A decision making model for outsourcing of manufacturing activities by ANP and DEMATEL under fuzzy environment

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ABSTRACT

Decision making about outsourcing or insourcing of manufacturing activities is a type of multiple criteria decision making (MCDM) problem, which requires considering quantitative and qualitative factors as evaluation criteria simultaneously. Therefore, a suitable MCDM method can be useful in this area as it can consider the interactions among quantitative and qualitative criteria. The analytic network process (ANP) is a relatively new MCDM method which can deal with different kinds of interactions systematically. Moreover, the Decision Making Trial and Evaluation Laboratory (DEMATEL) method is able to convert the relations between cause and effect of criteria into a visual structural model as well as handling the inner dependences within a set of criteria. However both ANP method and DEMATEL techniques in their original forms are incapable of capturing the uncertainty during value judgment elicitation. To overcome this problem, here, a new and effective model is proposed based on combining fuzzy ANP and fuzzy DEMATEL for decision making about outsourcing or insourcing of manufacturing activities in uncertain conditions. Data from a case study is used to illustrate the usefulness and applicably of the proposed method.

KEYWORDS

Outsourcing, Triangular fuzzy number, fuzzy ANP, fuzzy DEMATEL

1. Introduction

Nowadays, complexities in the business atmosphere, an increase in the competition between producers, shortage of resources, and lots of other factors have caused producing organizations to move toward making use of optimum processes and decisions in order to guarantee the organization's exuberant permanence. From the Industrial Revolution to early 1980s, producer's strategy was based on establishing processes and requirements related to the production of all the products or ordered ones within the organization. This was relied on the present resources and workforce; however, in facing lots of difficulties, so many organizations have moved toward specialization of activities, dividing chores, and a smarter planning of the issues. In this way, by improving primary qualities, reaching to competitive advantages is accessible.

It is clear that specialization and as a result, limiting the domain of activities, will be possible in the case that some of the chores are being outsourced. In fact, outsourcing is handing over some of the primary or non-primary chores of the organization which are carried out based on decision making processes; therefore some of these results will be acquired by using outsourcing and some others by insourcing. This results in a decrease in system's rate of vertical integration.

In general, outsourcing is used to declining production costs, access to a higher technology and skill, efficiently using the available time and limited resources on the organization, prevention of the activities being messy, and finally prevention of the organization's unrestrained development and the related expenses.[2]

Probert [3] presented a strategic methodology for production or purchasing decision which was based on a thorough analysis of all the different aspects of production technologies. McIvor et al [4] by emphasizing the establishment of a sharing relationship with the selected supplier, tried to present a conceptual framework for production or purchase of strategic goods. One of the

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applications of this framework is for the organizations in which so much strategic attention should be paid to decision-making about production or purchase. Padilo and Dibey [3] for the first time looked at this issue using a multitude of criterions. They presented a methodology of analyzing decision-making which was in seven stages to evaluate the strategies of production or purchase. This methodology contains a comparative model which furthers four aims simultaneously: maximizing the strategic performance of competition, maximizing the managerial performance, minimizing the risk of finding resources, and maximizing the financial performance. In this model various methods like complex programming and AHP have been used. Lance Dell [4] presented a conceptual framework to efficiently manage the risk of outsourcing, emphasizing taking into account the competitive advantages of the organization. Comann and Ronan [5] presented a model which investigates the state at which demand is more than supply and the management must decide to produce which quantity of that product and buy which quantity from contractors. They showed outsourcing as an issue of linear programming based on financial and capacity-related parameters. Vals-pierre and Clain-Hans [6] worked out a set of if-then laws considering the criteria of purchase or production decision-making which by using verbal utterances we can make appropriate strategic decisions. Aktan et al [7] developed a financial model for evaluating the value of outsourcing options. In fact, this model provides a comprehensive framework for evaluating the whole expected costs of outsourcing from a network of suppliers when the purchase is faced with unknown exchange rate. For this purpose, Monte Carlo simulation method has been used. Tills and Dreary [8] developed a model which supports decision-making related to purchase or production based on an investigation of the goods and investment's being strategic. Mom and Wallaby [9] developed a systematic framework for strategic outsourcing. This framework, with the help of internal management tools and external marketing tools, links 6 basic levels of outsourcing to strategic programming of the organization and helps the reciprocal linkages between the functions of the process of outsourcing to be known. Humphreys et al [10] used sophisticated systems based on KBS knowledge to design the model for evaluation of decisions made about purchase or production. This model is comprised of 5 major levels: identifying and weighing performance-related criteria, analyzing technical abilities, comparing internal and external capacities, analyzing the capabilities of the supplying organization, and analyzing the whole cost of ownership. KBS has linked all these 5 stages. Water and Pate [11] proposed a model of outsourcing decision-making which has more strategic focus and has a structure which makes it possible to use a technique in order to decrease the complexity of the process.

A comprehensive study of the related articles on this issue shows that by the passage of time, researchers have reached this conclusion that the criteria of costs is not sufficient in making decisions about outsourcing or insourcing and other criteria must also be taken into account. However, developing a comprehensive and systematic procedure for making decisions about insourcing or outsourcing can be very helpful in decreasing the dangers related to this decision-making.

In this article by proposing a new hybrid multi-criteria model for decision-making, we have attempted to make decisions about outsourcing and insourcing related to productive activities in the times when there is no absoluteness based on a variety of qualitative and quantitative criteria. This model which is based on the combination of ANP and DEMATEL methods in fuzzy environment can make clear the verbal evaluations of decision-makers and overcome one of the difficulties of ANP, which is surveying a large number of pairs for achieving the importance weights of those criteria which have an internal link to each other.

The rest of this paper is organized as follows. In Section 2, the theoretical foundations of outsourcing, and in Section 3 the foundations of the theory of fuzzy systems are described. In Section 4, an ANP fuzzy method, and in Section 5 the fuzzy DEMATEL technique is introduced. Section 6, is devoted to the proposed MCDM model. In Section 7, the proposed model is used for insourcing-outsourcing decision making process for several real cases finally, in Section 8, the conclusions are discussed.

2- Outsourcing

In this section we will talk about theoretical foundations and generalities of the theory of outsourcing.

Outsourcing is the shorthand form of "using outside resources". We present the meaning of each component of that:

Outside, means creating value outside the organization. In fact, outside considers the boundaries of the organization. The idea of the borderless organization is the integration of outside partners in order to establish and increase the value of the ultimate costumers.

From the point of resource, the organization is seen as a unique set of resources and knowledge. Without acquiring these resources from the environment, the organization is not able to survive and compete with other organizations. It is the supplying manager's duty to analyze the resource-finding markets in order to acquire competition advantages.

