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An order acceptance using FAHP and TOPSIS methods: A case study of Iranian vehicle belt production industry

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A B S T R A C T

Decisions related to acceptance or rejection of orders play an important role in companies engaged in make-to-order production. The incoming orders have a specific delivery date by which the customer expects the due date to be met and the order delivered. In some cases the level of input orders exceeds beyond the existing capacity. In such situations the main concern is to decide which orders must be accepted and which ones rejected taking into account the available production capacity. This paper prioritises the input orders according to a comprehensive and systematic multi criteria decision making (MCDM) model. It then proceeds with making decisions to either accept or reject orders according to the calculated prioritises and production constraints. Ultimately the optimum list of orders for acceptance is determined. The proposed model is a combination of two techniques of Fuzzy Analytical Hierarchy Process (FAHP) and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). In this model FAHP is used to determine the weights of criteria and TOPSIS is used for prioritizing the orders. Finally the proposed model is tested for its efficiency by application to a real case.

1. Introduction

In a general classification of manufacturing systems the two main groupings are make-to-order (MTO) and make-to-stock (MTS) systems. In MTO production occurs according to the orders placed (Arredondo & Martinez, 2010) and in MTS according to predicted demand levels (Soman et al., 2004). Decisions related to acceptance or rejection of orders play an important part in companies with MTO systems. The incoming orders have specified delivery dates anticipated by the customers. Sometimes the levels of incoming orders increase to levels beyond the available capacity. Managers initially attempt to seek extra capacity using tactics such as overtime, outsourcing etc to compensate for all or part of the missing capacity (Ebben et al., 2005; Zhang & Shaofu, 2010). Ultimately, by considering the total capacity (the sum of available capacity and extra capacities obtained via the mentioned tactics) against the required capacity a company will have to decline some of its clients'

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orders if faced with capacity shortage. The question is which orders to accept or reject. In other words, which orders are the most desirable orders? This problem has resulted in development of topic known as order acceptance (OA). The concern of OA is the decision as to whether accept or reject an order by a company which is facing excessive demand upon orders arrival (Herbots et al., 2007). Many researchers such as Rogers and Nandi (2007) and Zorzini et al. (2008) have emphasized the importance of order acceptance in MTO systems.

The complexity of decision making in the acceptance or rejection process is due to multiple criteria that need to be considered, simultaneously. Often those are contradictory criteria where an increase in the desirability of one criterion can result in the decrease of desirability of another criterion. In the past, acceptance or rejection would be based on a specific criterion such as profitability. Today, due to complexity and intense market competition, it is no longer to consider various factors in isolation from one another. The best solution is to take into account various relevant and criteria in order to reach a relatively desirable level of targets/objectives. Otherwise, such decisions can have grave consequences for a company. The multiple criteria decision making (MCDM) methods enjoy the capability to offer assistance to management within a coherent and logical framework to allow them choose the best orders by considering various criteria and evaluating all the orders. The literature on order acceptance has grown rapidly over the past decade (Slotnick & Morton, 2007). Thus, researchers have attempted to find an optimum system to either accept or reject orders using multitudes of techniques such as Dynamic Programming (Alidaee et al., 2001; Lewis & Slotnick, 2002; Herbots et al., 2007), Mathematics Programming (Guerrero & Kern, 1990; Slotnick & Morton, 1996; Slotnick & Morton, 2007), Simulation (Ten kate, 1994;Ten kate, 1995; Nandi & Rogers, 2003; Nandi & Rogers, 2004; Ebben et al., 2005), Decision theory (Balakrishnan et al.,1996; Balakrishnan et al.,1999), Heuristics (Ghosh, 1997; Defregger & Kuhn, 2004; Hing et al., 2007), Genetic algorithm (Roundy et al., 2005; Rom & Slotnick, 2009), Neural networks (Wang et al., 1994; Hing et al., 2002), Neuro-genetics (Snoek, 2000), Markov decision (Kniker & Burman, 2001) etc. References Slotnick and Morton (2007), Ghosh (1997), Jalora (2006) and Ivanescu (2004) provide more detailed information.

