Evaluate, analyze and selection of suppliers based on supply chain approach, Fuzzy TOPSIS (The study of Iran-Tabriz Tractor Manufacturing Company)

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Abstract

In today's world, competition between companies in any industry has been so stressful and organizations that controls any moment become shorter life products and the emergence of similar products are capable of more performance. Therefore all large organizations to maintain their sustainable competitive market must accommodate and synchronize themselves with their customer's needs. On the other hand, aligning and matching customer demands require organizations to constantly note how the process must focus on the products. Since the very high volume of activities related to these products, the company is done by external suppliers, attention and care on how they function is very important effects. Today, with considering the crucial and important factors of the customer's perspective such as quality, price, service, flexibility and etc. we can get the customer satisfaction and to help this process are not things that could be a part of the supply chain and to improve product supply. Because improving each of these parameters is subject to the total collection to improve supply-chain products. This study presented a fuzzy decision making method for supplier selection problems in the supply chain. In this research, in order to evaluate and select the suppliers for all scales and its weight specification, language phrases used by experts and judges in IRAN_TABRIZ Tractor Manufacturing Company and engineering & supplying tractor Parts Company, have been used. Phrasal ratings have been expressed by triangle fuzzy numbers. Finally, using Fuzzy TOPSIS written in C++ language, the ranking of the suppliers for tractor manufacturing company in supply chain and the consequences of the mentioned above were discussed and investigated.

Key Words: supply chain, supply chain management, supplier evaluation and selection, Fuzzy logic, FUZZY TOPSIS.

1. Introduction

Various industries pay millions of dollars annually to improve their products and services. Products and services move in coming through the supply chain. Chains constantly change and face unexpected conditions. More investment in "product development" and "operations" are spending a lot of impact and affect the supply chain. The costs are including research and development of product, updating systems, investment in construction and equipment and even increasing human resources [25]. The aim of all activists who are in the field of supply chain has seen increasing competition ability. There are two broad tools to improve competition ability in a supply chain. The first one is integrating involved organizations and the next one is better harmonization of material, information and financial flow [19]. A supply chain includes all the directly or indirectly steps of involved customer's demand. A supply chain not only includes manufacturers and suppliers but also includes parts of transport, warehouses, retail and even their customers [7]. Mentzer and others defined Supply Chain Management such as; systematic harmonization and strategies of traditional parts of the business and also the tactics is used, whether from special corporate chain or within total chain, with the aim of improving performance of each company and the entire supply chain in long-term [21]. An important aspect of supply chain management is selection and management of supplier. In fact, success in providing outside suppliers start with the correct selection and in long-term is directly dependent on managing of the relations with suppliers because suppliers play an important role on a company's success or failure [8].

In response to increasing competition, reduction of product life cycle and rapidly change in customer tastes, most of companies consider developing long-term capabilities of suppliers and this matter increases the importance of the supplier selection [12]. Decisions of evaluation and selection of a supplier is an important part of chain management. This subject is not only true for both manufacturing and service companies but also for getting products and services including equipment and material is true. In today's intense competition, producing high quality products with minimum cost without satisfactory suppliers is not possible.

2. Multiple Criteria Decision-Making

Optimization models after the industrial movement and especially after the Second World War are the center attention of mathematicians and industry mans. Main emphasis on classical optimization models is having a measure (or objective function); as following:

f: En → E1

F (x): optimized to

$$s.t: g_i(x)\begin{bmatrix}\leq\\ \geq\\ =\end{bmatrix} 0 \quad i=1,2,\ldots,m \qquad E^n \mapsto E^m$$

That the above model can be as total linear, nonlinear, or mixed. But the researchers in recent decades focused on Multiple Criteria Decision-Making (MCDM)[1] for complicated decisions. The decisions instead of using a measure of optimality of several criteria may be used.

This decision making model is divided into two main types as represented: Multiple Objective Decision-Making (MODM)[2] and Multiple Attribute Decision-Making (MADM)[3], note that MODM used to design and MADM applied to select best option [2]. TOPSIS method is a common method used in MCDM problems that plays the main role to select suppliers in developed models. The best option in TOPSIS method is the option that has the minimum distance from the positive ideal solution (PIS) and maximum distance from the negative ideal solution (NIS). In many conditions, Crisp and classic data for modeling real conditions seems inadequate. Human judgment has ambiguity and for this reason we can not express them with specified numeric. So instead of using numeric values, using verbal variables seems appropriate. In other words, criteria's weight and rating options express by verbal variable [5].

