MATHEMATICA APPLICANDA
Vol. 51(1) 2023, p. 13–31
doi: 10.14708/ma.v51i1.7105

Agustinus Silalahi (Tangerang)
Ronald Sukwadi* (Tangerang)
Vanessa (Tangerang)
Minh-Tai Le (Ho Chi Minh)
Nguyen Thi Bich Thu (Ho Chi Minh)

A hybrid model of optimal selection of restaurant food supplier

Abstract Supplier selection is one of the essential procurement processes in every business, including restaurants. Having suitable suppliers for restaurants is almost as important as having the best quality food. Many suppliers of food and beverages in Indonesia make it difficult for restaurant owners to choose the best. Therefore, determining the appropriate criteria for selecting suppliers and measuring suppliers' performance is crucial. This research aims to achieve maximum quality of raw material procurement in Sushi Man Restaurant, Kelapa Gading. The hybrid model is built using the Analytical Network Process (**ANP**) method, integrated with Mixed-Integer Programming (**MIP**), and solved with Super Decision and LINGO software. The objectives of this hybrid model are to maximize performance and minimize procurement costs. The result shows that the optimum solution for salmon suppliers is **PT** . Ind and **PT** . Rua, for chukka wakame's supplier are PT. Indos and CV. Mul, and for chukka idako's supplier are PT. Indos and CV. Mul. The other suppliers can still be used for the procurement in Sushi Man Restaurant, but their performance needs to be improved.

2010 Mathematics Subject Classification: Primary: 62J05; Secondary: 92D20.

Key words and phrases: supplier; restaurant; hybrid model; ANP; MIP..

Abbreviations

The following abbreviations are used in this manuscript:

ANP Analytical Network Process (p. 24)
CV. Commanditaire Vennootschap [eng. Limited partnership] (p. 25)
GP Goal Programming (p. 18)
MIP Mixed-Integer Programming (p. 24, 15)
TCP Total Cost of Purchase (p. 15)
TVP Total Value of Purchase (p. 15)

1. Introduction. The food and beverage industry, known as the F & B industry, is promising. Because, with more than 230 million of Indonesia's population, it will also give a large market. Based on the Indonesian Statistic

Bureau/BPS [6], the growth of food and beverages grew over the national economics' growth as significant as 5.06%. Currently, food and beverage are consumer products and have become the community's lifestyle [20, 22]. Customers expect their dining experience at restaurants to satisfy their appetites and enrich the quality of their lives. Food quality is a critical aspect of these dining experiences and customers' perceptions of courteous service [9, 21].

The selection of suppliers plays a crucial role in an organization because the cost of raw material constitutes the main cost of the final product [1, 10, 23]. Kokangul and Susuz [10] developed the model for supplier selection optimization in automotive manufacturers to maximize the purchase's total value and minimize the total simultaneously by developed Goal Programming (GP). There are three criteria for the purchase value, and each supplier can supply only one item of raw material. Thus the number index of variables and parameters for the mathematical formulation is only one. In this study, the case study is in a restaurant, there are four criteria for the value of the purchase, and all suppliers can supply three raw material items. The different number of raw material items caused changes in the number index of variables and parameters for mathematical formulation. In this case, there is no transportation cost. This study modified the mathematical formulation [10] in this case and applied it to a small business. The previous studies study supplier selection based on cost only by non-linear models such as Karimi and Naderi [8], with multi-suppliers and a single product. Nilesh et al. [24], with multi-suppliers and multi-products. Li et al. [11] and Mukherjee et al. [14] used AHP by developing fuzzy to select the supplier and then using supplier ranks to develop the multi-objective programming to minimize cost and order allocation with a single material and multiple suppliers.

Procurement is one of the essential things to be focused on in supply chain management and the first step to take the transaction [5]. Choosing the best supplier for the procurement activity requires some criteria to get more accessible for a company [15] because there are more than 200 food suppliers in Indonesia [7]. Sushi Man Restaurant is one Japanese Restaurant in Kelapa Gading, North Jakarta. The restaurant has a supplier's problem because it does not balance ordering the raw material with its suppliers.

The supplier selection process deploys an enormous amount of a firm's financial resources. It plays a crucial role in any organization's success. The selection process has a significant role in reducing cost, improving profits, and the quality of the products. Firms often misunderstand the supplier selection problem as a single-criterion decision-making problem, considering only cost factors when making decisions [2]. Quality, cost, flexibility, responsiveness, and delivery performance history are identified as the most criteria in supplier selection and vendor performance indicators [18]. This study focuses on cost, quality, delivery performance, and flexibility criteria for supplier selection.

There are various mathematical models for selecting suppliers, such as linear and non-linear programming. Tracey and Leng Tan [23] have developed supplier selection criteria, supplier involvement, and overall firm performance. In this case, the new mathematical model is built. The selection of suppliers is considered from predetermined three suppliers. Based on the interview, the restaurant owner needs to determine the best suppliers and the optimal quantity of the item to be purchased from each supplier under the constraints such as quantity discount, demand, capacity, and budget.

Before applying the mathematical model, the weight of the supplier needs to be determined as one of the objective functions to maximize the quality. The weight of the supplier will be solved by Analytic Network Process (**ANP**) method. **ANP** is one of the most advanced and complex multi-criteria decision-making methods [3, 13]. The dependencies and feedback between the decision-making elements are modeled. Then weights of criteria of both local and global priorities of alternatives are precisely calculated using the **ANP** [5, 13, 16].