There are widespread applications of MCDM methods in various fields such as quality control (Badri, 2001), supplier selection (Chamodrakas et al., 2010; Jadidi et al., 2008; Benyoucef & Canbolat, 2007; Kahraman et al., 2003; Bottani & Rizzi, 2005; Ghodsypour & O'Brien, 1998), risk management (Murtaza, 2003), personnel selection (Taylor et al., 1998; Liang & Wang, 1994), knowledge management (Ngai & Chan, 2005) resource allocation (Ramanathan & Ganesh, 1995), facility location (Kahraman et al., 2003; Yong, 2006), inventory classification (Cakir & Canbolat, 2008; Flores et al., 1992), operating system selection (Balli & Korukoğlu, 2009; Tolga et al., 2005), water management (Srdjevic, 2007), etc. However, there is limited reporting of MCDM being used in order acceptance. Wang et al. (1994) identified the following as factors contributing to the shortage of research in the application of multi-criteria analysis for order acceptance processing:

(1) difficult assumptions on problem structure;

(2) the need for having accurate information prior to defining effective criteria;

(3) difficulty in coordinating/integrating conflicting criteria.

Wang et al. (1994) used multiple criteria decision analysis for order processing when orders exceeded capacity. They first formulated order acceptance as a multi-criteria problem, But, they then deployed neural networks to accept or reject orders. In their case study considered three criteria i.e. profitability, customer credibility and delivery date. Korpela et al. (2002) used AHP process to prioritize orders according to the strategic importance of customer to an organization. Their objective was to prioritize those customers who were more important to the company when faced with shortage of production capacity. They used three criteria namely profitability rate, reliability and volume of orders for prioritizing. Wu and chen (1997) used MCDM methods in connection with response to rush orders. They deployed a multi-objective model which took into account four criteria (four production objectives), simultaneously. The model was able to forecast the cost of accepting such orders.

In this paper, a comprehensive and systematic model for decision making when faced with increasing orders and diminishing capacity is proposed which is based on MCDM for MTO systems. In this model the orders are first prioritized, then according to priority order and production constraints in connection with acceptance or rejection of orders, decisions will be made to allow selection of the best orders by considering capacity constraints.

A good decision-making model needs to tolerate vagueness or ambiguity because fuzziness and vagueness are common characteristics in many decision-making problems (Yu, 2002). In the present paper, a fuzzy multiple criteria decision making model suitable for these conditions is applied. In this model FAHP is used to determine weights for criteria and the technique of TOPSIS is used for prioritizing orders. In recent years, several international articles which simultaneously use AHP and TOPSIS have been published (Balli & Korukoğlu, 2009; Onüt & Soner, 2007; Wu, 2007; Taskin, 2008; Lin et al., 2008; Dagdeviren et al., 2009; Sun, 2010; Amiri, 2010). In all these papers, the hierarchy structures were designed first and then by using AHP they were allocated weights and finally prioritization was achieved by means of TOPSIS method. The full AHP-fuzzy AHP solution is only practically usable if the number of criteria and alternatives is sufficiently low so that the number of pairwise comparisons performed by evaluator must remain below a reasonable threshold (Dagdeviren et al., 2009). For example, if there are n criteria which have been assigned the importance weights and m alternatives, then to run a full AHP-Fuzzy AHP solution there are $n * m * (m-1)/2$ pairwise comparisons remaining to be performed for running a full AHP-fuzzy AHP solution (Shyur, 2006). Simultaneous deployment of FAHP and TOPSIS results in a reduction of pairwise comparisons. However, due to large number of potential alternatives for addressing the research problem, FAHP cannot always be used as a complete solution. That is why TOPSIS is used for find prioritization of orders.