It is not sufficient to be informed only of outside sources. They can be used in order to support the organization's position in the competitive environment. Chain supply management is a method which enables the organizations to make use of these resources.[12]

So many times, outsourcing is used as a synonym to decision-making for externalization. Terms like ' production or purchase', integration/disintegration of activities', all refer to outsourcing. [13]

2.2. Advantages of outsourcing

The rapid growth of outsourcing shows that both state-owned and private institutions expect to attain some profits by making use of outsourcing. For example, all organizations expect to economize in their expenses. It is impossible to mention all of the advantages of outsourcing, but some of these advantages are so general that are attained in all organizations.[14]

The advantages attributed to outsourcing are summarized in table 1.

Table 1- the expected advantages of outsourcing

Reference number	The expected advantage
[15],[16],[17],[18],[19],[20],[21],[22]	Economizing costs
[19],[16]	Decrease in the costs of investment
[20],[11]	Injection of liquidity
[15]	Turning permanent costs to variable costs
[20],[16]	Quality improvement
[20]	Increasing speed
[15],[16],[19],[20],[21]	More flexibility
[13],[12]	Access to most modern technology and infrastructure
[21],[20],[19],[16]	Access to skills and aptitudes
[13],[20],[16]	Increasing operational activities
[15],[16],[17],[19],[20],[22]	Increase focus on the basic functions
[22],[20]	Handing over the problematic functions
[14]	Replicating the rivals
[14]	Decrease in political pressures
[22],[20],[16]	Freeing the resources
[20]	Better management and responding
[22],[20],[15]	Financial clarity
[22],[19]	Sharing risks

3.2. Disadvantages and risks attributed to outsourcing

Studies show that all of the advantages attributed to outsourcing have been exaggerated. However, it is accepted that all of the risks attributed to it are not identified [14]. Some of the risks are mentioned in table 2.

Table 2- potential risks of outsourcing

Reference number	Potential risk
[19],[20[,[21],[22],[23]	unattained economizing or secret costs
[20],[21],[22],[24]	Decrease in flexibility
[16],[24]	Poor contract or selection of a weak supplier
[18],[20],[22],[23],[24]	Loosing knowledge, information, skills, or difficulty in regaining the function
[15],[16],[19],[20],[21],[22],[24]	Losing control and meritocracy
[16],[18],[22],[23],[25]	Dependency to the supplier
[21],[22],[23],[24]	The supplier risk (poor performance or bad relations, opportunistic behavior, poor understanding of business, lack of access to better skills or technologies.
[21]	Loosing costumer, opportunities, or validity
[21],[20]	Uncertainty, change in the environment
[19],[20],[23],[24]	Low morale, consequences related to the staff
[15]	Opposing benefits
[18],[19],[23]	Security consequences

4.2. Different degrees of outsourcing

By studying present articles we it is evident that we can categorize outsourcing into 2 different types:

1- from the point of view of the extent of outsourcing

2- from the point of view of level of outsourcing

From the point of view of extent, outsourcing is divided into two types naming partial outsourcing and full-scale outsourcing.

3. The theory of fuzzy sets

In actuality, so many decisions include vagueness in the definition of ends, limitations, and possible actions which are not defined clearly [26]. The roots of this vagueness are immeasurable data, incomplete data, and inaccessible information [27]. To solve this, fuzzy sets theory was proposed by Zade [28] as a mathematical method to face vagueness in decision-making. This theory is used where decision-making is facing unclear and equivocal human linguistic utterances. The decision-makers are inclined to evaluate everything based on their own past experiences and knowledge and usually utter estimates using equivocal linguist utterances. In order to unify the experiences, beliefs, and ideas of the decision-makers, it is better to transform linguistic estimates into fuzzy numbers. So, decision-making in the real world has made it necessary to use fuzzy numbers [29]. Decision-making in the domain of outsourcing is no exception.

In the next part of this chapter, some of the basic definitions of the theory of fuzzy sets, fuzzy numbers, and linguistic variables are summarized.

Definition 1-3- the fuzzy set $\tilde{A}$, is a subset of X which is defined by this function $\mu_{\tilde{A}}(x)$ which relates to each member of x in X an actual number in the distance of [0, 1]. The amount of function $\mu_{\tilde{A}}(x)$ is called the rate of the membership of x in $\tilde{A}$ [29].

Definition 2-3- the fuzzy set of $\tilde{A}$, is a convex set in the major set of X if and only if $\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2))$ for each x_1, x_2 in X and each $\lambda \in [0, 1]$, in which min shows the minimum of performance[30].

Definition 3-3- the height of a fuzzy set, is the highest enrollment rate which is obtained by each member of that set. The fuzzy set of $\tilde{A}$ is called normal when the height of $\tilde{A}$ is equal to 1[30].

Definition 4-3- fuzzy number is a fuzzy subset in the reference set of X which is both convex and normal. The picture (1) shows the fuzzy number of $\tilde{n}$ from the reference set of X which is in accordance with this definition [29].

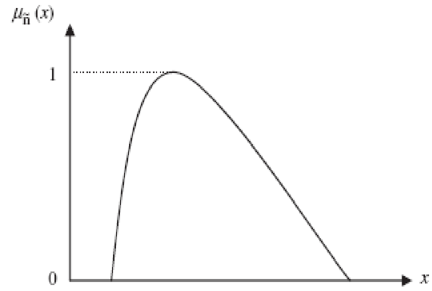


Figure 1- triangular fuzzy number $\tilde{n}$

Definition 5-3- the *a*-cut of the fuzzy number of $\tilde{n}$ is defined as follows:
$\tilde{n}^{\alpha} = \{x_i : \mu_{\tilde{n}}(x_i) \geq \alpha, x_i \in X\}$In which $\alpha \in [0, 1]$.
$\tilde{n}^{\alpha}$ Shows the closed not-empty set of X which is shown as $\tilde{n}^{\alpha} = \left[n_1^{\alpha}, n_u^{\alpha}\right]$. n_1^{α} And n_u^{α} are the lowest and highest limits of this set. For the fuzzy number of $\tilde{n}$, if $n_u^{\alpha} \leq 1, n_1^{\alpha} > 0$ is for each $\alpha \in [0, 1]$, in that case $\tilde{n}$ is called the standardized and positive fuzzy number [29], [31].