ANP is a system for using the network to structure a decision problem. The first step is to select the criteria for supplier selection and calculate the weights of the criteria and the alternative suppliers [17]. Figure 1 shows the network structure of the criteria. To get the weights of the criteria and alternative suppliers, Saaty's scales are applied, which is 1 for equal importance and 9 for extreme importance [16, 17]. After constructing the pairwise matrix, the consistency of the ratio for each matrix should be calculated. The valuable consistency ratio is less than or equal to ten percent or 0.1. If it is greater than ten percent, the matrix is inconsistent and should be revised (v. [19], [12]).

The other objective function will be used to minimize cost. Those multi-objective cases will be solved by Mixed-Integer Programming (**MIP**). **MIP** is an integer programming type where one of the variables is an integer and not an integer [3, 4, 25]. The models select the optimal set of suppliers in weighting and determine the number of items to be purchased from each supplier so that the budget and processing capacities are not violated under quantity discount.

In this study, the raw materials are purchased from three predetermined suppliers each raw material. Each supplier offers a discount which only depends on the quantity of the item purchased by the restaurant per order. The problem is setting the best suppliers and optimal order quantities for maximum **TVP** (Total Value of Purchase), minimum **TCP** (Total Cost of Purchase), and both. The hybrid model of the **ANP** and **MIP** method provides a systematic approach to solve the supplier selection decision problem. Therefore, the hybrid model is applied to maximize the quality of suppliers and minimize the cost simultaneously.

2. General model. After evaluating the supplier, the one with the highest weight is considered the best choice. However, if there are any requirements

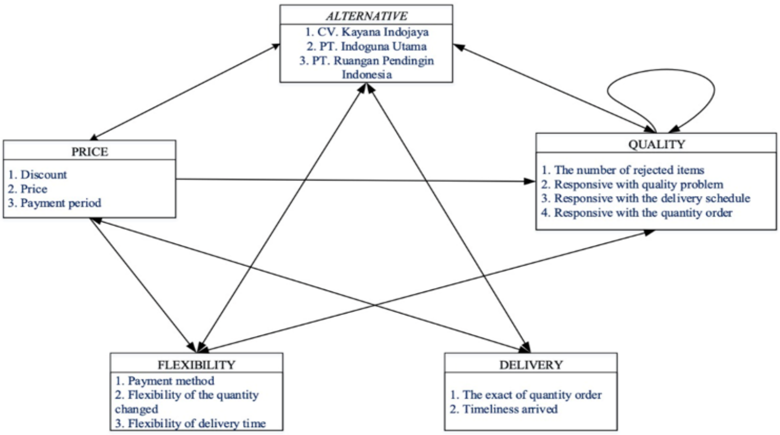

Figure 1: The Structure of **ANP**

or constraints, suppliers with lower weight need to be considered. In this case, there are constraints such as supplier's capacity, number of suppliers required, number of units demanded by the restaurant, and all the suppliers offering quantity discounts, which should be considered a special parameter in selecting suppliers and having the optimal orders. These are the objective function and constraint equations that reflect the procurement requirements for the restaurant. The mathematical model is as follows:

Objective functions

$$\max(\mathbf{TVP})_i = \sum_{j=1}^{N} W_{ij}X_{ij},\ \forall_i \tag{1a}$$

$$\min(\mathbf{TCP})_i = \sum_{j=1}^{N} P_{ij}X_{ij} + S_{ij}\sum_{j=1}^{N} Y_{ij},\ \forall_i \tag{1b}$$

Constraints:

$$\sum_{j=1}^{N} X_{ij} \geq D_i,\ \forall_i \tag{1c}$$

$$\sum_{j=1}^{N} X_{ij} \leq PC_{i_{\max}},\ \forall_i \tag{1d}$$

$$X_{ij} \geq V_{ij} \tag{1e}$$

$$Y_{ik} = \left\{ \begin{array}{l} 1, x_{ij} > 0 \\ 0, others \end{array} \right\}\ \forall_i, \forall_j \tag{1f}$$

$$n_{min} \leq \sum_{j=1}^{N} Y_{ij} \leq \ n_{\max}, \ \forall_i \tag{1g}$$

$$X_{ij} \leq \ C_{ij} \tag{1h}$$

$$P_{ik} = \left\{ \begin{array}{ll} P_{i1} & \text{for } 0 \leq X_{ij} \leq q_{i1} \\ P_{i2} & \text{for } q_{i1} \leq \ X_{ij} \leq \ q_{i2} \\ P_{i3} & \text{for } q_{i2} \leq \ X_{ij} \leq \ q_{i3} \end{array} \right\} \forall_i \tag{1i}$$

$$\sum_{j=1}^{N} C_i Y_{ij} \geq \ PC_{imax}, \ \forall_i \tag{1j}$$

$$X_{ij} \geq \ 0, \quad \forall_i \ \forall_j, \ X_{ij} \text{ integer} \tag{1k}$$

The following notations are applied:

N : the number of suppliers;
W_{ij} : ANP final weight of j-supplier for i-raw material;
X_{ij} : order quantity for i – raw material from j-supplier;
V_{ij} : minimum order for i – raw material from j-supplier;
C_{ij} : the capacity for i – raw material from j-supplier;
D_i : demand i – raw material for planning period;
P_{ij} : per unit net purchase for i – raw material from j-supplier;
S_{ij} : order/setup cost for i - raw material from j-supplier;
n_{min} : the minimum number of suppliers to be selected;
n_{max} : the maximum number of suppliers to be selected;
PC_{imax} : maximum processing capacity for i – raw material;

