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## **A NEW MULTICRITERIA DECISION SUPPORT TOOL BASED ON FUZZY SWARA AND TOPSIS**

DOI: 10.22367/mcdm.2021.16.01

Received: 30.06.2021 | Revised: 6.11.2021 | Accepted: 29.11.2021.

### **Abstract**

The problem of selecting 3PL (Third Party Logistics) suppliers is a major issue in the management of the supply chain and the improvement of the production management of a manufacturing company. A 3PL supplier can be defined as a company that provides contract logistics services to a manufacturer, supplier or main user of a product or service. It is called a third party because the logistics provider does not own the products but participates in the supply chain between the manufacturer and the user of a given product. In actual cases, several decision-makers intervene in the selection of 3PL suppliers and each one has his own points of view and wishes to take into account criteria which are not generally the same for all the decision-makers. Furthermore, the criteria have different weights. In this study, we propose a method to solve this problem. It consists of a combination of the fuzzy Stepwise Weight Assessment Ratio Analysis (SWARA) method with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The objective is to optimize the decision-making process and have another, more dynamic model and satisfy the needs of the decision-maker. Fuzzy SWARA is one of the new methods being used for ranking evaluation criteria based on decision makers' expected degree of importance to determine the weights of evaluation criteria (Selçuk, 2019).

This method can be used to facilitate estimation of decision makers' preferences regarding the meaning of attributes in the weight determination process. TOPSIS is a multi-criteria method for identifying solutions from a finite set of alternatives (Behzadian et al., 2012). To the

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best of our knowledge, this combination has not been developed in the literature, especially in the third-party logistic problems. The proposed model will be implemented to solve a 3PL problem of a company selling steel products.

**Keywords:** multicriteria decision support, 3PL suppliers, Fuzzy SWARA, TOPSIS.

## 1 Introduction

In a strong competitive environment, companies are constantly looking to improve their competitiveness. This is based as much on the quality of the products or services as on the costs and deadlines of their delivery. It is essential to be able to quickly respond to changes in the market. This remarkable dynamic of the economic context seems to require an ever-greater capacity for adaptation and responsiveness from the actors of an organization. Indeed, the accelerated scalability of markets has a direct impact on the necessary responsiveness of companies. The company's adaptation and responsiveness depend on its ability to interact effectively with all stakeholders. It is therefore a matter of breaking down cultural, organizational, functional and technological barriers within companies (Zougari and Benyoucef, 2011).

Today, decision-making processes interest manufacturers due to their importance for achieving the desired level of competitiveness and the overall goals of implementing process innovations (Garcia et al., 2020). Organizational studies and process analysis constantly show companies' needs for solutions to organize their activities around a workspace and improve their competitiveness in a strong competitive context (Batarlienė and Jarašūnienė, 2017). In this context, outsourcing part of the work of one or more services of a company leads to calling on an external intermediary who carries out the given 3PL activity. Many definitions have been proposed for 3PL. It is defined as a professional logistics company that makes a profit while taking over all or part of the logistics of a company's supply chain (Lambert and Cooper, 2000). The delegated function remains under the control of the company that owns the service, but the function is fulfilled by the partner who undertakes to carry out the work and to respect the principles of the master company. The chosen partner must be competent and trustworthy because he owns part of the commercial activity. This delegation can have significant repercussions on the functioning and image of the company. By outsourcing its logistics to a 3PL provider, a company can focus on its core business and competence, save transportation costs, and gain flexibility in many aspects, such as supply chain flexibility, operations flexibility in logistics management, and flexibility with warehouse space and labour (Yanhui, Hao and Ying, 2018).

Selection and assessment of 3PL suppliers remains the most critical activity in the supply chain due to its important role and ease of chain operation (Hosang, 2017). Decisions are complicated by the fact that different criteria should be taken into account in the decision-making process. This attracts many researchers; many approaches have been proposed in the literature.

In recent years, many researchers have focused on multiple-criteria decision-making (MCDM) models for making complex decisions under several criteria. In fact, this concept is often used in cases where a specific problem involves several different attributes, including simultaneously, quantitative and qualitative ones, such as cost, degree of importance, capacity, and lifetime (Seyedkolaei and Seno, 2021).

Therefore, our objective is to present a theoretical study and a case study dealing with the selection and evaluation of a group of suppliers, based on several criteria such as Cost, Delivery, Availability, Service, etc.

The remainder of this paper is organized as follows: Section 2 presents a literature review of main research papers dealing with this problem and describes a comparative study of the main existing methods. Section 3 presents the proposed method for solving the 3PL supplier choice problem with a solution of a practical case. Section 4 contains conclusions.