Definition 6-3- the triangular fuzzy number can be defined as (ℓ, m, u). The $\mu_{\tilde{n}}(x)$function is defined as follows:

$$\mu_{\tilde{n}}(x) = \begin{cases} 0, & x < \ell \\ (x-\ell)/(m-\ell), & \ell \leq x \leq m \\ (u-x)/(u-m), & m \leq x \leq u \\ 0, & x > u, \end{cases}$$

In which ℓ, m, u are real numbers and $\ell \leq m \leq u$. Look at this diagram:

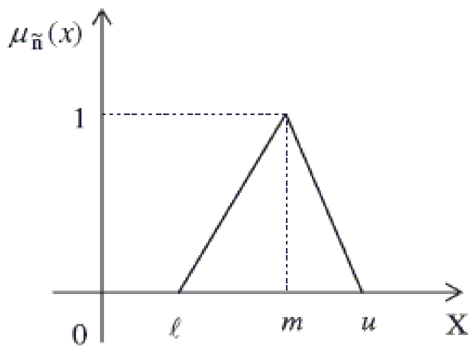


Figure 2- triangular fuzzy number $\tilde{n}$

Theorem 1-3- suppose that $\tilde{n} = (\ell, m, u)$is a triangular fuzzy number and k>0 is a crisp number, in that case:

$$k \times \tilde{n} = (k\ell, km, ku) \quad (1)$$

Theorem 2-3- suppose that $\tilde{n}_1 = (\ell_1, m_1, u_1)$ and $\tilde{n}_2 = (\ell_2, m_2, u_2)$ are two triangular fuzzy numbers. The result of the addition of these $\tilde{n}_1, \tilde{n}_2$ is another triangular fuzzy number.

$$\tilde{n}_1 \oplus \tilde{n}_2 = (\ell_1 + \ell_2, m_1 + m_2, u_1 + u_2) \qquad (2)$$

Theorem 3-3 supposes that $\tilde{n}_1 = (\ell_1, m_1, u_1)$ and $\tilde{n}_2 = (\ell_2, m_2, u_2)$ are two triangular fuzzy numbers. The result of multiplication of the $\tilde{n}_1$, $\tilde{n}_2$ is defined by the following function:

$$\begin{cases} 0 & ; x \le \ell_1 \ell_2 \\ \dfrac{2\ell_1\ell_2 - \ell_1 m_2 - \ell_2 m_1 + \sqrt{[\ell_1(m_2 - \ell_2) - \ell_2(m_1 - \ell_1)]^2 + 4x(m_1 - \ell_1)(m_2 - \ell_2)}}{2(m_1 - \ell_1)(m_2 - \ell_2)} & ; \ell_1\ell_2 \le x \le m_1 m_2 \\ \dfrac{2u_1u_2 - u_1 m_2 - u_2 m_1 + \sqrt{[u_1(m_2 - u_2) - u_2(m_1 - u_1)]^2 + 4x(m_1 - u_1)(m_2 - u_2)}}{2(m_1 - u_1)(m_2 - u_2)} & ; m_1 m_2 \le x \le u_1 u_2 \\ 0 & ; x \ge u_1 u_2 \end{cases} \qquad (3)$$

It is apparent that the result of the multiplication is not a triangular fuzzy number. The following theorem provides a formula to determine a number as triangular fuzzy number.

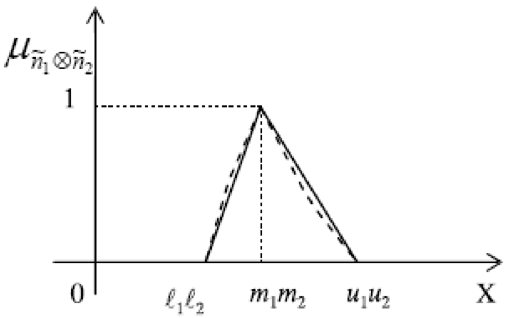
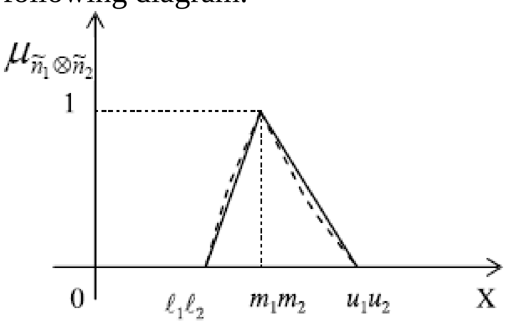


Figure 3- function $\tilde{n}_1 \otimes \tilde{n}_2$ and its estimate

Theorem 4-3- suppose that $\tilde{n}_1 = (\ell_1, m_1, u_1)$, and $\tilde{n}_2 = (\ell_2, m_2, u_2)$ are two triangular fuzzy numbers. $\tilde{n}_1 \otimes \tilde{n}_2$ Is an estimate of the triangular fuzzy number of $(\ell_1 \times \ell_2, m_1 \times m_2, u_1 \times u_2)$ [34], which means

$$\tilde{n}_1 \otimes \tilde{n}_2 \cong (\ell_1 \times \ell_2, m_1 \times m_2, u_1 \times u_2) \qquad (4)$$

This concept is shown in the following diagram.



Picture (3): $\tilde{n}_1 \otimes \tilde{n}_2$ Is an estimate of the triangular fuzzy number

Definition 7-3- a linguistic variable is a variable which its quantities are defined as linguistic expressions [31].
The concept of linguistic variable is used mainly by decision makers to express their evaluations, and it is very useful in situations where the common quantitative expressions are of no help. Linguistic quantities can be expressed as fuzzy numbers. For example, weight is a linguistic variable; its linguistic quantities can be expressions like very low, low, average, considerable, excess, etc. fuzzy numbers can also show these linguistic expressions [34].
In the majority of models, we have to turn the final fuzzy data into definite quantities. Of the methods of turning fuzzy numbers to definite numbers (defuzzification), is the method proposed by Apriquick and T Zheng [35] called CFCS. This method has the advantage of presenting a higher definite quantity with a larger function and differentiation of asymmetrical triangular fuzzy numbers.

Theorem 5-3-(CFCS defuzzification method) suppose that $\tilde{n}_k = (\ell_k, m_k, u_k); k = 1,2,...,n$ are triangular fuzzy numbers and $\tilde{n}_k^{def}$ is the referent of its quantity. Also we have $L = \min(\ell_k); R = \max(u_k)$; $k = 1,2,...,n$ and $\Delta = R - L$.

$$\tilde{n}_k^{def} = L + \Delta \times \frac{(m-L)(\Delta+u-m)^2(R-\ell)+(u-L)^2(\Delta+m-\ell)^2}{(\Delta+m-\ell)(\Delta+u-m)^2(R-\ell)+(u-L)(\Delta+u-m)} \quad (5)$$

4. Analytical fuzzy network process (FANP)
Up to now so many methods for solving multi-criteria problems have been proposed. One of the most efficient ones is the Analytical Hierarchy Process (AHP) which was proposed by Thomas Al Saati[36] in 1980. After awhile because it had not comprehensiveness, Al Saati in the year 1996 proposed a developed method under the name of analytical network process (ANP) [37]. In the following, we compare these two methods and then explain the steps in the fuzzy ANP method.
According to Dr Saati[38], ANP is more comprehensive than AHP and for comparing them we can mention the following:

1- ANP excels AHP by legalizing dependency. In fact, AHP is a special case of ANP.
2- ANP is linked with the dependency of elements in a set (internal dependency) and dependency of elements in other sets (external dependency).
3- The network structure of ANP makes it possible to present every decision-making problem without any worry about which comes first and which one next.
4- ANP is a non-linear structure, while a hierarchy is, having an aim at the highest level and other options at lower levels, has a linear structure.
5- ANP organizes not only elements, but also groups or bunches of elements which are also necessary in the real world, from the perspective of priority.