3. Overview of the scientific literature and works in the supplier selection

Relations of a machinery manufacturer supplier can be based on different criteria of supplier selection. Research in this field among a wide range of industry has created broad amplitude of supplier's criteria in order to facilitate the supplier selection process [24]. Kaharaman and colleagues in 2003 used analysis of fuzzy hierarchical model in order to supplier selection with the highest potential. In this model, the general criteria were categorized in one of four criteria as supplier criteria, product performance criteria, service performance criteria and cost criteria. Krishna and park in 2001 have used supplier selection exercises among the executives of small businesses and used three models, including rational-normative, external control and strategic choice. Tracy and tan in 2001 have used factor analysis and path analysis to study the relationship between selection criteria involving supplier, supplier the teams design and sustainable development programs, customer satisfaction dimensions and overall performance of the company [26]. Weber in 2000 presented an approach in order to evaluate a number of suppliers for employment using multi objective programming and then data envelopment analysis.

Kaharaman (2003) suggested that selection criteria had four main categories [16]:

- Supplier criteria
- product performance criteria
- Service performance criteria
- cost criteria

Participate in work relationships is important and thus evaluating criteria provided by its selection Supplier partner is more applicable. These indicators categorized in four groups: financial, organizational culture, strategy, and other [27]. Choi in a study in the automotive industry in America in 1996 has identified 80 factors to the supplier selection [6]. Gargeya also in his studies in 1993 has provided performance indicators in details [12]. He has offered 5 indicators in his studies:

[1] Multiple criteria decision-making
[2] Multiple objective decision-making
[3] Multiple attribute decision-making

- Quality
- Cost
- On time delivery
- Services
- Flexibility

Dickson also in 1966 has suggested 23 indicators in order to make decisions in supplier selection. These indicators are: Quality, delivery, performance history, warranty policies about parts, capacity and manufacturing facilities, price, technical capability, financial status, policy improvement, communications system, credit and position in industry, the desire for business (business enthusiasm), management, operational control, service maintenance, considering the amount of influence in dealings, the ability to packaging, working relationship history, geographical location, business and sales experience, educational needs in product and bilateral relations [18]. Kumar and others have used fuzzy planning phase ideal choice for solving vendor (supplier) problem with multiple objectives, with this sense that some parameters are fuzzy nature. They have used real-world data to show the effectiveness of the proposed model [17]. Hong and colleagues have been provided a mathematical programming model that features 11 changes in the supply needs of suppliers and customers during the period with the terms, have been provided. Model presented was used for supplier selection in the agriculture industry in Korea [13]. In a research paper by Franklin and Hai, a new method called Voting Analytical Hierarchy Process (VAHP) have provided for supplier selection. This method is a new weighting method instead of couple comprising of AHP for supplier selection. Also this method is simpler than AHP, but has a regular approach of weights adapted and ranking of performance of suppliers [11]. Eastona and his colleagues have used data covering analysis model for performance evaluation and supplier selection in purchase department. This method helps the buyer to categorize suppliers into two categories, efficient suppliers and deficient suppliers [10]. Humphreys and Huang have used a model as expert system for decision making about making or buying. This model used expert systems for the evaluating of decision making about making or buying used. Knowledge-based systems with an expert imitation behavior provide solutions for problems and related issues [14]. Talluri and Narasimhan have used strategic providing methodology for evaluating suppliers. This model using strategic factors and criteria offers an objective framework for evaluating suppliers [25]. Other works have done for evaluating and supplier selection: Burt and starhing have used conceptual model of supplier buyer relations in electronic commerce environment [4], Blanchar and Marqueza have used strategic spare parts model [20], Roi and Guin have used right time to buy model [23], Wynstra and Pierick have used the model of contribution of suppliers in new product development [29], Humphreys and colleagues have used the model of using environmental indicators in selecting suppliers [15] and Pedersen and Dubois have used buying portfolio's model for evaluating and selecting suppliers [9].

4. Fuzzy Logic

Fuzzy logic theory is the large theory that includes fuzzy set theory, fuzzy logic, fuzzy measure, etc. Fuzzy set theory is the extension of classical set theory. Fuzzy logic is extension of ordinary logic (binary). Fuzzy measure is extension of probability measure. Fuzziness as used in fuzzy logic is about kind of uncertainty and vagueness especially the uncertainty of linguistic terms and distinguishes from the uncertainty offered by probability theory [22]. The theory of fuzzy sets was founded by Zadeh in 1965, primarily in the context of his interest in the analysis of complex systems [30]. However, some of the theory was envisioned by Max Black, a philosopher, almost 30 years prior to Zadeh's seminal paper [3]. The main reason of using this theory is representing data that have ambiguous. Also in this method we can use mathematical operators as well as crisp sets. SC networks have a high degree of uncertainty in a system. This precisely because the actual characteristics and uncertainties common among their parameters - where the uncertainties in raw material procurement activities of the last poster is using - that make up this ambiguity in the SC. Because fuzzy set theory deals with uncertainty, it's the proper tool for upgrading and development with these complex systems [31]. Fuzzy set applications in decision-making is one of the most and efficient applications of this theory compared to classical set theory. In fact, fuzzy decision theory efforts to modeling uncertainty and ambiguity inherent in the preferences, goals and restrictions in decision making issues. Relationships between supply chain participation are very important and depend on human activities. This is one of the main reasons why the supply chain systems require modeling by fuzzy systems [31].

