathematical model is obtained as follows:

**Parameter**

- \( T_t \) = The Purchase value obtained from the LINGO software in Max TV calculation.
- \( R \) = The Purchase Budget limit that will be issued by the company is obtained from the LINGO software in Min TC calculation.

**Decision Variable**

- \( m_i^- \) = Achievement below the target of the objective function
- \( m_i^+ \) = Achievement above the target of the objective function

**Goals Function**

- Min \( m_i^- + m_i^+ \)

**Limit Function**

- Minimizing the total purchase cost, the order allocation does not exceed the purchase budget limit for the company, which is \( R \)
  \[
  \sum_{i=1}^{n} B_i \cdot k_i + m_i^- - m_i^+ = R \; \text{with } i = 1,2,...,n
  \]  
  (11)

- Maximization of purchase value based on weight, order allocation which gives the highest total purchase value.
  \[
  \sum_{i=1}^{n} V_i \cdot k_i + m_i^- - m_i^+ = T_t
  \]  
  (12)

- The Total order is equal to the total demand
  \[
  \sum_{i=1}^{n} k_i = D \; \text{with } i = 1,2,...,n
  \]  
  (13)

- The Order Allocation for each supplier does not exceed the supply capacity limit of the supplier
  \[
  \sum_{i=1}^{n} k_i \leq G_i \cdot l_i \; \text{with } i = 1,2,...,n
  \]  
  (14)

- Minimum suppliers are distributed are 2 suppliers
  \[
  n_{min} \leq \sum_{i=1}^{n} l_i \leq n_{max} \; \text{with } i = 1,2,...,n
  \]  
  (15)

- \( k_i \geq 0; \text{for } i = 1,2,...,n \)
- \( l_i = 0 \text{ atau } 1 \text{ integer}; \text{for } i = 1,2,...,n \)

3. Result and Discussion

Suppliers used in this study on maltodextrin raw materials consist of 5 suppliers at PT. Neopangan Selaras Indonesia, which is shown in table 2.

**Table 2. Supplier of Maltodextrin Raw Material**

| Supplier                                      | Price  | Capacity (kg) |
|-----------------------------------------------|--------|---------------|
| PT. Indo Asia Tirta Manunggal (P1)            | IDR 9.400 | 5000          |
| PT. Astamulya Mandiri (P2)                    | IDR 9.200 | 5000          |
| PT. Satya Anugerah Nutritama (P3)             | IDR 9.500 | 5000          |
| PT. Galic Bina Mada (P4)                      | IDR 9.300 | 5000          |
| PT. Selalu Lancar Maju Karya (P5)             | IDR 8.900 | 5000          |
There are 7 criteria and 20 sub-criteria which are considered by PT. Neopagan Selaras Indonesia. The criteria and sub-criteria used can be seen in Table 1. Ratings or rankings obtained are based on the results of the supermatrix limit. The sub-criteria priority weights in local and global can be seen in Table 3 with the main sub-priority being the ability to follow procedures by 0.0815. Supplier weights are shown in Table 4.

**Table 3. Global Rank & Local Rank**

| Criteria                | Sub-Criteria                                      | Global Weight | Normalized By Cluster | Global Rank | Local Rank |
|-------------------------|---------------------------------------------------|---------------|-----------------------|-------------|------------|
| Age of Material         |                                                   | 0.0431        | 0.4372                | 7           | 1          |
| Quality                 | Material Function                                 | 0.0253        | 0.2565                | 15          | 2          |
|                         | Material Compliance with Specifications           | 0.0302        | 0.3063                | 11          | 3          |
|                         | Accuracy of Order Quantity                        | 0.0143        | 0.3132                | 18          | 2          |
| Delivery                | Accuracy of Delivery Time                         | 0.0183        | 0.4007                | 17          | 1          |
|                         | Availability of Material                          | 0.0131        | 0.2861                | 19          | 3          |
|                         | Past Performance                                  | 0.0284        | 0.2665                | 12          | 2          |
| History                 | Flexibility to change the number of orders       | 0.0188        | 0.1762                | 16          | 3          |
|                         | Fulfillment in the cooperation agreement          | 0.0594        | 0.5572                | 2           | 1          |
|                         | Response Speed                                    | 0.0570        | 0.3450                | 3           | 1          |
| Garansi                 | Ease of contact                                   | 0.0468        | 0.2832                | 6           | 2          |
|                         | Service time                                      | 0.0268        | 0.1620                | 14          | 4          |
|                         | Ease of Replacing Reject items                   | 0.0347        | 0.2098                | 10          | 3          |
|                         | Discounts and Bonuses                             | 0.0382        | 0.3017                | 9           | 3          |
| Price                   | Payment Method                                    | 0.0482        | 0.3811                | 5           | 1          |
|                         | Product Prices                                    | 0.0401        | 0.3173                | 8           | 2          |
| Communication system    | Communication Skills                              | 0.0118        | 0.1312                | 20          | 3          |
|                         | The Speed of Information Exchange                 | 0.0504        | 0.5622                | 4           | 1          |
|                         | Flexibility in Sharing                            | 0.0275        | 0.3066                | 13          | 2          |
| Management & Organization| Ability to Follow Procedures                    | 0.0815        | 1.0000                | 1           | 1          |