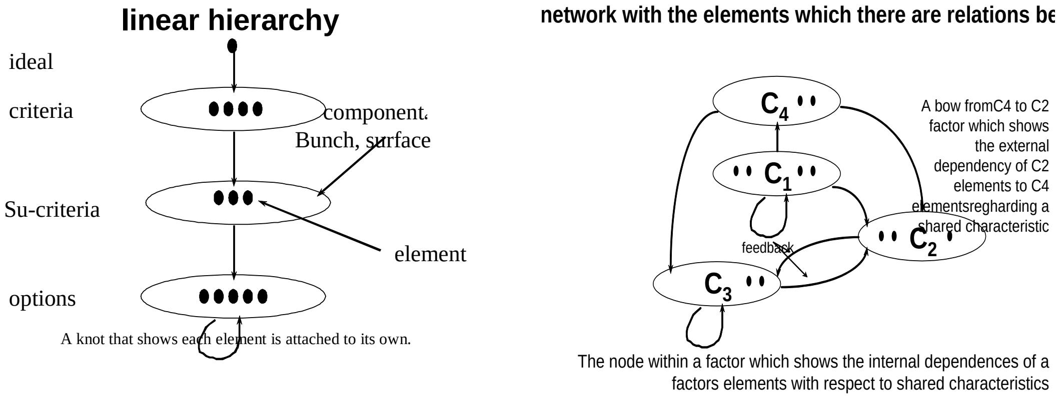


Figure 4 –structural differences between a linear and a non-linear network

Saati has presented the latest version of ANP as a method having twelve steps [39]. It must be kept in mind that because there are complex calculations, steps 8 to 12 are those which can be done using SuperDecisions software, in which case the difficulty of the method to a great extent ceases.

ANP for the rating and grading the priorities uses even comparisons matrices. The output numbers in these matrices are definite and in cases which the output numbers face ambiguity, we can use these matrices.

To solve this problem, Cheng and colleagues [40], have proposed a model that uses ANP in the fuzzy environment. The difference between this model and the ordinary ANP model is extracting the importance weights from even comparison matrices, which is explained in the following section. Other steps of this model are the same as the ordinary ANP model, so we avoid repeating them.

Accepting that each number in the matrices shows the personal opinion of decision-makers, and is a vague concept, for the purpose of unifying the different opinions of the experts, fuzzy numbers are used:

$$\tilde{u}_{ij} = (L_{ij}, M_{ij}, U_{ij}) \qquad L_{ij} \le M_{ij} \le U_{ij} \ , \ L_{ij}, M_{ij}, U_{ij} \in [1/9, 9] \tag{6}$$

$$L_{ij} = \min(B_{ijk}) \tag{7}$$

$$M_{ij} = \sqrt[n]{\prod_{k=1}^{n} B_{ijk}} \tag{8}$$

$$U_{ij} = \max(B_{ijk}) \tag{9}$$

In which, B_{ijk} refers to the k^{th} expert's judgment about the relative importance of the two criteria C_i and C_j.

In the following the fuzzy $\tilde{A}$ matrix of even comparisons is presented:

$$\tilde{A} = [\tilde{a}_{ij}] = \begin{matrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{matrix} \overset{\begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix}}{\begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \frac{1}{\tilde{a}_{12}} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{\tilde{a}_{1n}} & \frac{1}{\tilde{a}_{2n}} & \cdots & 1 \end{bmatrix}}$$

In which $\tilde{a}_{12}$ is the referent for a triangular fuzzy number which is used in determining the relative importance of C_1 and C_2. Meanwhile, $\lfloor \tilde{a}_{ij} \rfloor$refers to a matrix which has been produced by fuzzy numbers based on the formulas (6) to (9).

There are several defuzzification methods. The one used here, is the method proposed by Leo and Wang [42]. As is shown in formulas (10) and (11), this method clearly can make the fuzzy observations understood.

$$g_{\alpha,\beta}(\tilde{a}_{ij}) = \lfloor \beta . f_\alpha(L_{ij}) + (1-\beta). f_\alpha(U_{ij}) \rfloor \quad 0 \le \beta \le 1,\ 0 \le \alpha \le 1 \qquad (10)$$

In which $f_\alpha(L_{ij}) = (M_{ij} - L_{ij})\alpha + L_{ij}$ refers to the minimum amount of $\tilde{a}_{ij}$ section- α , and $f_\alpha(U_{ij}) = U_{ij} - (U_{ij} - M_{ij})\alpha$ refers to the maximum amount of $\tilde{a}_{ij}$ section- α.

$$g_{\alpha,\beta}(\tilde{a}_{ij}) = 1/ g_{\alpha,\beta}(\tilde{a}_{ij}) \qquad 0 \le \beta \le 1,\quad 0 \le \alpha \le 1, \qquad i > j \qquad (11)$$

Because of the ability of this method in clearly showing the priority tolerance (α) and risk tolerance (β) of the decision-makers, these people can feel and touch the risks which they are faced in different situations.

Furthermore α can be considered as stable or unstable conditions. When α =0, the uncertainty domain is in its highest amount. Also, the decision-making environment becomes more stable as α increases, and simultaneously, decision-making variance decreases. Also, α can be a number between 0 and 1 and usually is a set consisting ten numbers of 0/1, 0/2… 1 for showing the uncertainty. In addition, while α =0 refers to the maximum amount of U_{ij} and minimum amount of L_{ij} in triangular fuzzy numbers, and $\alpha = 1$ refers to the geometrical mean of M_{ij} in triangular fuzzy numbers, β is considered as the pessimism amount of the decision-maker. When $\beta = 0$, the decision-maker is more optimistic, so the experts' agreement is the maximum amount of the higher limit of the triangular fuzzy number. When $\beta = 1$, the decision-maker is pessimistic and the domain of numbers

Each person's even comparisons matrix is shown as follows:

$$g_{\alpha,\beta}(\tilde{A}) = g_{\alpha,\beta}([\tilde{a}_{ij}]) = \begin{matrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{matrix} \overset{\begin{matrix} C_1 & \quad C_2 & \quad \cdots & \quad C_n \end{matrix}}{\begin{bmatrix} 1 & g_{\alpha,\beta}(\tilde{a}_{12}) & \cdots & g_{\alpha,\beta}(\tilde{a}_{1n}) \\ \frac{1}{g_{\alpha,\beta}(\tilde{a}_{12})} & 1 & \cdots & g_{\alpha,\beta}(\tilde{a}_{2n}) \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{g_{\alpha,\beta}(\tilde{a}_{1n})} & \frac{1}{g_{\alpha,\beta}(\tilde{a}_{2n})} & \cdots & 1 \end{bmatrix}}$$

$\lambda_{\max}$Refers to the special amount of even comparisons of the matrix $g_{\alpha,\beta}(\tilde{A})$.