5. Some definitions in fuzzy logic

5.1Fuzzy sets and membership functions Although crisp sets are definitive by the characteristic functions, fuzzy functions characterize by membership functions. We can consider fuzzy sets as extension of crisp sets. Thus membership functions can also considered as extension of characteristic functions.

A fuzzy set (subset) "A" on universal set "X" defined by a membership function "μA" that represents following mapping:

$$\mu_A : X \rightarrow \{0,1\} \qquad (5\text{-}1)$$

Here, the value of $\mu_A(X)$ is value of membership or membership degree of $x \in X$.

Suppose that "A" is a fuzzy set on universal set"X". A normal fuzzy set, a convex fuzzy set and cardinality of a fuzzy set are defined as:

- Normal fuzzy set: fuzzy set "A" is normal if

$$\text{Max } \mu_A(x) = 1 \quad , x \in X \qquad (5\text{-}2)$$

- Convex fuzzy set: fuzzy set "A" is convex if

$$\begin{cases} \forall X_1 \in X, \forall X_2 \in X, \forall \lambda \in [0,1] \\ \mu_A\left(\lambda x_1 + (1-\lambda) x_2\right) \geq \min\left(\mu_A(X_1), \mu_A(X_2)\right) \end{cases} \qquad (5\text{-}3)$$

- Cuts: for a fuzzy set we define a-cuts as following:
- a-strong cut: $A_a = \{ X \mid \mu_A(X) \rangle a \}, a \in [0,1)$ (4-5)
- a-weak cut: $A_{\bar{a}} = \{ X \mid \mu_A(X) \geq a \}, a \in [0,1)$ (5-5)

a-weak cut, sometimes called level set of "A".

5.2 Fuzzy numbers arithmetic

- Summation:

$$\mu_{A \oplus B}(Z) = \sup_{X+Y} \left[\mu_A(X) \wedge \mu_B(Y) \right] \quad (6.5)$$

- Subtraction:

$$\mu_{A \ominus B}(Z) = \sup_{X-Y} \left[\mu_A(X) \wedge \mu_B(Y) \right] \quad (7.5)$$

- Multiplication:

$$\mu_{A \otimes B}(Z) = \sup_{X \times Y} \left[\mu_A(X) \wedge \mu_B(Y) \right] \quad (8.5)$$

- Divide:

$$\mu_{A \oslash B}(Z) = \sup_{X \div Y} \left[\mu_A(X) \wedge \mu_B(Y) \right] \quad (9.5)$$

Positive triangular fuzzy number (m) can be shown as m = (m_1, m_2, m_3). The membership function of triangular fuzzy number (m) is shown in figure 1. The membership function m(x) is equivalent to:

Insert Figure 1 about here

$$m(x) = \begin{cases} 0 & x < m_1 \\ \dfrac{x - m_1}{m_2 - m_1} & m_1 \leq x \leq m_2 \\ \dfrac{m_4 - x}{m_4 - m_3} & m_2 \leq x \leq m_3 \\ 0 & x > m_3 \end{cases}$$

6. *FUZZY TOPSIS method*

As mentioned, human thoughts are with Uncertainty and Uncertainty in decision-making is effective. For this reason we use fuzzy decision-making methods. One of these methods is fuzzy TOPSIS. In this case, the matrix elements of decision-making, or weights to the indices, or both of them express fuzzy and represented with fuzzy numbers. Before starting the algorithm of this method, we must form the decision matrix D that is a $m \times n$ matrix and vector of weight of indices to the target$W$, as input of the algorithm:

$$D = \begin{array}{c} \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} X_1 & \cdots & X_j & \cdots & X_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1j} & \cdots & \tilde{x}_{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{x}_{i1} & \cdots & \tilde{x}_{ij} & \cdots & \tilde{x}_{in} \\ \vdots & & \vdots & & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mj} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array} \qquad \begin{array}{l} \tilde{x} = (a \;\; b \;\; c\;) \\ \tilde{w}_j = (\tilde{\alpha}_j, \tilde{\beta}_j, \tilde{\chi}_j) \end{array}$$

zzy numbers.