This article consists of five main sections: section 2 provides concepts and definitions; section 3 outline methodology; in section 4 the proposed model is presented; in section 5 the case study is discussed followed by conclusion in section 6.

2. Concepts and definitions

2.1. Fuzzy sets theory

Fuzzy sets theory was introduced by professor Lotfizadeh, in 1965, to solve a ambiguous, imprecise and uncertain problems (Balli & Korukoğlu, 2009; Kahraman et al., 2004; Wang & Chen, 2008; Mula et al., 2006; kumar & Mahapatra, 2009). It is a powerful tool to model uncertainty of human judgments (Wang & Lee, 2009). Fuzzy set theory includes the fuzzy logic, fuzzy arithmetic, fuzzy mathematical programming, fuzzy graph theory and fuzzy data analysis, usually the term fuzzy logic is used to describe all of these (Kahraman et al., 2004; Chan & Kumar, 2007). Fuzzy set theory and it has been applied in a variety of fields in the last decades (Li & Huang, 2009). The main difference between fuzzy sets and crisp sets is that crisp sets only allow full membership or non-membership at all, whereas fuzzy sets allow partial membership (Balli & Korukoğlu, 2009). In fuzzy sets a membership value of zero for an element implies non-membership whereas a value of one shows full membership of a set. All the other value between zero and one indicate partial membership. Bellman and Zadeh (1970) were the first to study the decision-making problem in a fuzzy environment (Chen, 2009). In the remaining part of this section, some of the main key definitions related to fuzzy sets, fuzzy numbers and variables are reviewed in order to provide the background information for the subsequent sections.

2.2. Fuzzy sets

In the fuzzy set concepts, a fuzzy set over X is expressed by means of a membership function $\mu_{\tilde{A}}$ so that:

$\mu_{\tilde{A}}$: X⟶[0,1]

The set $\tilde{A}$ corresponds to a value in the range [0,1] for every x from the set of value in X. In the function $\mu_{\tilde{A}}$(x) the closer the value to one is the greater the membership of x to the set $\tilde{A}$ will be, and the closeness of the membership to zero indicates a lesser belonging to the set $\tilde{A}$.

2.3. Triangular fuzzy numbers (TFN)

Each fuzzy number is defined by a fuzzy set in the fuzzy sets theory. Of the most important fuzzy numbers are triangular ones. A triangular fuzzy number such as M = (1 , m , u) shown in Fig. 1. The membership function $\mu_{\tilde{A}}(x)$ is defined as follows,

$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & x < l \\ \dfrac{x-l}{m-l} & l \leq x \leq m \\ \dfrac{u-x}{u-m} & m \leq x \leq u \end{cases} \tag{1}$$

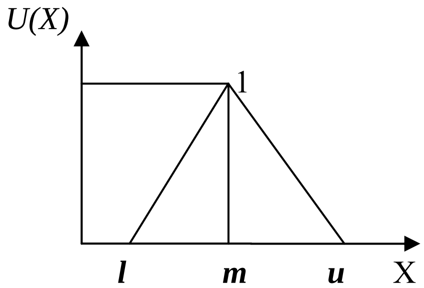

Fig.1. Triangular fuzzy number M

2.4. Algebraic operations

We will mention some algebraic operations concerning fuzzy number to be used later in this article. If someone is interested in more details concerning algebraic operations related to fuzzy numbers, he(she) can refer to Buckley (1985), Kaufmann and Gupta (1991), Zimmermann (1994), and Kahraman et al. (2002) sources.