$\lfloor g_{\alpha,\beta}(\tilde{A}) - \lambda_{\max} \mathrm{I} \rfloor W = 0$ And $g_{\alpha,\beta}(\tilde{A})W = \lambda_{\max} W$ in which W refers to the special vector of $0 \le \alpha \le 1$, $0 \le \beta \le 1,$, $g_{\alpha,\beta}(\tilde{A})$, .

5. DEMATEL fuzzy technique:

DEMATEL method has been developed by the science and knowledge program of the Battelle Memorial institute in Geneva between 1972 and 1976. it is used for studying and solving complex problems. DEMATEL method is based on directional diagraphs which can differentiate the related factors into two groups: causative and affective. These diagraphs show the dependency relations between elements in a system, in a way that the numbers on each graph shows the amount of effect of each element on the other elements. So, DEMATEL can turn the relations between the causative and affective elements into an understandable structural model of the system [43].

Considering that for using DEMATEL we need experts' opinions and these opinions often include unclear and equivocal linguistic expressions, for integrating and clearing them, it’s better to turn them into fuzzy numbers. To solve this problem, Lin and Wu [44], have presented a model that makes use of DEMATEL in the fuzzy environment. In the following, we explain the steps involved in DEMATEL:

First step: determine the ideal for decision-making and establish a committee for gathering the ideas.

Second step: determining the evaluation criteria and designing a fuzzy linguistic measure.

Because of confronting so many vagueness in human evaluations, we ignore the measures used in the ordinary DEMATEL model and instead, we use the fuzzy linguistic comparative measure, proposed by Lee [32]. Different degrees of 'effect' are expressed using five words: very high, high, low, very low, without effect. The related triangular fuzzy numbers are shown in the following table:

Table 3- numeric amounts of linguistic expressions

Numeric amounts	Linguistic expressions
(0.75,1.0,1.0)	(VH) Very high effect
(0.5,0.75,1.0)	(H) High amount
(0.25,0.5,0.75)	(L) Low amount
(0,0.25,0.5)	(VL) Very low effect
(0,0,0.25)	(No) No effect

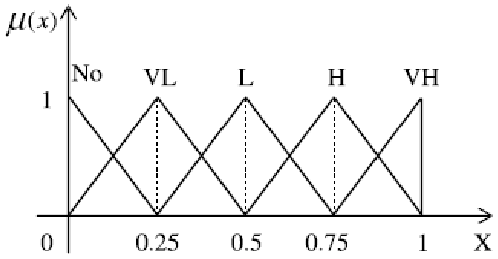


Figure 5- triangular fuzzy numbers for linguistic expressions

Third step: gather the evaluations made by decision-makers.

To determine the relation between the criteria of $C = \{C_i \mid i = 1,2,\ldots,n\}$, a group of experts consisted of p expert, are being questioned in order to obtain a set of even comparisons according to linguistic expressions. So, p amount of fuzzy matrix $\tilde{Z}^{\langle 1 \rangle}, \tilde{Z}^{\langle 2 \rangle}, \ldots, \tilde{Z}^{p}$ are produced using the experts' opinions.

$$k = 1,2,\ldots,p \qquad \tilde{Z}^{\langle k \rangle} = \begin{bmatrix} 0 & \tilde{z}_{12}^{\langle k \rangle} & \cdots & \tilde{z}_{1n}^{\langle k \rangle} \\ \tilde{z}_{21}^{\langle k \rangle} & 0 & \cdots & \tilde{z}_{2n}^{\langle k \rangle} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{n1}^{\langle k \rangle} & z_{n2}^{\langle k \rangle} & \cdots & 0 \end{bmatrix}$$

in which $\tilde{z}_{ij}^{\langle k \rangle} = \left(\ell_{ij}^{\langle k \rangle}, m_{ij}^{\langle k \rangle}, u_{ij}^{\langle k \rangle} \right)$. The initial direct-relation fuzzy matrix is called the k^{th} expert.

Fourth step: obtaining the normal direct-relation fuzzy matrix.

Suppose that $\tilde{a}_i^{\langle k \rangle}$ .is a triangular fuzzy numbers,

$$\tilde{a}_i^{\langle k\rangle} = \sum_{j=1}^{n} \tilde{z}_{ij}^{\langle k\rangle} = \left(\sum_{j=1}^{n} \ell_{ij}^{\langle k\rangle}, \sum_{j=1}^{n} m_{ij}^{\langle k\rangle}, \sum_{j=1}^{n} u_{ij}^{\langle k\rangle} \right) \quad , \quad r^{\langle k\rangle} = \max_{1\le i\le n} \left(\sum_{j=1}^{n} u_{ij}^{\langle k\rangle} \right)$$

Then to turn these criteria to comparable criteria, linear measure changing is used as a normalizing formula. The normalizing direct-relation fuzzy matrix of the k th expert is shown in the following:

$$\tilde{X}^{\langle k\rangle} = \begin{bmatrix} \tilde{x}_{11}^{\langle k\rangle} & \tilde{x}_{12}^{\langle k\rangle} & \cdots & \tilde{x}_{1n}^{\langle k\rangle} \\ \tilde{x}_{21}^{\langle k\rangle} & x_{22}^{\langle k\rangle} & \cdots & \tilde{x}_{2n}^{\langle k\rangle} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1}^{\langle k\rangle} & \tilde{x}_{n2}^{\langle k\rangle} & \cdots & \tilde{x}_{nn}^{\langle k\rangle} \end{bmatrix} \qquad k = 1,2,\ldots,p$$

$$\tilde{x}_{ij}^{\langle k\rangle} = \frac{\tilde{z}_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}} = \left(\frac{\ell_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}}, \frac{m_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}}, \frac{u_{ij}^{\langle k\rangle}}{r^{\langle k\rangle}} \right)$$

As the ordinary DEMATEL method, we suppose that there is at least one i which $\sum_{j=1}^{n} u_{ij}^{\langle k\rangle} < r^{\langle k\rangle}$.