## **2 Literature review**

The problem of choosing 3PL suppliers is one of the strategic decisions that have a significant impact on the company's performance. With the evolutions of the manufacturing systems, this decision becomes more and more critical. Different decision support approaches have been proposed in the literature for the problem of choosing 3PL providers. We classify these approaches according to their techniques: Artificial Intelligence, Methods based on total cost, Mathematical programming models, Linear weighting models and Outranking methods.

Table 1 summarizes these main approaches with the advantages and disadvantages presented in some related papers. It presents a classification into four categories of the approaches used for decision making in the problem of selecting supplier groups. For each category, the different techniques used to solve the selection problem have been presented under a finite number of important criteria. The main advantages and disadvantages of each approach have been listed to recognize their strengths and weaknesses.

Table 1: Advantages and disadvantages of different methods

Methods	Avantages	Disadvantages	Authors
<b>Linear weighting methods</b>	<ul style="list-style-type: none"> <li>– Quick and easy to use</li> <li>– Take into account subjective criteria</li> <li>– Inexpensive implementation</li> </ul>	<ul style="list-style-type: none"> <li>– Depend on human judgments</li> <li>– No possibility to introduce constraints in the model</li> </ul>	Jain, Wadhwa and Deshmukh (2007); Kahraman, Ufuk and Ziya (2003); Bozdag, Kahraman and Ruan (2003); Mafakheri, Breton and Ghoniem (2011); Nilay and Demirel (2012); Devendra and Ravi (2014); Şengül et al. (2015)
<b>Mathematical programming</b>	<ul style="list-style-type: none"> <li>– The criteria do not have a formal common dimension</li> <li>– Offers several solutions</li> <li>– Possibility to introduce constraints in the model</li> </ul>	<ul style="list-style-type: none"> <li>– Takes into account the difficulty related to subjective criteria</li> <li>– Does not offer an optimal solution</li> <li>– Difficult to analyse the results</li> </ul>	Ghodsypour and O'Brien (2001); Kumar (2014); Karsak and Dursun (2014)
<b>Cost-based methods</b>	<ul style="list-style-type: none"> <li>– Help identify the structure of all costs</li> <li>– Allow to negotiate cost values with suppliers</li> <li>– Very flexible</li> </ul>	<ul style="list-style-type: none"> <li>– Access to data on costs sometimes limited</li> <li>– Expression of certain costs in difficult monetary terms</li> </ul>	Jellouli and Benabdallah (2021); Hyunjun et al. (2021)
<b>Artificial intelligence</b>	<ul style="list-style-type: none"> <li>– Offers a flexible knowledge base</li> <li>– Takes into account qualitative factors</li> </ul>	<ul style="list-style-type: none"> <li>– Collecting knowledge on suppliers and accessing expertise is long and difficult</li> </ul>	Lin (2009); Zhang et al. (2020)
<b>Outranking methods</b>	<ul style="list-style-type: none"> <li>– The model can be based on both qualitative and quantitative information</li> <li>– The criteria are not fully compensatory</li> </ul>	<ul style="list-style-type: none"> <li>– A large number of technical parameters is required</li> </ul>	Chen and Zeshui (2015); Molla, Giri and Biswas (2021)

Ghodsypour and o'Brien (2001) presented an approach based on mixed non-linear programming (mono- and multi-objective cases) to solve the problem of supplier choice. Their approach takes into account the limitations of the budgets of the different customers, logistics costs, prices, etc. A numerical example is presented to show the effectiveness of the approach. Kahraman, Ufuk and Ziya (2003) presented an approach based on the fuzzy AHP method for the problem of selecting the location of entities in a supply chain. Similarly, Bozdag, Kahraman and Ruan (2003) implemented fuzzy AHP to choose the best manufacturing system. Decision makers usually find it more convenient to

express interval judgments than fixed value judgments, due to the fuzzy nature of the comparison process (Bozdag, Kahraman and Ruan, 2003). Kumar (2014) proposed an approach based on the GP (Goal Programming) method in a fuzzy environment. The authors seek to optimize three main criteria: minimize the overall cost, minimize the rejections of requests made and minimize the number of late deliveries. The set is subject to various constraints related to customer requests, supplier capabilities, budgets allocated to suppliers, etc.