The operational laws of TFN $a = (l_1, m_1, u_1)$ and $b = (l_2, m_2, u_2)$ are displayed as follows,

Addition of the fuzzy number:

$$a + b = (l_1, m_1, u_1) + (l_2, m_2, u_2) = (l_1 + l_2\,, m_1 + m_2\,, u_1 + u_2) \tag{2}$$

Subtraction of the fuzzy number:

$$a - b = (l_1, m_1, u_1) - (l_2, m_2, u_2) = (l_1 - u_2\,, m_1 - m_2\,, u_1 - l_2) \tag{3}$$

Multiplication of the fuzzy number:

$$a * b = (l_1, m_1, u_1) * (l_2, m_2, u_2) \cong (l_1 * l_2\,, m_1 * m_2\,, u_1 * u_2) \text{ if } ; l_i > 0\,, m_i > 0\,, u_i > 0 \tag{4}$$

Division of a fuzzy number:

$$a/b = (l_1, m_1, u_1)/(l_2, m_2, u_2) \cong (l_1/u_2\,, m_1/m_2\,, u_1/l_2) \text{ if } ; l_i > 0\,, m_i > 0\,, u_i > 0 \tag{5}$$

Reciprocal of the fuzzy number:

$$(a)^{-1} = (l_1, m_1, u_1)^{-1} \cong \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right) \quad (6)$$

2.5. Linguistic variable

Linguistic variable refers to the variable represented by a word or phrase naturally or linguistically (Chen, 2009). Linguistic variables can be very useful in complicated and undefined conditions to be defined only by such variables; for example, the rate of a linguistic variable creativity can be excellent, good, medium and weak and it is possible to show these variables by fuzzy numbers.

3. Methods

3.1. Fuzzy analytic hierarchy process (FAHP)

Analytic hierarchy process (AHP) was presented for the first time by Saaty and provided a vast field facilitating decision process (Forman & Selly, 2001). AHP has become one of the most applicable methods in multiple criteria decision since its presentation (Wang & Chen, 2008; Cheng et al., 1999; Bozbura et al., 2007; Chin et al., 2002; Condon et al., 2003; Ngai & Chan, 2005; Partovi, 2007; Chan & Kumar, 2007) and has been used to solve the complicated problems without structure (Cheng et al., 1999; Chan & Kumar, 2007; Dagdeviren & Yüksel, 2008; Kahraman et al., 2003; Kulak & Kahraman, 2005; Lee & Kim, 2001) in different fields necessary and interesting for people such as economics, social science, management, etc (Cheng et al., 1999; Lee & Kim, 2001; Sun, 2010; Jablonsky, 2006). This method is based on paired comparison. Saaty proposed to use precise numbers 1-9 to define the rate of one element priority to another one and their pairwise comparison. It is noteworthy that although the experts use their mental abilities and competencies in comparisons but the conventional AHP still cannot reflect the human thinking style (Kahraman et al., 2004; Duran & Aguilo, 2008). It is better to say that the fuzzy sets can be used more appropriately in human's verbal and ambiguous descriptions and we should decide in real world by benefiting from fuzzy sets. Hence, analytic hierarchy process method is used in fuzzy condition to achieve the weight of the criteria. The first works concerning fuzzy analytic hierarchy process method were done in 1983 by Laarhoven and Pedrycz. Then some researchers such as Buckley (1985), Boender et al. (1989), Chang (1996) and many others have worked in the field of fuzzy AHP.

In this study, we use the Chang's approach to analyze FAHP (Fuzzy analytic hierarchy process) since the steps and computations of this approach are easier than the other fuzzy-AHP Approaches (Taskin, 2008). In the following, the outlines of the extent analysis method on fuzzy AHP are given. Let $X = \{x_1, x_2, \ldots, x_3\}$ be an object set, and $U = \{u_1, u_2, \ldots, u_3\}$ be a goal set. According to the method of Chang (1996), each object is taken and extent analysis for each goal, g_i, is performed, respectively. Therefore, extent analysis values for each object can be obtained, with the following signs (Taskin, 2008; Kahraman et al., 2004):

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m, \quad i = 1,2,\ldots,n,$$

where all the $M_{g_i}^j$ *(j=1,2,…,m)* are triangular fuzzy numbers. The steps of Chang's extent analysis can be given as in the following:

Step 1. The value of fuzzy synthetic extent with respect to the *ith* object is defined as

$$s_i = \sum_{j=1}^{m} M_{g_i}^j \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \quad (7)$$

To obtain $\sum_{j=1}^{m} M_{g_i}^j$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j , \sum_{j=1}^{m} m_j , \sum_{j=1}^{m} u_j\right) \tag{8}$$

and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1}$, perform the fuzzy edition operation of *m* extent analysis values for a particular matrix such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i , \sum_{i=1}^{n} m_i , \sum_{i=1}^{n} u_i\right) \tag{9}$$

and then compute the inverse of the vector in Eq. (9) such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{10}$$

Step 2. The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

$V(M_2 \geq M_1) = \sup\,[\min\,(\mu_{M_1}(x), \mu_{M_2}(y)]$ and can be equivalently expressed as follows,

$$V(M_2 \geq M_1) = hgt(M_1 \cap \mathrm{M}_2) = \mu_{M_2}(d) \tag{11}$$

$$= \begin{cases} 1 & \text{if} \quad m_2 \geq m_1 \\ 0 & \text{if} \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{Otherwise,} \end{cases}$$

where *d* is the ordinate of the highest intersection point *D* between $\mu_{M_1}$and μ_{M_2}(see Fig. 2).

To compare $M_1$and M_2, both values of $V(M_2 \geq M_1)$ and $V(M_2 \geq M_1)$ are needed.

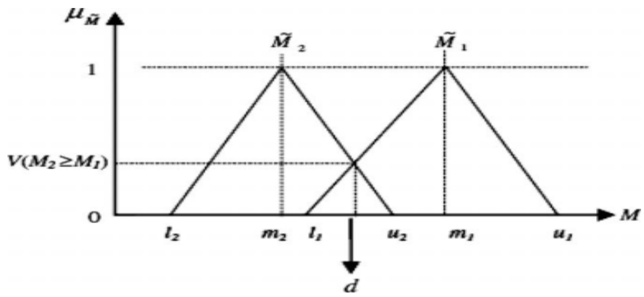

Fig. 2.The intersection between M_1 and M_2

Step 3. The degree possibility for a convex fuzzy number to be greater than convex fuzzy numbers M_i(i = 1,2,. . . ,k), which can be defined by

$$\mathrm{V}(\mathrm{M} \geq \mathrm{M}_1, \mathrm{M}_2, \ldots, \mathrm{M}_k) = V[(M \geq \mathrm{M}_1) and (M \geq \mathrm{M}_2) and \ldots and (M \geq \mathrm{M}_k)] \\ = \min V(M \geq \mathrm{M}_i), i = 1,2, \ldots, k \tag{12}$$

Let

$$d^{\prime}(A_i) = \min V(S_i \geq S_k). \tag{13}$$

For *k=1,2,…,n*; *k*≠ i, the weight factor is given by,

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T \quad (14)$$

where A_i *(i = 1,2,. . . ,n)* are *n* elements.

Step 4. The normalized weight vectors are

$$W = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^T, \quad (15)$$

where W is a nonfuzzy number.

3.2.TOPSIS

TOPSIS technique was presented on the basis of Hwang and Yoon (1981) studies by Chen and Hwang (1992). This model is one of the best techniques for Multi criteria decision making (MCDM). In this method, the alternative 'm' is assessed and compared by the criterion 'n'. In this technique, it is assumed that the ideality of each index increases or decreases, monotonously. TOPSIS has been successfully used in assessing or selecting a limited set of alternatives (Teodorovic, 1985; Jee & Kang, 2000; Yong, 2006; Zanakis et al., 1998). It is necessary to pass following steps in order to solve a problem by the technique:

Step 1. Calculate the normalized decision matrix. The normalized value n_{ij} is calculated as:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad i = 1, \ldots, m; j = 1, \ldots, n \quad (16)$$

Step 2. Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as:

$$v_{ij} = w_j n_{ij}, \ \ i = 1, \ldots, m; j = 1, \ldots, n, \quad (17)$$

where w_j is the weight of the *jth* attribute or criterion, and $\sum_{j=1}^{n} w_j = 1$.