This supposition is calculated well, practically. Then, formulas (1) and (2) are used to calculate the mean matrix of $\tilde{X}$, which is produced by $\tilde{X}^{\langle 1\rangle}, \tilde{X}^{\langle 2\rangle}, \ldots, \tilde{X}^{\langle p\rangle}$

$$\tilde{X} = \frac{\left(\tilde{X}^{\langle 1\rangle} \oplus \tilde{X}^{\langle 2\rangle} \oplus \cdots \oplus \tilde{X}^{\langle p\rangle} \right)}{p}$$

$$\tilde{x}_{ij} = \frac{\sum_{k=1}^{p} \tilde{x}_{ij}^{\langle k\rangle}}{p} \qquad \tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & x_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \tilde{x}_{nn} \end{bmatrix}$$

In that, the fuzzy matrix $\tilde{X}$ is called the normal direct-relation fuzzy matrix. Here, we use the arithmetic average to integrating all of the data collected after the calculation of the normal direct-relation fuzzy matrix ($\tilde{X}^{\langle k\rangle}$). This method is better than the integration of all the experts' data after calculating the initial direct-relation fuzzy matrix ($\tilde{Z}^{\langle k\rangle}$).

Fifth step: execution and analyzing the structural model.

To measure the total-relation fuzzy matrix, first of all we must guarantee the convergence of $\lim_{w\to\infty} \tilde{X}^w = 0$. In measuring $\tilde{X}^w$, we use the approximation formula (4) to multiply two triangular fuzzy numbers. In fact, formula (4) is in complete agreement with formula (3). So, the elements of $\tilde{X}^w$ are also triangular fuzzy numbers.

Suppose that $\tilde{x}_{ij} = \left(\ell_{ij}, m_{ij}, u_{ij}\right)$, and consider the following three matrixes from which the elements of $\tilde{X}$ are extracted:

$$X_u = \begin{bmatrix} 0 & u_{12} & \cdots & u_{1n} \\ u_{21} & 0 & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u_{n1} & u_{n2} & \cdots & 0 \end{bmatrix} \qquad X_m = \begin{bmatrix} 0 & m_{12} & \cdots & m_{1n} \\ m_{21} & 0 & \cdots & m_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ m_{n1} & m_{n2} & \cdots & 0 \end{bmatrix} \qquad X_\ell = \begin{bmatrix} 0 & \ell_{12} & \cdots & \ell_{1n} \\ \ell_{21} & 0 & \cdots & \ell_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_{n1} & \ell_{n2} & \cdots & 0 \end{bmatrix}$$

According to the definite state, we define the total-relation fuzzy matrix in this way:

$$\tilde{T} = \lim_{w\to\infty} \left(\tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^w \right) = X \times \left(\mathrm{I} - X \right)^{-1}$$

Theorem 1-5: suppose that:

in that case: $\tilde{t}_{ij} = \left(\ell''_{ij}, m''_{ij}, u''_{ij}\right)$ in which $\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \tilde{t}_{nn} \end{bmatrix}$

$$Matrix\left[u''_{ij}\right] = X_u \times \left(\mathrm{I} - X_u\right)^{-1} \quad , \quad Matrix\left[m''_{ij}\right] = X_m \times \left(\mathrm{I} - X_m\right)^{-1} \quad , \quad Matrix\left[\ell''_{ij}\right] = X_\ell \times \left(\mathrm{I} - X_\ell\right)^{-1}$$

Now that the T matrix has been acquired, we use CFCS, formula 5, to defuzzification and obtaining total-relation fuzzy matrix.

The total-relation matrix of DEMATEL method can easily be replaced to ANP importance-weighing matrix of internal relations.

6- The proposed model for outsourcing/insourcing decision-making:

Decision-making in issues related to insourcing and outsourcing of production activities, requires making use of a variety of qualitative and quantitative factors in a logical manner. So, decision-making in these issues is a multiple-criteria decision-making and for being solved, requires using systematic and highly dependable methods.

Most of the common MCDM methods are based on the supposition of independence of elements. But one criterion cannot be independent all the time. To solve the issue of facing with the elements reciprocal effects, Analytical Hierarchy Method was proposed by Saati as a rather new method of MCDM. ANP is able to consider various dependencies in a systematic way. This method has been successfully used in so many contexts. However, the function of ANP in dealing with dependencies is not faultless [45]. From another point of view, the DEMATEL method not only can turn the relations between cause and effect into a clear structural model, but also it can be used as a useful method in facing with the internal dependencies within a set of criteria. In fact, DEMATEL is able to present more valuable data to decision-makers than ANP method. [45, 46]

Considering that to use ANP and DEMATEL methods in decision making, it is necessary to make use of the experts' opinions and that these opinions are generally in the form of linguistic expressions, consisting of equivocal and vague concepts, both these methods are not able to make clear the linguistic evaluations conducted by the decision makers. In order to integrate and eliminate the vague points, it is good to turn the unclear linguistic expressions to fuzzy numbers and in fact these two methods be used in a fuzzy environment.

With respect to the mentioned advantages of ANP and DEMATEL, and the possibility of using them in the states of uncertainty, a new and effective method, based on the combination of ANP and DEMATEL methods is proposed in the fuzzy environment to help in decision making related to outsourcing and insourcing of production activities in the states of uncertainty.

The executive stages of this proposed model are based on the twelve steps of the common ANP method. The difference of this method with the common one is that where the internal elements of each bunch, or the secondary criteria of a controlling criterion, have reciprocal effects on each other, or technically speaking, have internal dependency, for determining the degree of this reciprocal effect and their dependency, instead of using the common method of even comparisons method in ANP, we use the results obtained by the total-relation matrix used in the fuzzy DEMATEL, introduced in part 5. In other situations, to do even comparisons between effective indicators, even comparisons between each bunch, or between elements which effect each other in other bunches, the results obtained by the matrix of even comparisons in the fuzzy ANP method, introduced in part 4, is used instead of the common method of even comparisons used in the common ANP. The executive stages of this model are shown in the following diagram. In this way, not only the amount of calculations decreases, but also the linguistic analyses of decision makers are used in a more effective and convenient way