Step 1. Normalization of decision matrix.

At first, we must normalize decision matrix in order to its elements to be "scale free". Therefore, we specify the maximum of each column x_j^+ and specify the maximum of each column x_j^- and calculate the values of r_{ij} that are normalized x_{ij} using the following relations:

When x_{ij} are fuzzy numbers (triangular numbers: $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ or Trapezoid number: $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})$), Certainly r_{ij} are also fuzzy numbers.

If the fuzzy numbers are triangular and $\tilde{x}_j^- = (a_j^-, b_j^-, c_j^-), \tilde{x}_j^+ = (a_j^+, b_j^+, c_j^+)$ have the lowest and the highest score, respectively, then:

$$\tilde{r}_{ij} = \begin{cases} \tilde{x}_{ij} (/) \tilde{x}_j^+ = \left(\dfrac{b_{ij}}{c_j^+}, \dfrac{c_{ij}}{b_j^+}, \dfrac{d_{ij}}{a_j^+} \right); \\ \tilde{x}_j^- (/) x_{ij} = \left(\dfrac{b_j^-}{c_{ij}}, \dfrac{c_j^-}{b_{ij}}, \dfrac{d_j^-}{a_{ij}} \right); \end{cases}$$

(6-1) if $\tilde{x}_{ij}$ has positive aspect
(6-2) if $\tilde{x}_{ij}$ has negative aspect

Step 2. Obtaining weighted normalized matrix
The elements of weighted normalized matrix $(\tilde{v}_{ij})$ obtained, using the following relation:

For triangular fuzzy numbers:
(6-3)

$$\begin{cases} \tilde{v}_{ij} = \tilde{r}_{ij} (.) \tilde{w}_j = \left(\dfrac{a_{ij}}{c_j^+}, \dfrac{b_{ij}}{b_j^+}, \dfrac{c_{ij}}{a_j^+} \right) (.) (\alpha_j, \beta_j, \chi_j) = \left(\dfrac{a_{ij}}{c_j^+} . \alpha_g, \dfrac{b_{ij}}{b_j^+} . \beta_j, \dfrac{c_{ij}}{a_j^+} . \chi_j \right) \\ \tilde{v}_{ij} = \tilde{r}_{ij} (.) \tilde{w}_j = \left(\dfrac{a_j^-}{a_{ij}}, \dfrac{b_j^-}{b_{ij}}, \dfrac{c_j^-}{c_{ij}} \right) (.) (\alpha_j, \beta_j, \chi_j) = \left(\dfrac{a_j^-}{c_{ij}} . \alpha_j, \dfrac{b_j^-}{b_{ij}} . \beta_j, \dfrac{c_j^-}{a_{ij}} . \chi_j \right) \end{cases} \quad (6\text{-}4)$$

The first for the state that j criteria have the positive aspects and the second relation is for the state that j criteria have the negative aspect.

Step 3. Obtaining a positive ideal solution (PIS) that shown by A^+ and negative ideal solution (NIS) which is shown by A^-.

In fuzzy mode, for comparing fuzzy numbers and specify $\tilde{v}_j^+, \tilde{v}_j^-$, we use processes of fuzzy numbers ranking. According to this method, the rank of each fuzzy number $\tilde{v}_{ij}$ that shown by $M(\tilde{v}_{ij})$ defined as follows:

(6-5)

$$M(v_{ij}) = \frac{-a_{ij}^2 + c_{ij}^2 - a_{ij} b_{ij} + c_{ij} b_{ij}}{3(-a_{ij} + c_{ij})}$$

After obtaining $M(\tilde{v}_{ij})$ for each j column, we introduce the $\tilde{v}_{ij}$ that attain the maximum value of $M(\tilde{v}_{ij})$

as $\tilde{v}_j^+$ and the $\tilde{v}_{ij}$ that attain the minimum value as $\tilde{v}_j^-$.

Step 4. Obtaining distance of each option to positive and negative ideals (S_i^+, S_i^-).