Step 3. Determine the positive ideal and negative ideal solution

$$A^+ = \{V_1^+, \ldots, V_n^+\} = \{(max\, V_{ij}\ |i \epsilon I), (min\, V_{ij}\ |i \in J)\}, \quad (18)$$

$$A^- = \{V_1^-, \ldots, V_n^-\} = \{(min\, V_{ij}\ |i \epsilon I), (max\, V_{ij}\ |i \in J)\}, \quad (19)$$

where I is associated with benefit criteria, and J is associated with cost criteria.

Step 4. Calculate the separation measures, using the *n*-dimensional Euclidean distance. The separation of each alternative from the positive ideal solution is given as,

$$d_i^+ = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2\right\}^{0.5}, \quad i = 1, \ldots, m. \quad (20)$$

Similarly, the separation from the negative ideal solution is given as

$$d_i^- = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2\right\}^{0.5}, \quad i = 1, \ldots, m. \quad (21)$$

Step 5. Calculate the relative closeness to the ideal solution, where the relative closeness of the alternative A_i with respect to A^+ is defined as

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-}\ , \qquad i = 1, \dots, m. \tag{22}$$

Since $d_i^+ \geq 0$ and $d_i^- \geq 0$, then, clearly, $C_i \in [0, 1]$.

Step 6. Rank the preference order. For ranking alternatives using this index, we can rank alternatives in decreasing order.

4. The proposed model

The model proposed for this problem consists of FAHP and TOPSIS techniques. It includes three main steps:

4.1. Group working

In this step, all the orders entered into the organization are examined by the decision group and the orders which do not meet the least standards are eliminated. The remained orders are defined as the final alternatives. Then the decision group defines the assessing and comparing criteria. Having defined the assessment alternatives and criteria the hierarchy structure is defined. The members of the group are to confirm the hierarchy structure.

4.2. FAHP (Computing the criteria weight)

Having confirmed the hierarchy structure, the pairwise comparisons matrix is designed to define the weight of the criteria and each member of the decision group assesses individually by virtue of the linguistic variables of Table 1. These variables are changed to homologous triangular fuzzy numbers to integrate the individual assessments and then the final matrix is computed. Finally, the weight of the criteria is defined by fuzzy AHP.

4.3. TOPSIS (Priorities of the orders)

TOPSIS begins by benefiting from the weights computed by fuzzy AHP and the orders priorities are by computing the relative distance between the alternatives and the ideal solutions.

Table 1
Linguistic values and fuzzy numbers

Linguistic terms	Triangular fuzzy numbers
Just equal	(1,1,1)
Equally important	(1/2,1,3/2)
Weakly more important	(1,3/2,2)
Strongly more important	(3/2,2,5/2)
Very Strongly more Important	(2,5/2,3)
Absolutely more important	(5/2,3,7/2)

5. Case study

Company ‘A’, an active vehicle belt production producer in Iran, is selected as a case study to examine and assess the model. We try to select the best orders received by the company by virtue of the organizational goals and the low capacity because of the increased rate of the orders. First, the decision group needs to be formed and the orders of the producing sections are ignored in the decision process (Ebben et al., 2005). We try to employ the personnel of different producing sections with the orders reception section employees in defining the group members in order to consider the production limits during accepting or refusing the orders. The vehicles producers consider the orders of company ‘A’ on a monthly basis as follows:

The method and time of delivering the orders in company ‘A’ are fixed in traditional form. The goods are delivered to the clients on 15^{th} and 25^{th} of every month. The prepared available orders are delivered to the vehicles producers on 15th day of the month. All the accepted orders must be completed and delivered on 25th day of the month and if an order is not completed, a fine should be paid and it influences the next orders rate, significantly. When an ordered is not completed, in some cases, the order is cancelled, completely and the produced items are refused. Therefore, the orders must be delivered on time and company 'A' sometimes is obliged to refuse some orders in each period because of low capacity. There are some assumptions hold for the proposed case study of this paper as follows,

a. The date of the delivery is strict and nonnegotiable.
b. The client does not give only a part of the order to the organization that is the organization is obliged to accept or refuse it totally.
c. The orders of each period are given to the organization in a defined interval before the period commencement. The orders received during the interval are examined to be produced for the next period.