Yan, Chaudhry and Chaudhry (2003) present an analysis of an effective approach to 3PL service provider evaluation, focusing on operational efficiency. An intelligent vendor report management system consisting of customer report management, vendor estimation and product coding systems to select vendors during the new product development process is proposed by Choy, Lee and Lo (2003). The authors note that the complexity of the problem is based on the number of criteria and sub-criteria used in an international dimension of the problem. Jain, Wadhwa and Deshmukh (2007) present a state of the art dedicated to the methods used to solve the problem of supplier choice. They list all the methods used and list the advantages and disadvantages of each. The authors propose a method based on “Association Rules Mining Algorithms” with fuzziness, to have more flexibility in the evaluation of suppliers and decision-making. They justify the choice of fuzzy logic by the nature of the decision-making information’s used, which has a qualitative and quantitative form. The authors use a database with certain information specific to each provider in relation to the selection criteria. On a numerical example, the authors show the effectiveness of the developed method and insist that rules can be exploited via a database to provide decision makers with a more flexible evaluation of potential suppliers. Tanonkou, Benyoucef and Xie (2007) deal with a stochastic distribution network design problem where 3PL provider selection, distribution center location and demand area assignment decisions are processed simultaneously. The goal is to solve a complex optimization problem that brings together three levels of decisions: (i) choice of locations of distribution centers, (ii) selection of suppliers to ensure supplies (in one type of product) and finally (iii) assignment of demand areas to distribution.

Jain and Benyoucef (2008) deal with a problem of selecting 3PL suppliers in textile industry. The problem is to choose a number of suppliers, the modes of transport to be used and the storage policy to be adopted by the single distribution center of the chain. They present a simulation-based optimization approach using multicriteria genetic algorithms to solve this problem. Lin (2009) proposed a method for selecting suppliers by considering the effects of interdependence among the selection criteria (price, quality, delivery and

technique), as well as achieving optimal order allocation among the chosen suppliers. The proposed method incorporates, accordingly, two steps: (i) combination of Analytic Network Process (ANP) with fuzzy Preference Programming (PP) in a more powerful fuzzy ANP (FANP) to select suppliers, (ii) application of multipurpose linear programming (MOLP) to determine the order assignment among the chosen suppliers. Mafakheri, Breton and Ghoniem (2011) proposed a two-stage dynamic multi-criteria programming approach for the problem of supplier choice and order allocation. In the first phase, the AHP method is used to address the multicriteria decision for the ranking of suppliers. In the second step, the order allocation model is proposed. It aims to maximize a service function for the company as well as to minimize all the supply chain costs. Nilay and Demirel (2012) used another method of group choice: the VIKOR method to solve multiple criteria decision-making problems with contradictory and non-commensurable criteria. This method is used for the choice of insurance companies by investors in Turkey. It is applied to determine the best feasible solution according to the chosen criteria.

Devendra and Ravi (2014) proposed an integer linear programming model to simultaneously determine the timing of supply, lot size, suppliers, and carriers. They proposed a model based on the GP to solve a problem of multiple choice; indeed, the intention of the model is to determine the timings (moments), the size of batch to be procured and the supplier and the carrier to be selected in each replenishment period.

Karsak and Dursun (2014) proposed a group decision-making method based on DEA and QFD. This methodology identifies the characteristics that the purchased products should possess to meet the needs of the business and then it attempts to establish the relevant vendor's evaluation criteria.

Kumar (2014) proposed a new model consisting of two complementary methods: AHP and FGP (Fuzzy GP) to provide support for identification and classification suppliers, based on the preferences of a group of decision makers. He proposed a hybridization of two methods to solve the problem. The first is based on fuzzy AHP with the method of geometric means to prioritize and aggregate the preferences of a group decision makers. In the second, the obtained priorities are integrated with GP (Goal Programming) for the discriminant analysis to provide solution.

Şengül et al. (2015) proposed a model based on the TOPSIS Soft method for the analysis a renewable energy supply systems in Turkey. Chen and Zeshui (2015) presented a new approach, called the HF-ELECTRE II approach, which combines the idea of HFS (Hesitant Fuzzy Sets) with the ELECTRE II method to effectively aggregate different opinions of group members.

Figure 1 presents the taxonomy of the selection of supplier problem and its related approaches. The supplier selection problem is summarized in the following diagram which describes the main sub-problems and the different methods used to solve them.

#### **Abbreviations used**

**TOPSIS:** Technique for Order of Preference by Similarity to Ideal Solution; **FST:** Fuzzy Set Theory; **AHP:** Analytic Hierarchy Process; **QFD:** Quality Function Deployment; **GP:** Goal Programming; **DEA:** Data Envelopment Analysis; **ABC:** Activity-Based Costing; **TCO:** Total Cost of Ownership; **ANN:** Artificial Neural Network; **CBR:** Case-Based Reasoning; **RBR:** Rule-Based Reasoning.