For fuzzy data, the distance between two fuzzy numbers in definition of Zadeh is calculated as follows:

$$D_{ij}^+ = 1 - \sup_x \left\{ \min \left[\alpha_{v_{ij}}(x), \alpha_{v_j^+}(x) \right] \right\}$$

$$D_{ij}^- = 1 - \sup_x \left\{ \min \left[\alpha_{v_{ij}}(x), \alpha_{v_j^-}(x) \right] \right\}$$

This relation can extend for triangular numbers as follows:

$$D_{ij}^+ = \begin{cases} 1 - \dfrac{c_{ij} - a^+}{b^+ + c_{ij} - a^+ - b_{ij}} & for(b_{ij} < b^+) \\ 1 - \dfrac{c^+ - a_{ij}}{b_{ij} + c^+ - a_{ij} - b^+} & for(b^+ < b_{ij}) \end{cases}$$

W

$$D_{ij}^- = \begin{cases} \dfrac{\cdots}{b_{ij} + c^- - a_{ij} - b^-} \\ 1 - \dfrac{c_{ij} - a^-}{b^- + c_{ij} - a^- - b_{ij}} & for(b_{ij} < b^-) \end{cases}$$

It

Distance of option i of a positive ideal: $S_i^+ = \sum_{j=1} D_{ij}^+$ (6-8)

Distance of option i of a negative ideal: $S_i^- = \sum_{j=1}^{n} D_{ij}^-$ (6-9)

Step 5. Calculating the relative distance of each option to the ideal $\left(C_i^+\right)$.

We define this index to combine the values of S_i^+, S_i^- and thus to compare the options. This index can be calculated as following:

$$C_i^+ = \frac{S_i^+}{S_i^+ + S_i^-} \quad (6\text{-}10)$$

Step 6. Rating options can be based on descend ordering of C_i^+ .

7. *Evaluating and selection of suppliers in supply chain Tabriz Tractor Company with Fuzzy TOPSIS approach*

In this research required information for problem solving has been gathered through questionnaires and data obtained were FUZZY TOPSIS program and analyzed. Linguistic terms used in this research shown in tables 1 and 2.

Table 1 the importance degree of criteria

much less important	(0, 0, .1)
less important	(0, .1, .3)
almost less important	(.1, .3, .5)
Apathetic	(.3, .5, .7)
almost important	(.5, .7, .9)
important	(.7, .9, 1)
very important	(.9, 1, 1)

Table 2 voting options

very low	(0, 0, 1)
low	(0, 1, 3)
almost low	(1, 3, 5)
proper	(3, 5, 7)
almost high	(5, 7, 9)
high	(7, 9, 10)
very high	(9, 10, 10)

Decision matrix "D" and the criteria weight matrix "W" in the figure 2 is shown

Insert Figure 2 about here

The output of each stage of the FUZZY TOPSIS program as results is given in figures 3 to 8.

Insert Figure 3 about here

Insert Figure 4 about here

Insert Figure 5 about here
Insert Figure 6 about here
Insert Figure 7 about here
Insert Figure 8 about here

8. Conclusion

Many scholars and thinkers have shown the benefits of supply chain management. In order to increase competitive advantage, many companies consider design and implementation of a proper supply chain management as a key tool. In this situation, creating long-term and close relationship between supplier and buyer as one of the key factors in creating successful supply chain is considered, so the most important issue is suppliers' selection problem. In general, the problem of supplier selection faced with vague data and using of fuzzy set theory for the review of this type of uncertainty seems appropriate. In other words, when we cannot use numerical values to stating the performance indices, the use of variables and verbal phrases to express the values is very suitable indicators. As shown earlier, using FUZZY TOPSIS method in evaluating and supplier selection in the fuzzy environment is very suitable and flexible. In FUZZY TOPSIS method we can consider both quantitative and qualitative criteria in the supplier selection process.

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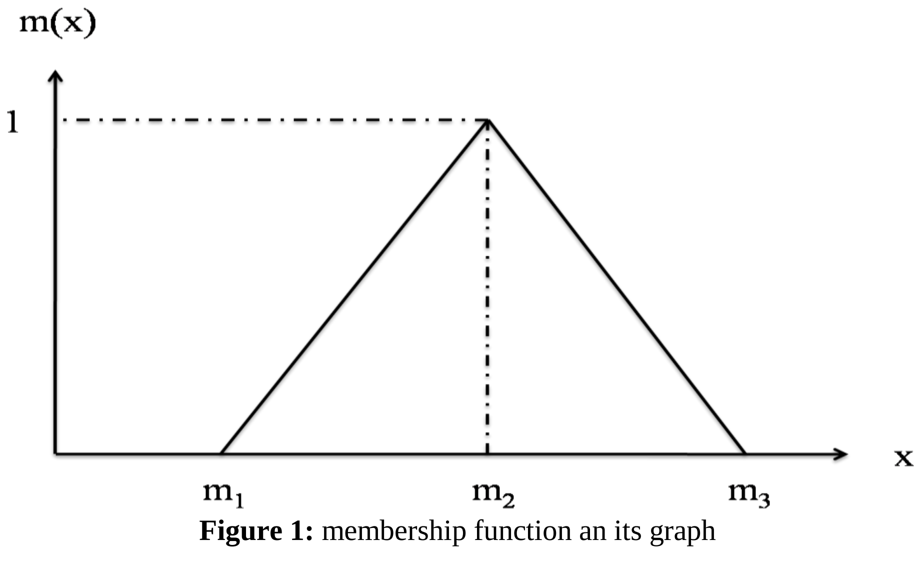