The priorities of the orders are defined for the organization on the basis of the model proposed in fourth step; then the orders are accepted or refused on the basis of the gained priorities and actual capacity to define the best received orders.

5.1. Group working

Having formed the decision group, all the orders entered into the organization were examined and three of total 21 orders entered into company 'A' were eliminated because they did not meet the minimum required standards. The remaining ones (O_1, O_2, …., O_{18}) were selected to be assessed and compared on the basis of the directors' criteria. The alternatives of the decision matrix are set up based on these orders.

The following summarizes the criteria used for the proposed case study,

The rate of profitability (C_1) The importance of client (C_2)

Production simplicity (C_3) The importance of the ordered goods (C_4)

Having defined the orders entered into the organization and the assessment criteria the hierarchy structure was formed and confirmed by group members.

5.2. FAHP (Computing the weight of the criteria)

Having formed the hierarchy structure on the basis of the defined goal, criteria and alternatives the pairwise comparisons matrix of the criteria have to be defined in this step in order to define the weights of the criteria. The pairwise comparison of the criteria was done by using the linguistic variables. These variables and their homologous triangular fuzzy numbers are shown in Table 1. Having discussed and views exchange the members of the decision group agreed with pairwise comparisons matrix are shown in Table 2. The Chang's fuzzy hierarchy analytic process was used in order to define the weight of the criteria.

Table 2
The pairwise comparison matrix for criteria

	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(3/2,2,5/2)	(3/2,2,5/2)	(1,3/2,2)
C_2	(2/5,1/2,2/3)	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)
C_3	(2/5,1/2,2/3)	(1,3/2,2)	(1,1,1)	(1/2,2/3,1)
C_4	(1/2,1,3/2)	(1,3/2,2)	(1,3/2,2)	(1,1,1)

Using Eq. (7) the values of S_1 to S_4 are calculated as $S_1 = (0.2190 \quad 0.3611 \quad 0.5797)$,

$S_2 = (0.1051 \quad 0.1574 \quad 0.2657), S_3 = (0.1270 \quad 0.2037 \quad 0.3382), S_4 = (0.1533 \quad 0.2778 \quad 0.4710)$.

The degrees of possibility are calculated as below (see Eq.(11)):

$$V(S_1 \geq S_2) = 1.0000,\ V(S_1 \geq S_3) = 1.0000,\ V(S_1 \geq S_4) = 1.0000, V(S_2 \geq S_1) = 0.1866, V(S_2 \geq S_3) = 0.7497,$$

$$V(S_3 \geq S_1) = 0.4309, V(S_3 \geq S_2) = 1.0000, V(S_3 \geq S_4) = 0.7139, V(S_4 \geq S_1) = 0.7515, V(S_4 \geq S_2) = 1.0000, V(S_4 \geq S_3) = 1.0000.$$

For each pairwise comparison, the minimum degrees of possibility is calculated using Eq. (13) as follows,

$$minV(S_1 \geq S_2, S_3, S_4) = \min(1.0000 \quad 1.0000 \quad 1.0000) = 1.0000$$

$$minV(S_2 \geq S_1, S_3, S_4) = \min(0.1866 \quad 0.7497 \quad 0.4829) = 0.1866$$

$$minV(S_3 \geq S_1, S_2, S_4) = \min(0.4309 \quad 1.0000 \quad 0.7139) = 0.4309$$

$$minV(S_4 \geq S_1, S_2, S_3) = \min(0.7515 \quad 1.0000 \quad 1.0000) = 0.7515$$