#### **Description of the taxonomy of the decision problem presented in Figure 1.**

Selection of suppliers, divided into two sub-problems: Number of Suppliers and Choice of Suppliers.

We start with the first sub-problem: Number of Suppliers, which has several criteria, such as Characteristics of the company and Strategic plan, and a basic objective, which is the choice of suppliers. The second sub-problem, choice of Suppliers, can be solved under several criteria, such as Cost, Delivery, Service and Quality, using several types of methods, such as Outranking methods (PROMETHEE, ELECTRE), Linear weighting models (TOPSIS, FST, AHP), Mathematical programming models (QFD, DEA, GP), Artificial Intelligence (ANN, CBR, RBR) and Methods based on total cost (ABC, TCO).

In the previous section, we described some existing approaches that describe the decision problem. In this section, we provide a comparison between the different methods used for solving decision problems.

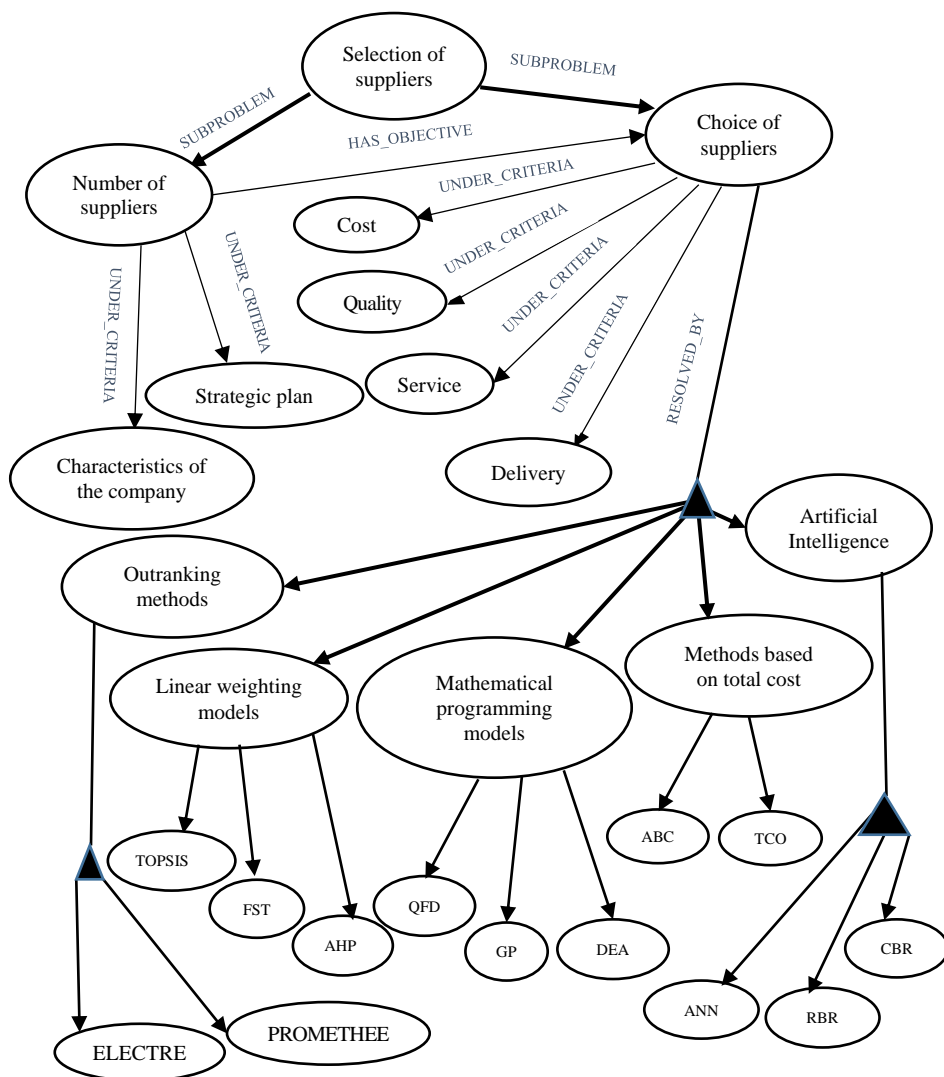


Figure 1: Selection of suppliers

### 3 The proposed model

We propose a new model called Fuzzy SWARA–TOPSIS. Figure 2 describes the problem. The decision-making process is described as follows: the selection of  $m$  suppliers ( $A_1, A_2, \dots, A_m$ ) taking into account the opinions of the decision-maker under several criteria ( $C_1, C_2, \dots, C_n$ ).