Figure 1: membership function an its graph

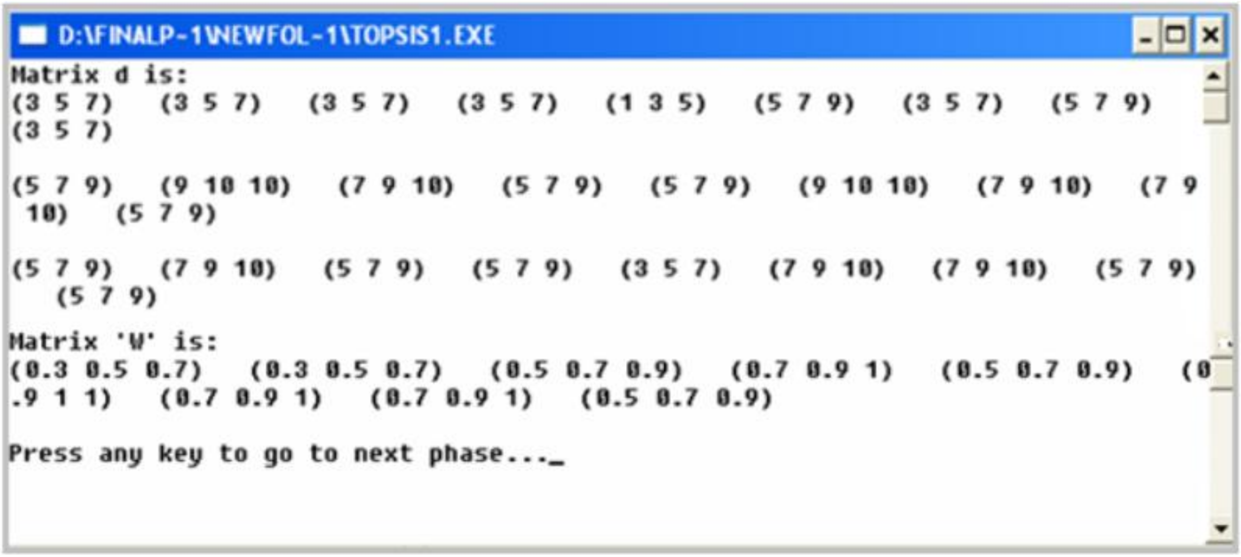

Figure 2: decision matrix "D" and the criteria weight matrix "W"