Equations (1a) and (1b))show the objective function to maximize the **TVP** and minimize **TCP** . Equation (1c) shows the lower demand forecast for the frame. Equation (1d) shows that the total order quantity assigned to the suppliers cannot order more than the processing capacity. The minimum order quantity to be ordered from each supplier is shown in Equation (1e). Equation (1f) shows the binary programming whether the suppliers are chosen or not. The limitation of the number of suppliers selected is shown in Equation (1g). The order quantity for each supplier that cannot exceed its capacity is shown in Equation (1h). The quantity discount constraint is shown in Equation (1i), where $0 \leq \ X_i \leq \ q_{i1}$ is the sequence of quantities for the i-supplier. Finally, the total capacity of the selected suppliers at least satisfy the maximum processing capacity of the firm (1j). These models can be solved by optimization software such as **LINGO**[1].

[1] LINDO is a product of *LINDO Systems, Inc.*. It is a comprehensive tool designed to

After we obtain $\max \mathbf{TVP}_{\ i}$, and $\min \mathbf{TCP}_{\ i}$, $\forall_i$, $i = 1, 2, 3$, then developed Goal Programming (**GP**) for each row material, the mathematics formulation :

$$\textbf{Minimize } S_i^+ + D_i^- \tag{2}$$

Subject to:

$$\sum_{j=1}^{N} W_{ij}X_{ij} + S_i^+ - S_i^- = \mathbf{TVP}_{\ i},\ \forall_i \tag{3}$$

$$\sum_{j=1}^{N} P_{ij}X_{ij} + S_{ij}\sum_{j=1}^{N} Y_{ij} + D_i^+ - D_i^- = \mathbf{TCP}_{\ i},\ \forall_i \tag{4}$$

$$(\mathbf{TVP}_{\ i})(S_i^+) - (TCP_i)(D_i^-) = 0\ \forall_i \tag{5}$$

$$S_i^+, S_i^-, D_i^+ \text{ and } D_i^-$$

are deviation variables.

3. Result and Discussion In this case, the actual data from the restaurant is applied (v. Table 4). The criteria for selecting suppliers are presented in Table 5. The best suppliers are chosen, and their optimum order quantities are determined according to the weight of the supplier. There are a few steps to follow to obtain the optimum solution.

a. Make the analytic network process on the Super Decision software in Figure 1.
b. Input all the pairwise comparison matrix values.
c. Get the result of the unweighted matrix, weighted matrix (Figure 1), limit matrix (Figure 2), and cluster matrix (Figure 3)
d. Find the weight of each supplier with the **ANP** method.

The further step used in this study is:

(a) find the maximum value of **TVP** ,
(b) find the minimum level of **TCP** , and (3) develop **GP**by using the value Maximum **TVP** and Minimum **TCP** simultaneously.

Based on Table 6, the **ANP** rating (wij) is used to maximize **TVP** as an objective function. The mathematical formulation to obtain **TVP** 1 and **TCP** 1 (in this study we take raw material salmon, $i = 1$).

$$\max\ \mathbf{TVP}_{\ i} = 0.506454x_{11} + 0.232418x_{12} + 0.241128x_{13} \tag{6}$$

make building and solving Linear, Nonlinear (convex & nonconvex/Global), Quadratic, Quadratically Constrained, Second Order Cone, Semi-Definite, Stochastic, and Integer optimization models faster, easier and more efficient.

Table 1: Unweighted Matrix vs. Weighted Matrix

Unweighted Matrix

	CV Kayana Indojaya	PT Indoguna Utama	PT Ruangan Pendingin Indonesia	Method∼	Var∼	Var∼	Discount	Price b∼	Period∼	Amount∼	Respon∼	Respon∼	Respon∼	Accuracy
CV Kayana Indojaya	0.00000	0.00000	0.00000	0.33333	0.16667	0.20000	0.20000	0.33268	0.33333	0.37500	0.16667	0.16667	0.20813	0.33333
PT Indoguna Utama	0.00000	0.00000	0.00000	0.33333	0.16667	0.60000	0.60000	0.32490	0.33333	0.37500	0.66667	0.66667	0.66076	0.33333
PT Ruangan Pendingin Indonesia	0.00000	0.00000	0.00000	0.33333	0.16667	0.20000	0.20000	0.34242	0.33333	0.25000	0.16667	0.16667	0.13111	0.33333
Method∼	0.16342	0.19580	0.13501	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Var∼	0.53961	0.49339	0.58416	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.66667	0.00000	0.00000	0.00000	0.00000
Var∼	0.29696	0.31081	0.28083	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000
Discount	0.08213	0.07193	0.08875	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Price b∼	0.36806	0.27896	0.35219	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000
Period∼	0.54981	0.64912	0.55907	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Amount∼	0.13019	0.14645	0.12679	0.00000	0.00000	0.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Respon∼	0.53470	0.43934	0.50718	0.00000	0.10853	0.33333	0.00000	0.00000	0.23849	0.67381	0.00000	0.00000	0.00000	0.00000
Respon∼	0.22634	0.31066	0.29282	0.00000	0.34454	0.33333	0.00000	0.00000	0.62501	0.10065	0.00000	0.00000	0.00000	0.00000
Respon∼	0.10878	0.10355	0.07321	0.00000	0.54693	0.33333	0.00000	0.00000	0.13650	0.22554	0.00000	0.00000	0.00000	0.00000
Accuracy	0.25000	0.66667	0.75000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Accuracy	0.75000	0.33333	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Weighted Matrix