Therefore, we have,

$$W' = (1.0000 \quad 0.1866 \quad 0.4309 \quad 0.7515)^T \qquad W = (0.4221 \quad 0.0788 \quad 0.1819 \quad 0.3172)^T$$

5.3. TOPSIS (Priorities of the orders)

Note that the entry of TOPSIS technique is the vector of the weight of the criteria and decision matrix before using the steps of the technique priorities of the orders. Table 3 summarizes the input values of all alternatives based on four criteria.

Table 3
The decision matrix of the problem

	C_1	C_2	C_3	C_4
O_1	274253	8.5	6.00	6.25
O_2	269865	8.5	5.25	7.17
O_3	164917	8.5	8.54	3.50
O_4	213479	6.4	8.00	4.42
O_5	313043	8.5	6.50	6.34
O_6	274390	8.5	5.67	6.92
O_7	225609	8.5	5.67	7.34
O_8	318432	8.5	4.09	9.08
O_9	331421	8.5	3.83	9.25
O_{10}	266528	6.4	7.25	6.41
O_{11}	266528	4.1	7.25	6.41
O_{12}	252292	6.4	5.41	8.25
O_{13}	278937	8.5	6.25	7.41
O_{14}	229040	4.1	5.75	8.17
O_{15}	213246	4.1	7.92	6.67
O_{16}	229040	4.1	5.75	8.17
O_{17}	252815	8.5	8.84	5.50
O_{18}	268800	8.5	5.59	9.50

Once the input information are completed we can compute the priorities of all alternatives based on the criteria. Table 4 summarizes the results of the ranking the alternatives. The results of the ordering represents the ordering as (O_{17} , O_1 , O_{11} , O_{10} , O_2 , O_6 , O_5 , O_{13} , O_{18} , O_8 , O_9), which were practically accepted for the proposed study of this paper. Although the orders of O_{12} and O_{16} were acceptable compared with other ones, the decision group eliminated them because of some limits concerning their first materials preparation and their producing program different from others.

Table 4
Final evaluation of the orders

Orders	d_i^*	Ranking	d_i^-	Ranking	C_i	Ranking
O_1	0.0443	11	0.0536	13	0.5472	12
O_2	0.0412	8	0.0571	8	0.5810	8
O_3	0.0888	18	0.0331	18	0.2715	18
O_4	0.0697	17	0.0351	17	0.3350	17
O_5	0.0369	5	0.0669	4	0.6443	5
O_6	0.0403	6	0.0572	7	0.5864	7
O_7	0.0507	14	0.0488	15	0.4908	15
O_8	0.0322	1	0.0830	2	0.7205	2
O_9	0.0334	3	0.0877	1	0.7241	1
O_{10}	0.0421	9	0.0544	11	0.5635	9
O_{11}	0.0431	10	0.0542	12	0.5568	10
O_{12}	0.0403	6	0.0606	6	0.6007	6
O_{13}	0.0342	4	0.0624	5	0.6464	4
O_{14}	0.0474	13	0.0557	10	0.5401	13
O_{15}	0.0552	16	0.0464	16	0.4569	16
O_{16}	0.0462	12	0.0567	9	0.5513	11
O_{17}	0.0511	15	0.0527	14	0.5074	14
O_{18}	0.0322	1	0.0754	3	0.7006	3

6. Conclusion

In this paper, a comprehensive, systemic and applicable decision model was presented to select the best alternatives associated with order increase when the production capacity is limited. The proposed model of this paper uses fuzzy analytical hierarchy process to prioritize the criteria and it implements TOPSIS to prioritize the possible alternatives based on the criteria. The proposed model of this paper has been used for a real-world case study of safety belt industry. The main advantage of this algorithm is that it reduces the number of comparisons, which reduces the burden of the computations, significantly.

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