Third-Party Logistics Provider Selection by Using Fuzzy AHP and Interval TOPSIS

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**Abstract.** The strategic importance of 3PL (Third-Party Logistics) aims to reduce costs and improve company performance through efficient supply chain management. Companies should select a 3PL provider that suits their needs and consider important aspects such as the ability of 3PL to mitigate supply risk. 3PL provider selection is a complex and vital process. Thus, the identification of evaluation criteria and solution approaches is required. This study aims to select an appropriate 3PL provider, considering evaluation criteria holistically, including resilience in selecting 3PLs that can increase the company's resilience. Integrated multi-criteria decision-making, including fuzzy AHP and interval TOPSIS, is applied to tackle the problem of incorporating decision-making under an uncertain environment. A case study of a food processed company is presented to illustrate the solution approach that helps the company in choosing the best 3PL provider.

**Keywords :** 3PL provider selection, multi-criteria decision-making, Resilience, Fuzzy AHP, Interval TOPSIS.

# INTRODUCTION

In the current era of globalization, companies reduce costs without compromising service quality and efficiency through third-party logistics services, commonly known as 3PL (Third-Party Logistics). An efficient and effective supply chain needs to be designed to deliver products to customers quickly, precisely, and in good condition [1]. Gaining a competitive advantage can be focused on 3PL as an important strategy for companies in the current globalization. Therefore, 3PL provider selection is crucial for successful outsourcing [2].

3PL or third-party logistics providers provide outsourced logistics services by involving the management of one or several aspects. Outsourcing logistics services provides more benefits for companies, especially at a lower cost and efficiency and expertise that the company does not have [3]. 3PL offers various services for companies, including warehousing, logistics information systems, warehousing management, and even inventory management [2] [4]. Companies can gain cost savings ranging from 12% to 15% through outsourcing logistics services [5].

Disruptions may occur at 3PL providers in various forms and have a negative impact. It is necessary to handle logistic activities properly since it involves high complexity caused by delivery delays, loss or damage of goods, cost issues, quality degradation, and technology failures [6]. Therefore, selecting the 3PL provider should take into account resilience aspects in order to increase the resilience of logistics activities [7]. 3PL provider selection is a complex decision that requires a comprehensive decision-making process as well as the identification of evaluation criteria.

Several previous studies focused more on evaluating the performance of 3PLs, while this study focuses on choosing 3PLs by considering resilience criteria. 3PLs are evaluated by decision-makers based on general criteria that have been widely discussed in previous research, such as cost, delivery, and quality. Rosiana, Garside [8], Jovčić and Průša [9], and Wang, Nguyen [4] consider many criteria for decision-making related to disruptions, including operational performance, service quality, on-time delivery, service costs, flexibility, and information technology. However, these studies do not consider resilience criteria in evaluating 3PL performance.

3PL provider selection is a multi-criteria decision-making process that employs MCDM techniques to deal with complex situations with multiple choices and criteria. These techniques include AHP, WSM, TOPSIS, and VIKOR. Nguyen and Chinh [10] applied AHP to evaluate 3PL providers in the oil and gas industry. Švadlenka, Bošković [11] employed the Best-Worst Method (BWM) and the Combined Compromised Solution (CoCoSo) method to evaluate 3PL providers for sustainable last-mile delivery, emphasizing the importance of flexibility and environmental considerations in logistics. Ly, Roh [12] demonstrated the application of integrated DEMATHEL and AHP to select 3PL providers. Bianchini [13] tackled 3PL provider selection using integrated AHP and TOPSIS in a food company. However, these solution approaches do not accurately handle the uncertainty of decision makers' judgment, particularly in determining criteria weight and evaluating 3PL providers. Therefore, to fill the literature gap, this study’s contributions lay in focusing on selecting resilient 3PL providers with the incorporation of uncertain decision-maker judgments. First, the proposed fuzzy AHP method is used to determine criteria weight. Second, the interval TOPSIS method is used to assess the performance of 3PL. Both proposed methods can help decision makers to express their vague opinions when weighting criteria and selecting 3PL, especially with consideration of resilience criteria.

# METHODS

This study employs integrated multi-criteria decision-making techniques, fuzzy AHP, and interval TOPSIS.  The fuzzy AHP method is used to calculate the weight of criteria and sub-criteria. The interval TOPSIS method is used to assess the performance of 3PL providers and derive the rank. Furthermore, a more detailed description of the fuzzy AHP method and the interval TOPSIS method are as follows.