	CV Kayana Indojaya	PT Indoguna Utama	PT Ruangan Pendingin Indonesia	Method∼	Var∼	Var∼	Discount	Price b∼	Period∼	Amount∼	Respon∼	Respon∼	Respon∼	Accuracy
CV Kayana Indojaya	0.00000	0.00000	0.00000	0.33333	0.08333	0.06667	0.06667	0.11089	0.11111	0.12500	0.16667	0.16667	0.20813	0.16667
PT Indoguna Utama	0.00000	0.00000	0.00000	0.33333	0.33333	0.20000	0.20000	0.10830	0.11111	0.12500	0.66667	0.66667	0.66076	0.16667
PT Ruangan Pendingin Indonesia	0.00000	0.00000	0.00000	0.33333	0.08333	0.06667	0.06667	0.11414	0.11111	0.08333	0.16667	0.16667	0.13111	0.16667
Method∼	0.01399	0.01676	0.01156	0.00000	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Var∼	0.04620	0.04224	0.05001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.22222	0.00000	0.00000	0.00000	0.00000
Var∼	0.02542	0.02661	0.02404	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.11111	0.00000	0.00000	0.00000	0.00000
Discount	0.02769	0.02425	0.02992	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Price b∼	0.12408	0.09404	0.11873	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	5.00000
Period∼	0.18536	0.21884	0.18848	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Amount∼	0.04389	0.04937	0.04275	0.00000	0.00000	0.00000	0.33333	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Respon∼	0.18026	0.14811	0.17099	0.00000	0.05426	0.11111	0.00000	0.00000	0.07950	0.22460	0.00000	0.00000	0.00000	0.00000
Respon∼	0.07630	0.10473	0.09872	0.00000	0.17227	0.11111	0.00000	0.00000	0.20834	0.03355	0.00000	0.00000	0.00000	0.00000
Respon∼	0.03667	0.03491	0.02468	0.00000	0.27347	0.11111	0.00000	0.00000	0.04550	0.07518	0.00000	0.00000	0.00000	0.00000
Accuracy	0.06003	0.16009	0.18010	0.00000	0.00000	0.06667	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Accuracy	0.18010	0.08005	0.06003	0.00000	0.00000	0.26667	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000

Table 2: Limit Matrix

	CV Kayana Indojaya	PT Indoguna Utama	PT Ruangan Pendingin Indonesia	Method∼	Var∼	Var∼	Discount	Price b∼	Period∼	Amount∼	Respon∼	Respon∼	Respon∼	Accuracy
CV Kayana Indojaya	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473	0.09473
PT Indoguna Utama	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008	0.19008
PT Ruangan Pendingin Indonesia	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050	0.09050
Method∼	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970	0.03970
Var∼	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912	0.02912
Var∼	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574	0.01574
Discount	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994	0.00994
Price b∼	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242	0.10242
Period∼	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621	0.07621
Amount∼	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486	0.05486
Respon∼	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241	0.08241
Respon∼	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055	0.06055
Respon∼	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965	0.02965
Accuracy	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678	0.05678
Accuracy	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731	0.06731

Table 3: Cluster Matrix

Clusters	ALTERNATIVE	FLEXIBILITY	PRICE	QUALITY	DELIVERY
ALTERNATIVE	0.000000	0.333333	0.250000	0.333333	0.500000
FLEXIBILITY	0.085608	0.000000	0.250000	0.333333	0.000000
PRICE	0.337128	0.000000	0.000000	0.000000	0.500000
QUALITY	0.337128	0.333333	0.250000	0.333333	0.000000
DELIVERY	0.240136	0.333333	0.250000	0.000000	0.000000

ST:

$$\sum_{j=1}^{3} x_{ij} \geq 70 \tag{7}$$

$$\sum_{j=1}^{3} x_{ij} \leq 90 \tag{8}$$

$$Y_{ik} = \left\{ \begin{array}{ll} 1, & x_{ij} > 0 \\ 0, & \text{others} \end{array} \right\} \forall_j \tag{9}$$

$$x_{11} \leq 49.8, \quad x_{12} \leq 46.2, \quad x_{13} \leq 44.5 \tag{10}$$

$$P_{11} = \begin{cases} 20300 & \text{for } 0 < X_{11} \leq 20 \\ 193600 & \text{for } 20 < X_{11} \leq 45 \\ 176000 & \text{for } 45 < X_{ij} \leq 100 \end{cases}$$

$$P_{12} = \begin{cases} 198000 & \text{for } 0 < X_{12} \leq 20 \\ 189200 & \text{for } 20 < X_{11} \leq 45 \\ 172000 & \text{for } 45 < X_{ij} \leq 100 \end{cases} \tag{11}$$

$$P_{13} = \begin{cases} 193000 & \text{for } 0 < X_{12} \leq 20 \\ 183700 & \text{for } 20 < X_{11} \leq 45 \\ 167000 & \text{for } 45 < X_{ij} \leq 100 \end{cases} \tag{12}$$

$$49.8y_{11} + 46.2y_{12} + 44.5y_{13} \geq 90 \tag{13}$$

$$x_{ij} \geq 0, \quad y_{ij} \in (0, 1) \tag{14}$$

The mathematical formulation to optimize **TCP** for 1$^{\text{st}}$ raw material (Salmon) is:

$$\min \mathbf{TCP}_i = \sum_{j=1}^{3} P_{ij} X_{ij} + 6352.5 \sum_{j=1}^{3} y_{ij} \tag{15}$$

Subject to: (4)–(10).