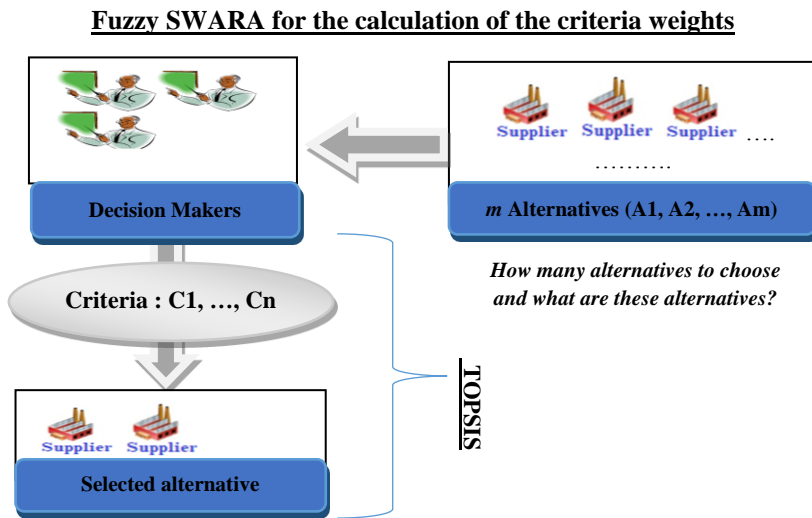


Figure 2: Description of the problem

We notice the complexity and difficulty of the analysis of the results obtained for the majority of the proposed methods. Our goal is to propose a more efficient decision support tool capable of solving the problem in a shorter time. For this reason, we propose the following model which consists of a hybrid method based on Fuzzy SWARA and TOPSIS to solve the decision problem.

### 3.1 Fuzzy SWARA

The SWARA method is one of the new methods used to evaluate criteria weights. Its main feature is its ability to estimate the preferences of decision makers regarding the meaning of attributes in the weight determination process (Kersuliene, Zavadskas and Turskis, 2010).

The main reason for using Fuzzy SWARA is that it considers the expected importance of the assessment criteria identified by the experts. In addition, it is used to determine the weights of the criteria in a decision-making process in a fuzzy environment.

The steps of this method are as follows:

**Step 1:** Sort the evaluation criteria from maximum preference to minimum, considering the goal of decision making.

**Step 2:** The process is started from the second factor where the experts allocate a score between zero and one to the factor  $j$  in relation to the previous criterion ( $j - 1$ ). This process is then applied to each factor. This ratio represents the

comparative importance of  $\hat{S}_j$  (Kersuliene, Zavadskas and Turskis, 2010). The values are shown in Table 3.

**Step 3:** Calculation of the values of the coefficient  $\hat{e}_j$ :

$$\hat{e}_j = \begin{cases} 1, & j = 1 \\ \hat{S}_j + 1, & j > 1 \end{cases} \quad (1)$$

**Step 4:** Recalculation of fuzzy weights  $\hat{g}_j$ :

$$\hat{g}_j = \begin{cases} 1, & j = 1 \\ \frac{\hat{g}_{j-1}}{\hat{e}_j}, & j > 1 \end{cases} \quad (2)$$

**Step 5:** Calculation of weight of fuzzy criteria  $\hat{w}_j$ :

$$\hat{w}_j = \frac{\hat{g}_j}{\sum_{k=1}^n \hat{g}_k} \quad (3)$$

where  $w_j = (l, m, u)$  is the fuzzy relative importance weight of the  $j$ th criterion and  $n$  is the number of criteria.

These fuzzy weights are converted into crisp weights ( $w_j$ ) by the following equation:

$$w_j = \frac{w_j^l + w_j^m + w_j^u}{3} \quad (4)$$

Moreover, let  $A_1 = (l_1, m_1, u_1)$  and  $B_1 = (l_2, m_2, u_2)$ .