**Table 4. The weight of each supplier**

| Alternative                        | Weight | Rank |
|------------------------------------|--------|------|
| PT. Indo Asia Tirta Manunggal      | 0.4421 | 1    |
| PT. Astamulya Mandiri              | 0.1352 | 5    |
| PT. Satya Anugerah Nutritama       | 0.1434 | 2    |
| PT. Galic Bina Mada                | 0.1414 | 3    |
| PT. Selalu Lancar Maju Karya       | 0.1379 | 4    |

The results of the goal programming method, obtained values based on 3 conditions namely cost minimization, value maximization and a combination of cost minimization and value maximization. From the results of the Recommendation, it can be used as a basis for allocating other than January 2019. The January 2019 election was due to this month having accumulated demand at PT. Neopagan.
Selaras Indonesia. The results of the Recommendation of Allocation with the help of LINGO software are shown in Table 5.

| Goals       | Allocation Orders in January 2019 | Total Value | Cost Incurred |
|-------------|----------------------------------|-------------|---------------|
| Min TC      | P1: 500 P2: 5000 P3: 0 P4: 5000 P5: 5000 | 2293,55 IDR | IDR 141.700.000 |
| Max TV      | P1: 5000 P2: 0 P3: 5000 P4: 5000 P5: 500 | 3703,45 IDR | IDR 145.450.000 |
| Min TC & Max TV | P1: 5000 P2: 168 P3: 332 P4: 5000 P5: 5000 | 3677,322 IDR | IDR 142.699.600 |

While the actual order allocation in January 2019 is shown in Table 6. It is seen that the costs incurred by January 2019 are said to be incompatible with the budget calculations previously planned by PT. Neopangan Selaras Indonesia.

| Actual Allocation Order in January 2019 | Total Value | Cost Incurred |
|----------------------------------------|-------------|---------------|
| P1: 5000 P2: 4000 P3: 4500 P4: 0 P5: 2000 | 3672,4 IDR | IDR144.350.000 |

From the results of the proposed allocation it can be seen that in the TC minimization, the costs incurred are lower than the actual allocation results but with the existing value below the actual value. In TV maximization conditions it is shown that the proposed value is higher than the actual value, but the resulting costs are greater than the actual costs incurred by the company. In the Combined condition between Min TC and Max TV, it is known that the cost value obtained is lower than the actual value and the value obtained is greater than the actual. The most optimal proposal overall can be seen in the merging condition between Min TC and Max TV from Table 5. Table 7 shows a comparison of the achievement of the combined goal between actual and recommendation in January 2019.

| Goal Programming | Actual | Recommendation | Differences |
|------------------|--------|----------------|-------------|
| Total Cost       | 3672,4 | 3677,322       | -0,134%     |
| Total            | IDR144.350.000 | IDR142.699.600 | 1,143%     |

From the percentage comparison table between actual and recommendation, it can be seen that by using goal programming, the recommendation can save costs by 0.134% and also increase the value by 1.143%.

4. Conclusion
The results of the Fuzzy ANP calculation are weights generated for the assessment or evaluation of each supplier. PT. Neopangan Selaras Indonesia considers 7 criteria and 20 sub-criteria in selecting suppliers of maltodextrin raw materials. These criteria include quality, delivery, history and performance of the company, warranty & service complaints, price, communication systems, management & organization.

The resulting weights can determine priority sub-criteria based on PT. Neopangan Selaras Indonesia, represented by 3 respondents who took over in the interaction of raw material sealing
activities. The resulting priority sub-criteria is the ability to follow procedures, which is equal to 0.0815 from the global ranking, while the lowest sub-criteria is the ability to communicate. Weights obtained for each supplier is PT. Indo Asia Tirta Manunggal at 0.4421. Weight with sequence 2 is PT. Satya Anugerah Utama in the amount of 0.1434. The number 3 weight is PT. Galic Bina Mada of 0.1414. The 4th weight is PT. Always Current Advanced Work of 0.1379. The weight with the 5th order is PT. Astamulya Mandiri of 0.1352.

Mathematical modelling is done with 3 conditions and is also limited by the actual conditions of the company itself. The 3 conditions are cost minimization, value maximization and a combination of cost minimization and value maximization. Based on the results obtained, it is known that the optimal solution is when using the combined conditions of Min TC and Max TV, where the allocation is carried out as much as 5000 kg to the supplier of PT. Indo Asia Tirta Manunggal, 168 kg to the supplier of PT. Astamulya Mandiri, 322 kg to the supplier of PT. Satya Anugerah Utama, 500 kg to the supplier of PT. Galic Bina Mada, 5000 kg to the supplier of PT. Always Working Smoothly Forward. This optimal allocation results in a decrease of actual costs of IDR 142,669.600 or as much as 0.134% of the actual and an increase of 4.922 or in other words as much as 1.143% of the actual company.

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