(16)

The number of raw materials that should be purchased if we want to achieve Maximum TVP is 49.8 kg from supplier 1 and 20.2 kg from supplier 2 with **TVP** $_{\max} = 30.32005$, otherwise for Minimum **TCP** is 46.2 kg from supplier 2 and 23.8 kg from supplier 3 with **TCP** $_{\min} = 12,331,160$ as shown in Table 7. There is no limitation for the minimum order for i – the raw material from j-supplier; that's why (1e) is ignored.

Maximum **TVP** $_i$ and Minimum **TCP** $_i$, and the number of raw materials to buy for all raw materials as shown in Table 7 (Salmon i=1, Chukka Wakame i=2 , Chukka Idako i=3). Using the maximizing **TVP** and minimizing **TCP** simultaneously, **GP** formulation is:

$$0.506454x_{11} + 0.252418x_{12} + 0.241128x_{13} \geq 30.32005$$
$$\sum_{j=1}^{3}\sum_{i=1}^{3} P_{ij}x_{ij} + 6352.5\sum_{j=1}^{3}\sum_{i=1}^{3} y_{ij} \leq 12,331,160$$

The right-hand sides are constraint variables with flexibility which are managerial goals to be approached as closely as possible. These constraints are equated to:

$$0.506454x_{11} + 0.252418x_{12} + 0.241128x_{13} + S_1^{+}{}^{\smile}S_1^{-} = 30.32005$$
$$\sum_{j=1}^{3}\sum_{i=1}^{3} P_{ij}x_{ij} + 6352.5\sum_{j=1}^{3}\sum_{i=1}^{3} y_{ij} + D_1^{+} - D_1^{-} = 12331160$$

Where $S_1^{+}, S_1^{-}, D_1^{+}, D_1^{-}$ represent the deviation variables.

1. Make the comparison of optimum **TVP** and **TCP** with the slack.

$$12331160 \times \; S_1^{+} = 30.32005 \times D_1^{-}$$

   The objective function is

$$\min S_1^{+} + D_1^{-}.$$

2. The result of the goal programming is to get the optimal value of **TVP** and **TC** in Table 7.

Figure 2 and Figure 3 provide the analytic network process and each of the weights of criteria and supplier. As seen in Table 7, the best suppliers and optimal order quantities and cost are obtained. If the management wants to maximize **TVP** , they should choose to maximize TVP and choose the supplier with the optimal order quantities. If the management wants to minimize **TCP** , they should choose the objective of minimizing **TCP** . Suppose the

Table 4: Case Study Data

Raw Material	Supplier	Capacity (kg)	Demand (kg)	Max. Cap. (kg)	Min. Supplier	Order Cost	Discount Cost	
							Unit	Price/Unit
Salmon (1)	I	49.8	95	125	2	6352.5	0-20	203,000
							21-45	193,600
							46-100	176,000
	II	46.2					0-20	198,000
							21-45	189,200
							46-100	172,000
	III	44.5					0-20	193,000
							21-45	183,700
							46-100	167,000
Chukka Wakame (2)	I	6	8	10	2	5082	0-2	207,900
							3-5	198,000
							6-10	180,000
	II	6					0-2	218,000
							3-5	214,500
							6-10	195,000
	III	4					0-2	222,600
							3-5	216,240
							6-10	212,000
Chukka Idako (3)	I	6	8	12	2	5028	0-2	308,000
							3-5	290,000
							6-10	278,000
	II	6					0-2	300,000
							3-5	285,000
							6-10	265,500
	III	4					0-2	306,000
							3-5	290,700
							6-10	276,100

objective of the management is to get both maximize **TVP** and minimize **TCP** . In that case, they should choose the supplier to maximize TVP and minimize **TCP** . It all can be used for all the raw materials.

When we compare with the history of the salmon procurement in this restaurant, maximizing the TVP of salmon will increase 5.11%, minimizing **TCP** will increase 7.39%, and maximizing **TVP** and minimizing **TCP** will increase 6.04% on the profit they will improve.

For maximizing the **TVP** of *Chukka Wakame*, it will decrease 0.6%; for minimizing **TCP** , it will not get any improves or drops. For maximizing TVP and minimizing **TCP** , it also will not get any improvements from the history. For maximizing the **TVP** of *Chukka Idako*, it will increase 3.94%; for minimizing **TCP** , it will increase 6.71%. For maximizing **TVP** and minimizing **TCP** , it will increase 3.94%.