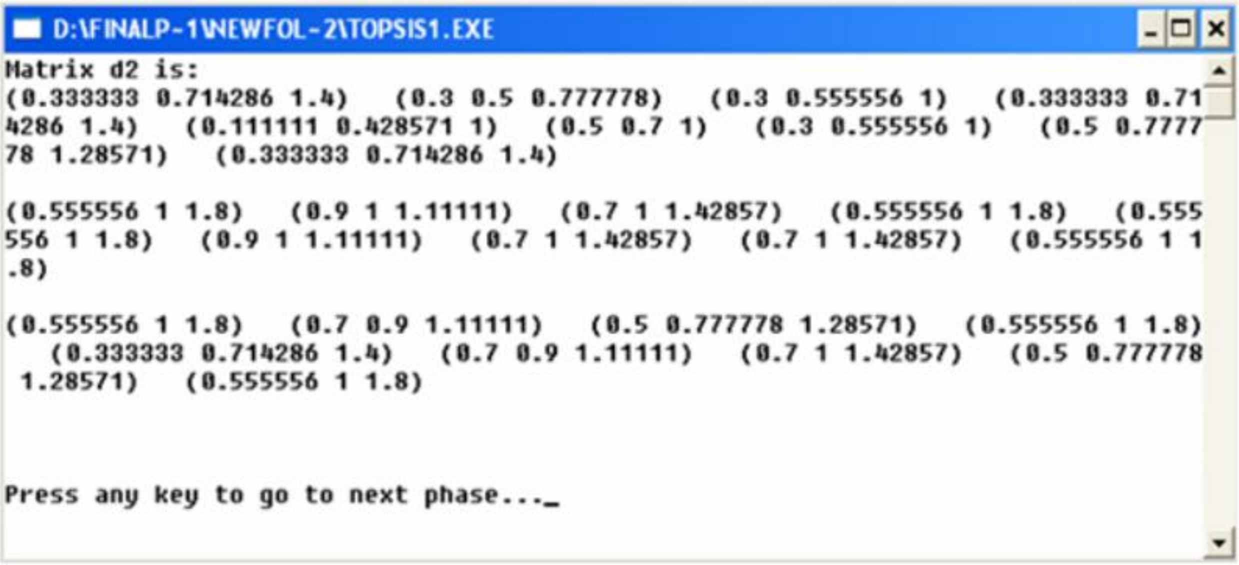

Figure 3: normalized decision matrix in FUZZY TOPSIS

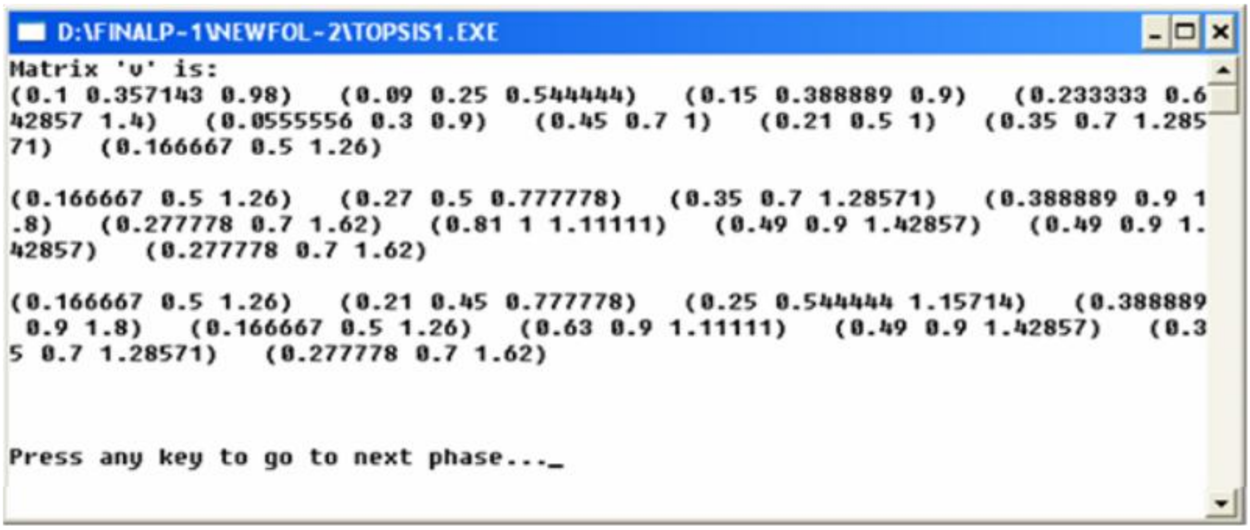

Figure 4: weighted normalized decision matrix in FUZZY TOPSIS

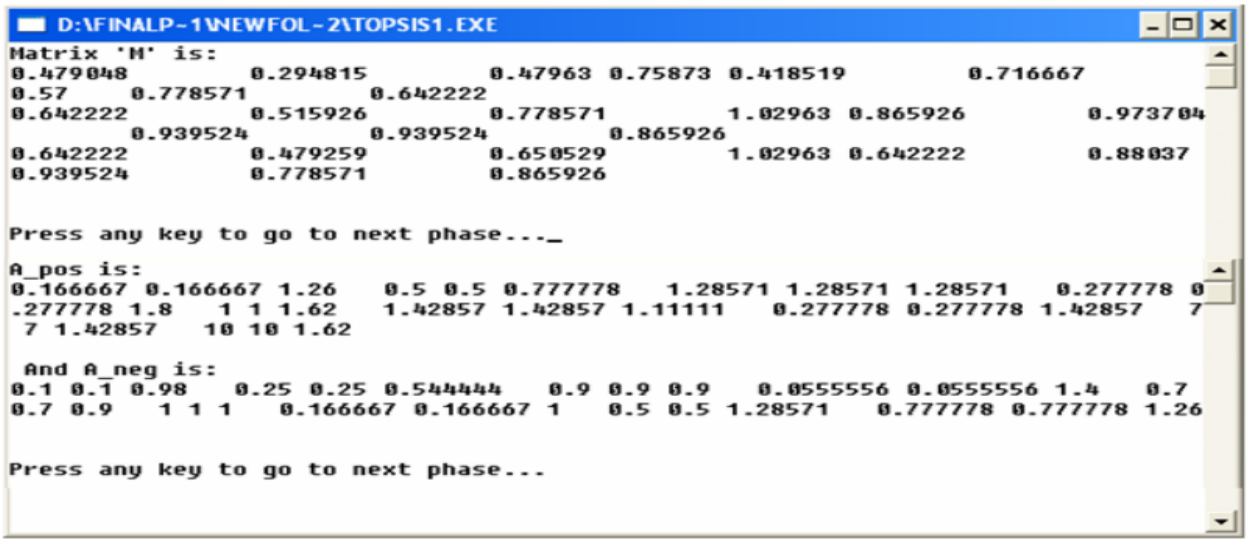

Figure 5: matrix "M" and the positive ideal solutions (PIS) and negative ideal solution (PIS)