## FUZZY AHP (ANALITIC HIERARCHY PROCESSH)

Fuzzy AHP accommodates uncertainty by transforming scales of pairwise comparison matrices into Triangular Fuzzy Numbers (TFN). The detailed steps of fuzzy AHP proposed by [14] are as follows.

**Step 1**. Determine the pairwise comparison matrix between criteria and sub-criteria using the TFN scale shown in **TABLE 1**.

**TABLE 1** Linguistic variables and the respective triangular fuzzy number (TFN) based on Fuzzy AHP

|  |  |  |  |
| --- | --- | --- | --- |
| **Scale** | **Linguistic Variables** | **Triangular Fuzzy Number** | **Reciprocal Triangular Fuzzy Number** |
| 1 | Equally Important | (1, 1, 1) | (1 , 1 , 1) |
| 2 | Importance between two adjacent scales of equal importance | (1, 2, 3) | (1/3 , 1/2 , 1) |
| 3 | Moderately Important | (2, 3, 4) | (1/4 , 1/3 , 1/2) |
| 4 | Importance Score Between Two Scales Nearly Important | (3, 4, 5) | (1/5 , 1/4 , 1/3) |
| 5 | More Important | (4, 5, 6) | (1/6 , 1/5 , 1/4) |
| 6 | Importance Score Between Two Scales Adjacent More Important | (5, 6, 7) | (1/7 , 1/6 , 1/5) |
| 7 | Very Important | (6, 7, 8) | (1/8 , 1/7 , 1/6) |
| 8 | Importance Score Between Two Scales Adjacent Very Important | (7, 8, 9) | (1/9 , 1/8 , 1/7) |
| 9 | Most Important | (9, 9, 9) | (1/9 , 1/9 , 1/9) |

**Step 2**. Determining the fuzzy synthesis value (Si) using equation (1)

(1)

**Step 3**. Determining the degree of possibility according to equation (2) and weight vector using equations (3) and (4)

(2)

d’ (Ai) = min V (Si ≥ Sk) (3)

W’ = (d’(A1), d’(A2), d’(A3), … , d’(An))T (4)

**Step 3**. Normalize the weight vector value (W) according to equation (5).

W = (d(A1), d(A2), d(A3), … , d(An))T (5)

## INTERVAL TOPSIS (TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION)

The interval TOPSIS method is used to incorporate uncertain decision-making based on interval value. Furthermore, The procedure of the interval TOPSIS method is given in detail in the following [16].

**Step 1**. Determine the decision matrix of criteria and sub-criteria using scales expressed in **TABLE 2**.

**TABLE 2** Linguistic variables and scales for alternatives evaluation

|  |  |
| --- | --- |
| **Linguistic Variables** | **Interval Scale** |
| Very Poor | 0, 1 |
| Poor | 1, 3 |
| Medium Poor | 3, 4 |
| Fair | 4, 5 |
| Medium Good | 5, 6 |
| Good | 6, 9 |
| Very Good | 9, 10 |

**Step 2**. Calculate the normalization of the decision matrix using equations (6) and (7).

, where i ϵ M , j ϵ N (6)

, where i ϵ M , j ϵ N (7)

**Step 3**. Calculate the weighted normalized decision matrix according to equation (8)

(8)

**Step 4**. Calculate the positive ideal solution using equations (9) and (10) and the negative ideal solution using equations (11) and (12).

(9)

(10)

(11)

(12)

**Step 5**. Calculate the distance of each alternative Ak from PIS (dk+(l), dk+(u)) according to equations (13) and (14) and NIS (dk-(l), dk-(u)) in equations (15) and (16).

(13)

(14)

(15)

(16)

**Step 6**. Calculate the closeness coefficients (CCk(l) , CCk(u)) according to equations (17) and (18).

(17)

(18)

**Step 7**. Rank the best alternatives by calculating the mid-point m(CCk) in equation (19) and half-width according to equation (20) of the interval closeness coefficients w(CCk).

(19)

(20)

# RESULT AND DISCUSSION

## CASE STUDY

This study presents a case study dealing with the selection of 3PL providers that supply raw materials for a food-processed company. There are three alternatives of 3PL to be evaluated based on multi-criteria. Five criteria and eleven sub-criteria are identified, taking resilience into account (shown in **TABLE 3**).