After all the results, the management can choose the supplier and what

Table 5: Criteria for Selecting Suppliers

Criteria	Sub Criteria
Price	Price
	Payment period
	Discount
Delivery	Timeliness arrived
	The exact order quantity
Flexibility	Flexibility of delivery time
	Flexibility of the quantity
	Payment method
Quality	The number of rejected items
	Responsive with quality problems
	Responsive with the schedule
	Responsive with the quantity order

Table 6: The Weight of Suppliers

Raw Material	Suppier	ANP Rating
Salmon	PT. Ind	0.506454
	CV. Kay	0.252418
	PT. Rua	0.241128
Chuka Wakame	PT. Indos	0.500118
	CV. Mul	0.249753
	CV. Kay	0.250129
Chuka Idako	PT. Indos	0.497382
	CV. Mul	0.256921
	CV. Kay	0.245697

they want to do for the next procurement. Because almost all results will increase or improve the optimal value of TVP and decrease the optimal value of **TCP** .

4. Conclusion. This paper provides the appropriate selection and assigns order quantities to suppliers of discounted cost. The hybrid model in this paper applies the **ANP** , which uses pair-wise comparison to calculate the weight of suppliers. The best suppliers and optimal order quantities can be determined by applying these weights as an objective function of the **MIP** model. In considered example, it aims to achieve maximum quality of raw material procurement in *Sushi Man Restaurant*, *Kelapa Gading*. The hybrid model is built using the Analytical Network Process (**ANP**) method, integrated with Mixed-Integer Programming (**MIP**), and solved with *Super*

Table 7: Results of ANP Weight and Order Quantity

Raw Material (i)	Objective	Supplier/Order Quantity (j)			ANP Weight	Cost(Rp)
		Xi1	Xi2	Xi3		
Salmon (1)	max **TVP**	49.8	20.2		30.32005	12,599,340
	min **TCP**		46.2	23.8	17.40056	12,331,160
	max **TVP** and min **TCP**	49.8		20.2	30.09200	12,488,240
Chukka Wakame (2)	max **TVP**	6		2	3.500966	1,535,364
	min **TCP**	6	2		3.500586	1,526,164
	max **TVP** and min **TCP**	6	2		3.500586	1,526,164
Chukka Idako (3)	max **TVP**	6	2		3.498134	2,278,164
	min **TCP**	2	6		2.536290	2,219,164
	max **TVP** and min **TCP**	6	2		3.498134	2,278,164

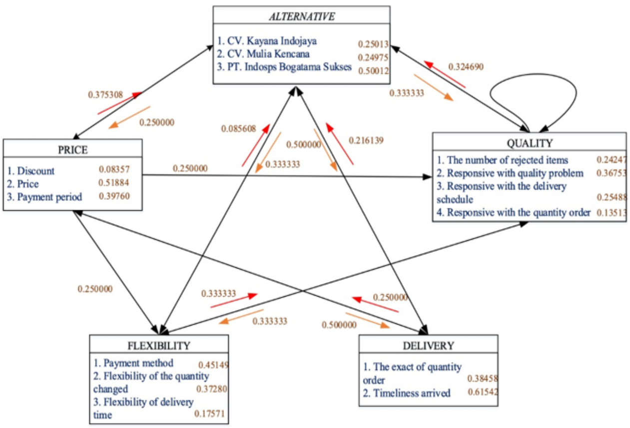

Figure 2: Analytic Network Process for *Chukka Wakame*.

Decision and *LINGO* software. The objectives of this hybrid model are to maximize performance and minimize procurement costs. The result shows that the optimum solution for salmon suppliers is **PT** . Ind.[2] and **PT** . Rua, for chukka wakame's supplier are **PT** . Indos and **CV**. Mul, and for *Chukka*

[2]Perseroan Terbatas (**PT**) refers to a form of business structure or legal entity type in Indonesia. **PT** is also known as a Limited Liability Company (LLC) in Indonesia and can be a publicly-listed entity or a privately-owned entity.

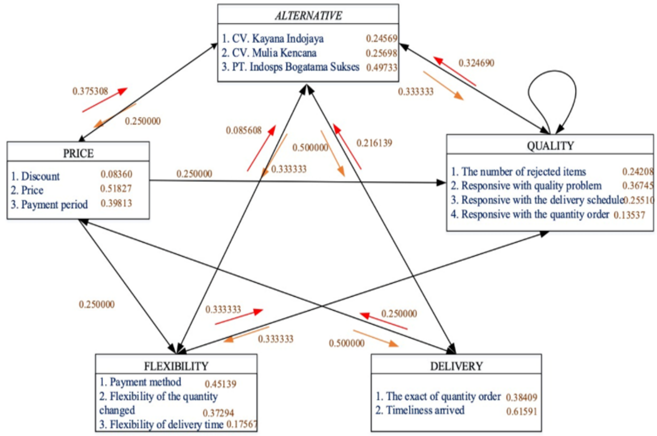

Figure 3: Analytic Network Process for Chukka Idako

Idako's supplier are **PT** . Indos and **CV**. Mul[3,4]. The other suppliers can still be used for the procurement in Sushi Man Restaurant, but their performance needs to be improved.

Author Contributions: All authors equally contributed to the conceptualization, methodology, formal analysis, investigation and writing–original draft preparation. Agustinus Silalahi and Ronald Sukwadi are responsible for the description of the importance measure concepts, examples, visualization and Vanessa is responsible for the project conceptualization and its administration.

Funding: The authors declare no conflict of interest.

Conflicts of Interest: The authors declare no conflict of interest.

[3] ***CV****. Multi Solution Marketing* is a company or organization that focuses on providing a variety of marketing solutions to its clients. This can include services such as market research, advertising, public relations, branding, and event management. The goal of the company is to help its clients achieve their business goals by providing a comprehensive approach to marketing.