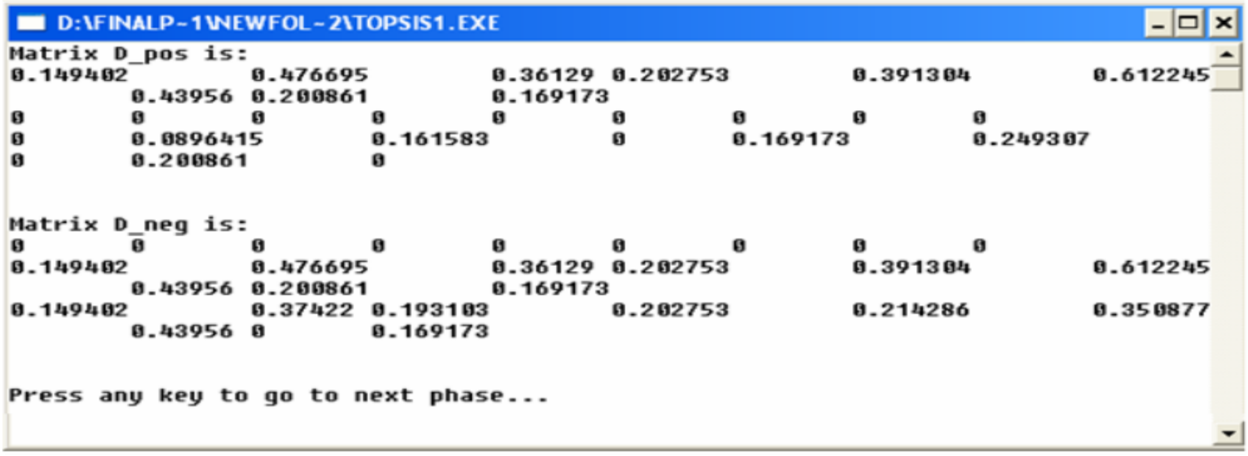

Figure 6: D-POS and D-NEG matrices

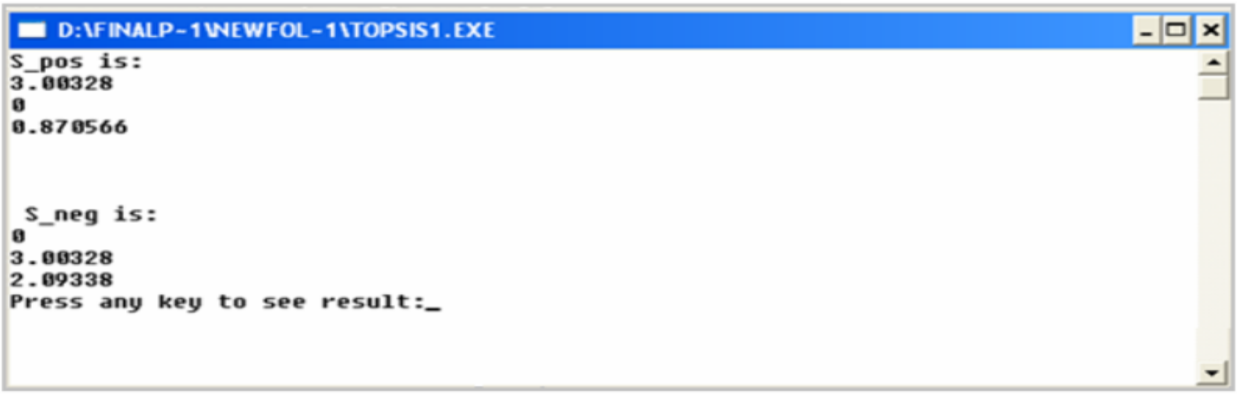

Figure 7: distance of each option to positive and negative ideals

Figure 8: final score and ranking suppliers by FUZZY TOPSIS method