**TABLE 3** Criteria and sub-criteria for 3PL provider selection

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Code** | **Sub-criteria** | **Code** |
| Service Quality | SQ | Ability to respond to claims / problems | SQ1 |
| Frequency of claims | SQ2 |
| Technology | T | Information Technology | T1 |
| Information Sharing | T2 |
| Service Level | SL | Flexibility | SL1 |
| Reliability | SL2 |
| Timeliness | SL3 |
| Price | P | Cost of delivery service | P1 |
| Cost negotiation | P2 |
| Resilience | R | Repair/Restoration | R1 |
| Contingency Planning | R2 |

## WEIGHTS OF CRITERIA AND SUB-CRITERIA

The pairwise comparison matrices are constructed based on a decision-maker judgment using TFN (shown in **TABLES 4, 5, 6, 7, 8, and 9)** to determine the weight of criteria and sub-criteria. Based on these matrices, the weights are obtained using fuzzy AHP. The global weight of sub-criteria is calculated and transformed into a crisp value, summarized in Table 10. The results show that the price (P) and service quality has the highest weight, referred to as a priority. The existence of criteria weight allows companies to prioritize consideration when choosing a 3PL provider. The price or cost incurred less with maximum service can benefit the company. The sub-criteria comprising the highest weight or high importance level are the delivery service (P1) and negotiation (P2) costs. Moreover, ability to respond to claims /problems is considered important for the company’s competitiveness (SQ1).

**TABLE 4** Pairwise Comparison Matrix between criteria

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Criteria** | **SQ** | **T** | **SL** | **P** | **R** |
| **SQ** | (1, 1, 1) | (2, 3, 4) | (1, 1, 1) | (1/3 , 1/2 , 1) | (1, 2, 3) |
| **T** | (1/4 , 1/3 , 1/2) | (1, 1, 1) | (1/3 , 1/2 , 1) | (1/4 , 1/3 , 1/2) | (1, 2, 3) |
| **SL** | (1, 1, 1) | (1, 2, 3) | (1, 1, 1) | (1/4 , 1/3 , 1/2) | (1, 1, 1) |
| **P** | (1, 2, 3) | (2, 3, 4) | (2, 3, 4) | (1, 1, 1) | (2, 3, 4) |
| **R** | (1/3 , 1/2 , 1) | (1/3 , 1/2 , 1) | (1, 1, 1) | (1/4 , 1/3 , 1/2) | (1, 1, 1) |

**TABLE 5** Pairwise Comparison Matrix between Sub-Criteria: Service Quality

|  |  |  |
| --- | --- | --- |
| **Sub-Criteria** | **SQ1** | **SQ2** |
| **SQ1** | (1, 1, 1) | (1, 2, 3) |
| **SQ2** | (1/3 , 1/2 , 1) | (1, 1, 1) |

**TABLE 6** Pairwise Comparison Matrix between Sub-Criteria: Technology

|  |  |  |
| --- | --- | --- |
| **Sub-Criteria** | **T1** | **T2** |
| **T1** | (1, 1, 1) | (1, 1, 1) |
| **T2** | (1, 1, 1) | (1, 1, 1) |

**TABLE 7** Pairwise Comparison Matrix between Sub-Criteria: Service Level

|  |  |  |  |
| --- | --- | --- | --- |
| **Sub-Criteria** | **SL1** | **SL2** | **SL3** |
| **SL1** | (1, 1, 1) | (1, 1, 1) | (1/3 , 1/2 , 1) |
| **SL2** | (1, 1, 1) | (1, 1, 1) | (1, 1, 1) |
| **SL3** | (1, 2, 3) | (1, 1, 1) | (1, 1, 1) |

**TABLE 8** Pairwise Comparison Matrix between Sub-Criteria: Price

|  |  |  |
| --- | --- | --- |
| **Sub-Criteria** | **P1** | **P2** |
| **P1** | (1, 1, 1) | (1, 1, 1) |
| **P2** | (1, 1, 1) | (1, 1, 1) |

**TABLE 9** Pairwise Comparison Matrix between Sub-Criteria: Resilience

|  |  |  |
| --- | --- | --- |
| **Sub-Criteria** | **R1** | **R2** |
| **R1** | (1, 1, 1) | (1/3 , 1/2 , 1) |
| **R2** | (1, 2, 3) | (1, 1, 1) |