[4] In this context, "***CV***." is an abbreviation for "CVentura" or "CVenture" which is commonly used in Indonesia and some other countries. It is a legal abbreviation for a type of business entity, similar to "*Inc.*" or "*Ltd.*" in the United States and other countries. It stands for "*Commanditaire Vennootschap*" which is a Dutch term for a type of partnership in which one or more partners (known as "silent partners" or "comanditaire vennoten") provide capital to the company, but do not take an active role in its management.

References

[1] H. Adeinat and J. Ventura. Integrated pricing and supplier selection in the two-stage supply chain. *International Journal of Production Economics*, 201(July):192–202, 2018. doi: 10.1016/j.ijpe.2018.03.021. Cited on p. 14.

[2] A. Brard and H. Taherdoost. Analyzing the process of supplier selection criteria and method. *Procedia Manufacturing*, 32:1024–1034, 2019. doi: 10.1016/j.promfg.2019.02.317. Cited on p. 14.

[3] J. Chinneck. *Practical Optimization: a Gentle Introduction. System and Computer Engineering*. Carleton University, Ottawa, 2016. Cited on p. 15.

[4] F. Hillier and G. Liebermen. *Introduction to Operation Research*. McGraw Hill, , New York, 2015. Cited on p. 15.

[5] L. Hosseini, R. Tavakkoli-Moghaddam, B. Vahdani, S. Mousavi, and R. Kia. Using the analytical network process to select the best strategy for reducing risks in a supply chain. *Journal of Engineering*, 1:2–5, 2013. doi: 10.1155/2013/375628. Cited on pp. 14 and 15.

[6] Indonesian Statistic Bureau/BPS. Pertumbuhan Industri Makanan dan Minuman Terhadap PDB Nasional (TW I 2014 - TW II 2017). BPS, 2018. Cited on p. 14.

[7] Indotrading. Supplier Makanan dan Minuman di Jakarta (October, 2019). Indotrading, October 2019. Cited on p. 14.

[8] M. Karimi and A. Naderi. A mixed integer non-linear model for supplier selection, under conditions of incremental quantity discount and inventory shortage. *International Industrial Engineering Conference*, pages 20–21, January 2013. . Cited on p. 14.

[9] W. Kim, C. Y. N. Ng, and Y. S. Kim. Influence of institutional dineserv on customer satisfaction, return intention, and word-of-mouth. *International Journal of Hospitality Management*, 28(1):10–17, 2009. doi: 10.1016/j.ijhm.2008.03.005. Cited on p. 14.

[10] A. Kokangul and Z. Susuz. Integrated analytical hierarchy process and mathematical programming to supplier selection problem with quantity discount. *Applied Mathematical Modelling*, 33:4–11, 2008. doi: 10.1016/j.apm.2008.01.021. Cited on p. 14.

[11] Z. Li, W. K. Wong, and C. K. Kwong. An integrated model of material supplier selection and order allocation using fuzzy extended ahp and

multiobjective programming selection and order allocation using fuzzy extended ahp and multiobjective programming. *Mathematical Problems in Engineering*, 2013. doi: 10.1155/2013/363718. Cited on p. 14.

[12] LINDO. LINDO. Technical report, LINDO Systems, Inc., October 2019. URL `https://www.lindo.com`. . Cited on p. 15.

[13] M. Modak, K. Ghosh, and K. Pathak. A bsc-anp approach to organizational outsourcing decision support- a case study. *Journal of Business Research*, 103:432–447, 2019. doi: 10.1016/j.jbusres.2018.01.040. Cited on p. 15.

[14] K. Mukherjee, B. Sarkar, and A. Bhattacharyya. Supplier selection by f-compromise method: a case study of cement industry of ne india. *International Journal of Computational Systems Engineering*, 1(3):162–174, 2013. doi: 10.1504/IJCSYSE.2013.052586. Cited on p. 14.

[15] I. Pujawan. *Supply Chain Management*. Guna Widya, Surabaya, 2005. Cited on p. 14.

[16] R. Saaty and T. Saaty. *Decision Making in Complex Environments*. Super Decisions, Pittsburgh, 2016. Cited on p. 15.

[17] T. Saaty. *Theory and Applications of The Analytic Network Process*. RWS Publications, Pittsburgh, 2005. Cited on p. 15.

[18] T. Saaty and G. Luis. *Decision Making with The Analytic Network Process, Economic, Political, Social, and Technological Applications with Benefits, Opportunities, Cost, and Risk*. Springer Science, Pittsburgh, 2006. Cited on p. 14.

[19] L. Schrage. *Optimization Modeling with LINGO*. Duxbury Resource Center, Duxbury MA, 5th revised edition, 1997. ISBN 978-0534348571. Cited on p. 15.

[20] R. Sukwadi. Penerapan model IS-DEMATEL dalam analisis kualitas restoran Solaria di Jakarta Timur. *Spektrum Industri*, 17(1):69–78, 2019. doi: 10.12928/si.v17i1.10192. Cited on p. 14.

[21] R. Sukwadi and D. Agustin. Analisis kualitas layanan restoran dengan menggunakan model Kano-PRCA dan AIM. *Spektrum Industri*, 14(1): 89–98, 2016. doi: 10.12928/si.v14i1.3707. Cited on p. 14.

[22] R. Sukwadi and I. D. Susanto. Integrasi model Dineserv-CSI-IPA-Dematel dalam perbaikan kualitas layanan Bar XYZ. *Jurnal Teknik & Ilmu Komputer*, 7(26):313–321, 2018. Cited on p. 14.