The basic arithmetic operations on triangular fuzzy numbers (TFNs) can be defined as follows:

$$\begin{aligned} A_1 + B_1 &= (l_1 + l_2, m_1 + m_2, u_1 + u_2) \\ A_1 - B_1 &= (l_1 - l_2, m_1 - m_2, u_1 - u_2) \\ A_1 * B_1 &= (l_1 * l_2, m_1 * m_2, u_1 * u_2) \\ A_1 / B_1 &= (l_1 / u_2, m_1 / m_2, u_1 / l_2) \end{aligned}$$

### 3.2 The TOPSIS method

TOPSIS is a method developed to classify solutions from a finite set of alternatives (Behzadian et al., 2012). The basic principle is that the best alternative should have the shortest distance from the positive ideal solution and the furthest distance from the negative ideal solution.

TOPSIS makes it possible to use the idea of a compromise solution to classify the alternatives. In addition, it helps the decision maker to establish the ranking order of the alternatives by deriving compromise indices based on the distances of the alternatives between the positive ideal solution and the negative ideal solution.

The TOPSIS method procedure can be expressed as a series of steps for  $m$  alternatives and  $n$  criteria.

**Step 1:** Construct the decision matrix and determine the criteria weights. The normalized decision matrix  $B = (b_{ij})_{m \times n}$  is computed as follows:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^m a_{ij}}, \text{ for } i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (5)$$

**Step 2:** Calculate the normalized decision matrix. The weighted normalized decision matrix  $C = (C_{ij})_{m \times n}$  is computed as follows:

$$C_{ij} = w_j * b_{ij} \text{ for } i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (6)$$

where the weight vector of criteria is  $W = (w_1, w_2, \dots, w_n)$ , with  $\sum_{j=1}^n w_j = 1$ .

**Step 3:** Determine the positive ideal solutions and negative ideal solutions:

$$P^+ = c_1^+, c_2^+, \dots, c_n^+ = \{(Max_{j \in I} c_{ij}). (Min_{j \in J} c_{ij})\} \quad (7)$$

$$P^- = c_1^-, c_2^-, \dots, c_n^- = \{(Min_{j \in I} c_{ij}). (Max_{j \in J} c_{ij})\} \quad (8)$$

where  $C^+$  is a benefit criterion,  $C^-$  is a cost criterion, I is the set of benefit criteria, and J is the set of cost criteria.

**Step 4:** Compute separation measures based on the  $n$ -dimensional Euclidean distance. The separation measure of the alternative  $A_i$  from  $P^+$  is computed as follows:

$$d_j^+ = \sum_{j=1}^n |c_{ij} - c_j^+|, \text{ for } i = 1, 2, \dots, m \quad (9)$$

Similarly, the separation measure from  $P^-$  is computed as follows:

$$d_j^- = \sum_{j=1}^n |c_{ij} - c_j^-|, \text{ for } i = 1, 2, \dots, m \quad (10)$$

**Step 5:** Compute relative closeness coefficient to the ideal solutions. For an alternative  $A_i$ , the relative closeness coefficient is defined as follows:

$$R_i = \frac{d_i^-}{d_i^- + d_i^+} \quad (11)$$

**Step 6:** Rank the alternatives. The smaller the value of relative closeness coefficient, the better the rank of the alternative.