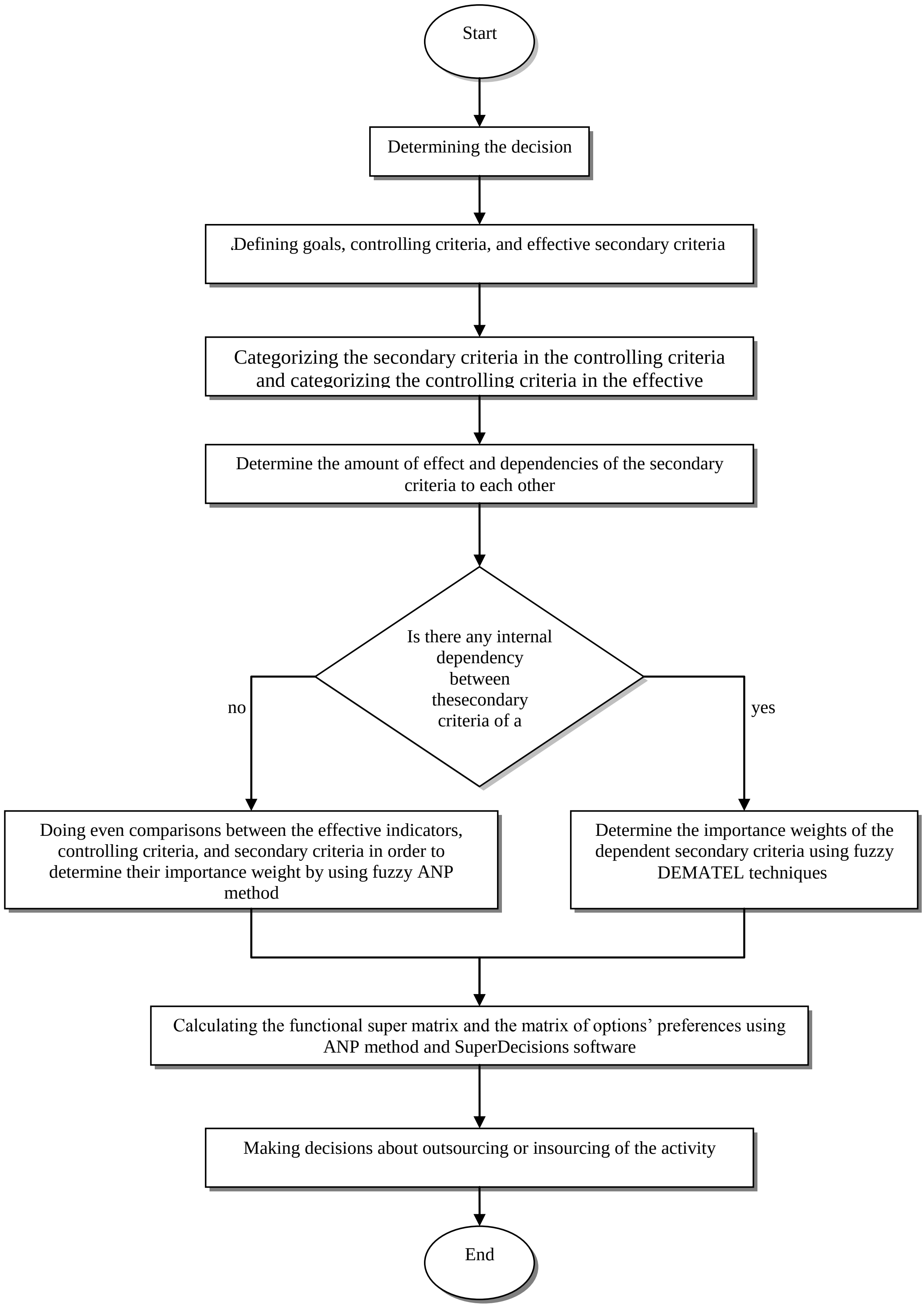


Figure 6-the executive of proposal model of outsourcing or insourcing

7-case study

In order to show the practicality of the proposed model, we tried to execute this model for four products of a production corporation. These products include the set below the engine, the supporting set of back shield, the supporting set of front shield, and the set of glass lift in a kind of automobile. The rum under the engine, is the protecting tray under the engine and its' related parts that connects the engine to the automobile's chassis. This device decreases the tremors caused by the engine by using the engine handle and other elastic shock-absorbers. The function of the other devises is clear by their names. The corporation wants to know considering the supplier's and its own condition is it good to try to do outsourcing of each in the products or to try to produce them itself. For this goal, the researcher after designing the decision-making model, after having several sessions with the experts involved in these matters, tried to justify the problem and the proposed model and based on this, the model was proposed in the framework of BOCR of ANP method. The reason for using BOCR framework is that each producing corporation gains some profit, spends some costs, and is faced with some risks by way of outsourcing or insourcing in producing some product, this altogether must have convenient added value for the corporation.

For all of the mentioned products, we define a similar model, the ideal of which is to answer this question: is it better to outsource or insource in the production of this product? The options for this kind of decision-making are: outsourcing the production to one of A or B companies, insourcing the production, which means doing the job by the company itself, controlling criteria and their secondary criteria which have been used in the model, were determined by the decision-makers by using a questionnaire and were categorized in the effective indicators (BOCR) shown in the following table.

Table 4- controlling criteria of decision-making networks and their secondary criteria

Secondary criteria	Controlling criteria	BOCR
1. Matching with the indicators 2. Mean time of replacement of the deported goods 3. Having quality management systems	quality	advantages
1. On-time delivery 2. Time of delivery	delivery	
1. Instrumental and capacity-related power 2. infrastructural power 3. expertise power and technical knowledge 4. Financial power	power	
1-focus on basic activities 2-Focus on the activities which are in accordance with the goals of the organization	staff	opportunities
1-costs 2-Transportation costs	Product cost	costs
1-Continuity in the production line 2-Quality control 3-Having the experience of expertise work	Work processes	risks
1-morale 2-permanence in the relations between management and staff	staff	
geographical distance	location	
Firm		The whole networks
Firm B		
Insourcing		

Each of the secondary criteria mentioned above have an indicator for evaluation and measurement by using which, each option is being measured. These indicators are also determined by the decision-makers.

According to decision-makers' opinions, three controlling criteria of quality, delivery, and power which are defined for the benefits section of the model, added by the decision-making options, constitute a secondary network as shown in Figure 7. For the 'opportunities', 'costs', and 'risks', similar secondary networks have been designed.