[23] M. Tracey and C. Leng Tan. Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance. *Supply Chain Management*, 6(4):174–188, 2001. doi: 10.1108/EUM0000000005709. Cited on pp. 14 and 15.

[24] S. Ware, N.R.and Singh and D. Banwet. A mixed-integer non-linear program to model dynamic supplier selection problem. *Expert Systems with Applications*, 41:671–678, 2014. doi: 10.1016/j.eswa.2013.07.092. Cited on p. 14.

[25] H. Williams. *Model Building in Mathematical Programming*. John Wiley & Sons Ltd., Chichester, 2013. Cited on p. 15.

Hybrydowy model optymalnego doboru dostawcy żywności do restauracji.

Agustinus Silalahi, Ronald Sukwadi, Vanessa,
Minh-Tai Le i Nguyen Thi Bich Thu

Streszczenie Wybór dostawców jest jednym z podstawowych problemów decyzyjnych dla projektu wykorzystującego różne półprodukty i surowce. Widać to wyraźnie w przypadku restauracji. Posiadanie odpowiednich dostawców dla restauracji wiąże się z terminowym dostarczaniem surowców o odpowiedniej jakości. Wielu dostawców żywności i napojów w Indonezji utrudnia właścicielom restauracji wybór najlepszego. Dlatego ważne jest ustalenie odpowiednich kryteriów wyboru dostawców i ocena ich skuteczności. Przedstawione badania mają na celu osiągnięcie maksymalnej jakości pozyskiwanych surowców dla przykładowych restauracji. W artykule podano przykład restauracji: Sushi Man i Kelapa Gading. Do analitycznego modelowania problemu wykorzystano model hybrydowy. Model hybrydowy zbudowany jest metodą analitycznego procesu sieciowego (ANP), zintegrowanego z mieszanym programowaniem całkowitoliczbowym (MIP). Rozwiązanie problemu dla tak skonstruowanego modelu można przeprowadzić za pomocą dostępnego oprogramowania do rozwiązywania zadań badań operacyjnych. W przykładzie zawartym w pracy wykorzystano oprogramowanie: **Super Decision** oraz **LINGO**. Autorzy postawili sobie za cel maksymalizację efektywności dostawców i minimalizację kosztów zaopatrzenia. Zaprezentowane wyniki pokazują, jak praktycznie wykorzystać takie podejście do problemu.

Klasyfikacja tematyczna AMS (2010): 62J05; 92D20.

Słowa kluczowe: Badania operacyjne; Dostawcy; Zarządzanie dostawiami do restauracji; Model hybrydowy.

Agustinus Silalahi is an Assistant Professor of Industrial Engineering at the Atma Jaya Catholic University of Indonesia. He got his Master's degree of Actuarial Science froma Bandung Institute of Technology and Bachelor in Mathematics from University of North Sumatera, Indonesia. His research interests include operational research and optimization.

Ronald Sukwadi is an Associate Professor of Industrial Engineering at the Atma Jaya Catholic University of Indonesia and received his Ph.D. in Industrial & Systems Engineering from Chung Yuan Christian University, Taiwan. He earned his Master's degree of Management and Bachelor in Industrial Engineering from Diponegoro University, Indonesia. He is currently the Dean of the Faculty of Engineering, Atma Jaya Catholic University of Indonesia. Dr. Sukwadi has published widely in national conferences, international conferences, Indonesian accredited journals, and reputable international journals. His research interests include quality management, service innovation, and operations management optimization.

Vanessa is an alumnus of Industrial Engineering at the Atma Jaya Catholic University of Indonesia. Now she works at Shopee Indonesia in the Business Development Division

Minh-Tai Le is a Senior Lecturer of Industrial Systems Engineering at the Ho Chi Minh City University of Technology and Education. He is currently the Head of the Department of Industrial Systems Engineering at the Ho Chi Minh City University of Technology and Education. His research interests include optimization methods and industrial engineering

Nguyen Thi Bich Thu is a Lecturer of Industrial Systems Engineering at the Ho Chi Minh City University of Technology and Education Her research interest includes quality management.

Agustinus Silalahi
Atma Jaya Catholic University of Indonesia
Department of Industrial Engineering
Faculty of Engineering
Jalan Raya Sampora Cisauk
Tangerang 15345, Indonesia
E-mail: agustinus.silalahi@atmajaya.ac.id

Ronald Sukwadi*
Atma Jaya Catholic University of Indonesia
Department of Industrial Engineering
Faculty of Engineering
Jalan Raya Sampora Cisauk
Tangerang 15345, Indonesia
E-mail: ronald.sukwadi@atmajaya.ac.id

Vanessa

Atma Jaya Catholic University of Indonesia
Department of Industrial Engineering
Faculty of Engineering
Jalan Raya Sampora Cisauk
Tangerang 15345, Indonesia
E-mail: veronica3397@gmail.com

Minh-Tai Le
HCMC University of Technology and Education
Department of Industrial Systems Engineering
E-mail: tailm@hcmute.edu.vn

Nguyen Thi Bich Thu
HCMC University of Technology and Education
Department of Industrial Systems Engineering
E-mail: thuntb@hcmute.edu.vn

Communicated by: Krzysztof J. Szajowski

(Received: 31st of October 2021; revised: 25th of February 2023)