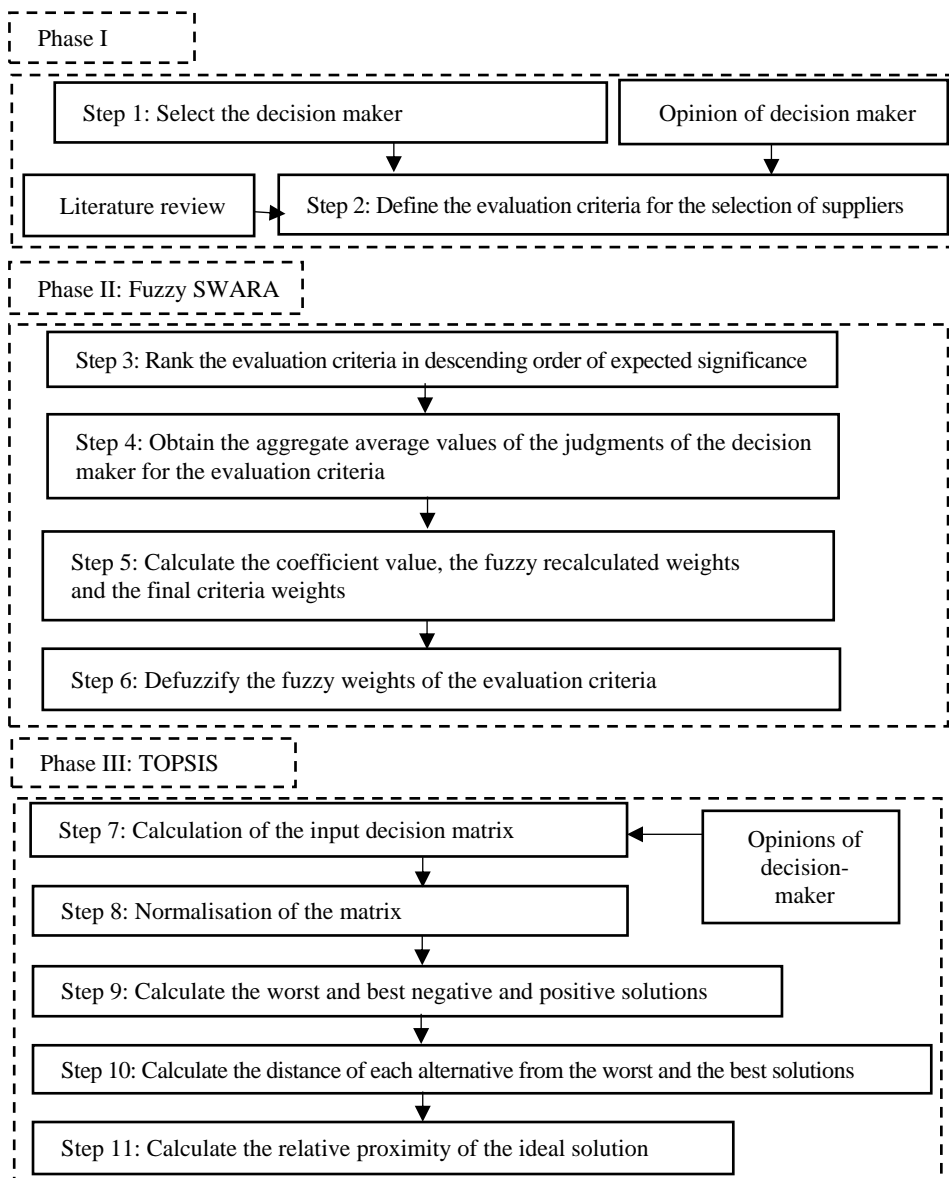


Figure 3: Algorithm of the proposed model

Figure 3 shows the details of the proposed model. First, in phase I, we identify the decision maker and obtain his opinion to define the criteria to be used in the selection of 3PL suppliers based on the literature. Then, in phase II, we apply the steps of Fuzzy SWARA to determine the criteria weights and finally, in phase III, we apply TOPSIS to select 3PL suppliers.

### 3.3 A case study: distribution of steel products

The new Fuzzy SWARA–TOPSIS model can be applied to a wide range of problems. The case study concerns the distribution of steel products located in Sousse, Tunisia. The company has been one of the main suppliers of steel products. It operates with a staff of approximately 100 people, employed in various divisions. The problem faced by this company is the choice of suppliers from among several.

The potential candidates are: SFAX METAL, SOQUIBAT, SOTIC, PROSID and EPPM.

Our objective is to rank and select suppliers by priority according to well-defined criteria.

The experts listed the criteria according to their expected level of importance.

Table 2: Criteria

Criteria	Designation	Maximize or minimize the value of the criterion (Max/Min)
Availability	AV	Max (AV)
Delivery	DE	Max (DE)
Quality	QU	Max (QU)
Service	SCE	Max (SCE)
Cost	C	Min (C)

From the second criterion, the  $(j - 1)$ th criterion is compared to the  $j$ th criterion using the values from Table 3. In this comparison, decision-maker use linguistic values expressing  $\hat{S}_j$  which is the first step of Fuzzy SWARA. The decision maker prioritizes criteria according to their importance.

Table 3: Linguistic Values by Chang (1996)

Linguistic scale	Triangular Fuzzy Number (TFN)
<b>Much Less Important</b>	(0.222, 0.25, 0.286)
<b>Less Less Important</b>	(0.286, 0.333, 0.40)
<b>Less Important</b>	(0.4, 0.5, 0.667)
<b>Moderately Important</b>	(0.667, 1, 1.5)
<b>Equally Important</b>	(1, 1, 1)

The results of Fuzzy SWARA are shown in the table below.