**TABLE 10** Criteria and Sub-Criteria Weights

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Criteria** | **Weights** | **Sub-Criteria** | **Weights** | **Global Weights** |
| SQ | 0.289 | SQ1 | 0.692 | 0.200 |
| SQ2 | 0.308 | 0.089 |
| T | 0.103 | T1 | 0.5 | 0.052 |
| T2 | 0.5 | 0.052 |
| SL | 0.141 | SL1 | 0.197 | 0.028 |
| SL2 | 0.251 | 0.035 |
| SL3 | 0.553 | 0.078 |
| P | 0.455 | P1 | 0.5 | 0.228 |
| P2 | 0.5 | 0.228 |
| R | 0.011 | R1 | 0.308 | 0.003 |
| R2 | 0.692 | 0.008 |

## 3PL PROVIDER SELECTION

The 3PL providers’ evaluation is performed by a decision maker based on 11 sub-criteria. The decision maker’s judgment for each alternative is summarized in **TABLE 11**.

**TABLE 11** The decision maker’s judgment for 3PL providers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Criteria** | **Sub-Criteria** | **Evaluation** | | |
| **3PL A** | **3PL B** | **3PL C** |
| Service Quality | Ability to respond to claims / problems | F | G | MP |
| Frequency of claims | MG | MG | F |
| Technology | Information Technology | G | G | G |
| Information Sharing | F | F | F |
| Service Level | Flexibility | F | G | P |
| Reliability | F | F | F |
| Timeliness | F | G | F |
| Price | Cost of delivery service | MG | G | MG |
| Cost negotiation | MG | G | MP |
| Resilience | Repair/Restoration | F | MG | F |
| Contingency Planning | F | F | F |

The scores of 3PL providers are then calculated based on the evaluation shown in **TABLE 11** using interval TOPSIS. To determine the rank of alternatives, finding the mid-point value of the closeness coefficients interval value m(CCk) is necessary. **TABLE 12** indicates the value of m(CCk) and the respective rank of alternatives. The result shows that 3PL B is the best alternative. While 3PL A and 3PL C are found to be the second and third rank.

**TABLE 12** Alternatives scores and rank

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Alternatives** | **Interval** | **m(CCk)** | **w(CCk)** | **Rank** |
| **3PL A** | [0.223, 0.724] | 0.473 | 0.251 | 2 |
| **3PL B** | [0.513, 0.675] | 0.594 | 0.081 | 1 |
| **3PL C** | [0.135, 0.585] | 0.361 | 0.226 | 3 |

## IMPLICATIONS OF 3PL PROVIDER SELECTION

This study draws profound implications. The decision maker is more concerned with the responsiveness of the 3PL provider to claims and issues that arise during the supply process since it can enhance overall supply chain resilience. The appropriate criteria, including responsiveness, can strengthen the ability to mitigate uncertainties and enhance predictability in 3PL provider performance, which in turn contributes to a more resilient supply chain [17]. In addition, this responsiveness can foster long-term supplier relationships in collaborative strategy mitigation for operational stability that can withstand supply risks such as market fluctuations [18].

# CONCLUSIONS

The selection of 3PL in this study aims to select an appropriate 3PL provider in accordance with the conditions and needs of the company so that the disruption that occurs can be mitigated. This study employ fuzzy AHP for weighting criteria and interval TOPSIS for evaluating alternatives incorporating decision makers judgment under uncertainty. According to the eleven sub-criteria, evaluation is performed for each alternative. Sub-criteria including delivery service, negotiation costs, and responsiveness are considered the most critical dimensions, particularly in a food processed company. The best alternative is selected since it represents superior performances particularly in dealing with responsiveness, repair/restoration flexibility, timeliness, delivery service and negotiation costs. On the hands, the proposed methods are effective to address complex multi-criteria decision-making.

Regardless of the contribution in considering resilience and uncertain decision maker’s judgment, this study remains a limitation. This limitation lies in qualitative resilient aspects, which are evaluated by a single decision maker. Therefore, future work needs to be conducted by taking into account resilience performance metrics that can be measured quantitatively, such as recovery time and the speed of response. A solution approach can be enhanced by considering multiple objective functions for the respective metrics to optimize the evaluation and provide objective decision-making.

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