Table 4: Fuzzy SWARA Results

Criteria	$\hat{S}_j$			$\hat{e}_j$			$\hat{g}_j$			$\hat{w}_j$			w
AV				1	1	1	1	1	1	0.38	0.833	0.882	0.422
C	0.667	1	1.5	1.667	2	2.5	0.4	0.5	0.6	0.152	0.417	0.529	0.221
DE	0.4	0.5	0.667	1.4	1.5	1.667	0.24	0.333	0.428	0.091	0.278	0.378	0.150
SCE	0.286	0.333	0.4	1.286	1.333	1.4	0.171	0.250	0.333	0.065	0.208	0.294	0.114
QU	0.222	0.25	0.286	1.222	1.25	1.286	0.133	0.2	0.273	0.051	0.167	0.241	0.092

The decision maker listed the criteria according to their importance level obtained. Then it assigned the  $\hat{S}_j$  value to compare criteria (Step 2). Using equation 3, fuzzy weights ( $\hat{w}_j$ ) are converted into crisp weights. The results of fuzzy SWARA are in Table 4. Next step of the proposed model is to use TOPSIS to make the final selection of suppliers by using the crisp weights.

In this paper, we consider TOPSIS to solve the decision problem. We gave a score from the interval [0, 10] for each supplier  $i$  compared to criterion  $j$ . The basic data for the decision are listed in Tables 5 and 6.

Table 5: Criteria weights

	AV	C	DE	SCE	QU
W	0.422	0.221	0.150	0.114	0.092

Table 6: Decision Matrix

	AV	QU	SCE	DE	C
SFAX METAL	8	6	6	6	8
SOQUIBAT	9	5	5	7	7
PROSID	7	6	6	7	8
SOTIC	9	5	6	6	8
EPPM	7	6	7	8	7

Table 7: Weighted Normalized decision matrix

	AV	QU	SCE	DE	C
SFAX METAL	0.186	0.106	0.066	0.044	0.043
SOQUIBAT	0.211	0.088	0.056	0.052	0.038
PROSID	0.165	0.106	0.066	0.052	0.043
SOTIC	0.211	0.088	0.066	0.044	0.043
EPPM	0.165	0.106	0.078	0.059	0.038

Table 8: Positive and Negative ideal solutions

<b>P<sup>+</sup></b>	0.211	0.106	0.078	0.059	0.038
<b>P<sup>-</sup></b>	0.165	0.088	0.056	0.044	0.043

The consecutive steps in the supplier selection problem are explained below.

**Step 1:** Normalize the alternatives (results in Table 7).

**Step 2 + 3:** Calculate the weighted normalized decision matrix. The positive and negative ideal solutions are given in Table 8.

Table 9: Separation measures

<b>d<sup>+</sup></b>	0.032	0.029	0.048	0.027	0.046
<b>d<sup>-</sup></b>	0.029	0.047	0.022	0.047	0.033

Table 10: Relative Closeness coefficients to the ideal solutions

<b>SFAX METAL</b>	<b>SOQUIBAT</b>	<b>PROSID</b>	<b>SOTIC</b>	<b>EPPM</b>
0.475	0.618	0.314	0.635	0.418

**Step 4:** Calculate the separation measures. The separations of each alternative from the positive and negative ideal solutions are given in Table 9.

**Step 5:** Calculate the relative closeness degrees. The results are given in Table 10.

## Discussion

The methodology proposed for the classification of suppliers depends on the number of suppliers, decision makers and evaluation criteria. Our application consists in arranging and selecting suppliers of steel products in Tunisia on the basis of criteria (C, AV, ...). Criteria weights were obtained by fuzzy SWARA. According to the results of this method, the most important criterion was AV, followed by C, DE, SCE, and QU. After this process, the selection of suppliers of STEEL Products were obtained by TOPSIS. The best supplier turned out to be "PROSID", followed by EPPM, SFAX METAL, SOQUIBAT and SOTIC. To the best of our knowledge, a combination of Fuzzy SWARA and TOPSIS has not been developed and we didn't find papers related to such a combination in the literature. This research fills this gap. In this study, the proposed model will be used for the first time.

## 4 Conclusions

In this paper, we presented a literature review on 3PL supplier selection problem and the different methods used to solve it. We proposed a new approach based on Fuzzy SWARA and TOPSIS methods. Within this approach, the ratings of suppliers with respect to each criterion are expressed with linguistic variables. Fuzzy SWARA is used for the calculation of criteria weights and TOPSIS for the classification of suppliers. The advantages of the proposed model are as follows: (1) it considers the relationship among various criteria and fuzzy situation for ranking suppliers; (2) it minimizes the end customer's level of dissatisfaction using demand and capacity limiting. Future studies may like to include such practices in the selection criteria to further enhance the accuracy of supplier selection and may consider fuzzy data in the evaluation process, for example. Fuzzy TOPSIS and our method can be developed as a group decision making problems.

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