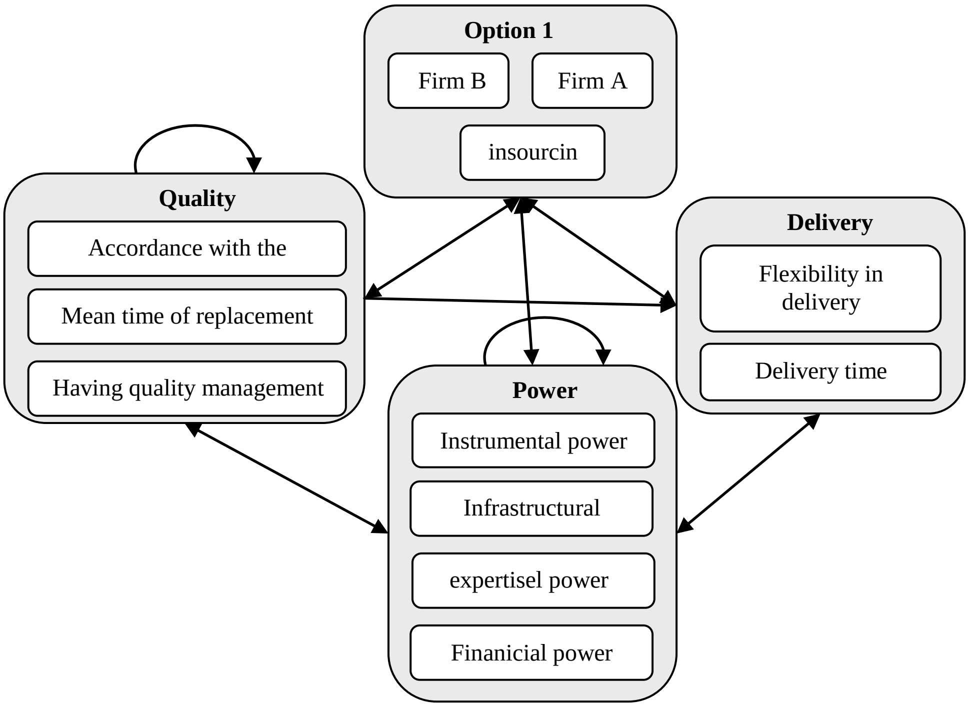


Figure 7- secondary network of the advantages

After the evaluation made by companies A and B, and insourcing using the above criteria's measurement indicators, and considering the formed relationships in decision-making models, we try to make even comparisons matrices of the importance of effective factors (BOCR), the controlling criteria, secondary criteria, and the even comparison matrices of those bunches which do not have any internal dependencies, and complete them with the help of decision-makers, using the results obtained of the evaluation of the measurement indicators. Then using the fuzzy ANP introduced in part 4, we measure the importance weights of each matrix and try to establish super matrices. In this super matrix, the place of importance weight of those matrices which do have any internal dependencies is empty. With the help of the decision-makers opinions, we find that in the benefits section, the two secondary controlling criteria of power and quality do have internal dependencies. In the opportunities section of the models also, the secondary criteria of the controlling criteria of the staff have internal dependencies, and in the risks section of the models, secondary criteria of the two controlling criteria, the staff and working processes have internal dependencies. So, for measuring their matrix of importance weights, we only use a total-relation fuzzy DEMATEL technique, introduced in section 5, instead of several fuzzy ANP matrices of even comparisons. We can do other stages of the model by using SuperDecisions software. Because of the high quantity of the data and the conducted measurements, we only summarize the output of different super matrices and the final result of the model. In non-weight super matrices, those parts that are colored as grey show the importance weight measured by the total-relation matrix in fuzzy DEMATEL technique, and other parts show the importance weights measured by the ANP method.

For example, in the case of the rum under the engine, we use the total-relation matrix to measure the controlling criteria of power and replace that with the importance weight measured by the ANP method.

Table5- linguistic analysis of the decision makers on the effects in the controlling criteria of power

	D1	D2	D3	D4
D1	NO	H	VL	L
D2	L	NO	VL	H
D3	VL	VL	NO	H
D4	VL	VH	L	NO

Table 6- the primary direct-relation matrix

	D1	D2	D3	D4
D1	0.0000	0.6091	0.5333	0.5674
D2	0.5333	0.0000	0.3671	0.7052
D3	0.5674	0.3333	0.0000	0.3333
D4	0.6000	0.6415	0.2638	0.0000

Table 7- the normal direct-relation matrix

	D1	D2	D3	D4
D1	0.0000	0.0901	0.0792	0.0843
D2	0.0792	0.0000	0.0546	0.1044
D3	0.0843	0.0496	0.0000	0.0496
D4	0.0892	0.0955	0.0393	0.0000

Table 8- complete direct-relation matrix

	D1	D2	D3	D4
D1	0.2630	0.4231	0.5465	0.1412
D2	0.4556	0.2275	0.1384	0.2634
D3	0.1413	0.1234	0.2324	0.1415
D4	0.1413	0.2276	0.0845	0.4556

Table 9-No weight super-matrix of advantages

		A1	A2	A3	B1	B2	B3	C1	C2	D1	D2	D3	D4
A1	Outsourcing	0.0000	0.0000	0.0000	0.7778	0.7778	0.8182	0.7778	0.7694	0.8182	0.7778	0.8182	0.8182
A2	Company(A)	0.0000	0.0000	0.0000	0.1111	0.1111	0.0909	0.1111	0.1778	0.0909	0.1111	0.0909	0.0909
A3	Company(B)	0.0000	0.0000	0.0000	0.1111	0.1111	0.0909	0.1111	0.0528	0.0909	0.1111	0.0909	0.0909
B1	Adaption with specification	0.8182	0.4737	0.7778	0.6370	0.1634	0.1634	0.0000	0.0000	0.1667	0.2500	0.6667	0.1220
B2	The average time to replace items returned	0.0909	0.4737	0.1111	0.2583	0.5396	0.5396	0.0000	0.0000	0.8333	0.7500	0.3333	0.2296
B3	Quality management systems	0.0909	0.0526	0.1111	0.1047	0.2970	0.2970	0.0000	0.0000	0.0000	0.0000	0.0000	0.6483
C1	Flexibility in delivery	0.8750	0.8333	0.8750	0.0000	0.2500	0.8333	0.0000	0.0000	0.1667	0.7500	0.6667	0.7500
C2	Delivery time	0.1250	0.1667	0.1250	1.000	0.7500	0.1667	0.0000	0.0000	0.8333	0.2500	0.3333	0.2500
D1	Power equipment and capacity	0.2111	0.6829	0.0700	0.0000	0.0000	0.0000	0.0000	0.0000	0.2630	0.4231	0.5465	0.1412
D2	Power infrastructure	0.6162	0.1762	0.0700	0.0000	0.0000	0.0000	0.0000	0.0000	0.4556	0.2275	0.1384	0.2634
D3	Professional and technical knowledge can	0.1391	0.0454	0.5384	0.0000	0.0000	0.0000	0.0000	0.0000	0.1413	0.1234	0.2324	0.1412
D4	Power financial	0.0336	0.0954	0.3215	1.0000	1.0000	1.0000	1.0000	1.0000	0.1413	0.2276	0.0845	0.4556

Table 10- Weight super-matrix of advantages

		A1	A2	A3	B1	B2	B3	C1	C2	D1	D2	D3	D4
A1	Outsourcing	0.0000	0.0000	0.0000	0.1944	0.3889	0.2045	0.3889	0.3847	0.2045	0.1944	0.2045	0.2045
A2	Company(A)	0.0000	0.0000	0.0000	0.0278	0.0556	0.0277	0.0556	0.0889	0.0227	0.0278	0.0227	0.0227
A3	Company(B)	0.0000	0.0000	0.0000	0.0278	0.0556	0.0227	0.0556	0.0264	0.0227	0.0278	0.0277	0.0227
B1	Adaption with specification	0.1564	0.0906	0.1487	0.1528	0.0392	0.0392	0.0000	0.0000	0.0417	0.0625	0.1667	0.0305
B2	The average time to replace items returned	0.0174	0.0906	0.0212	0.02620	0.1295	0.1295	0.0000	0.0000	0.2083	0.1875	0.0833	0.0574
B3	Quality management systems	0.0174	0.0101	0.0212	0.251	0.0712	0.0712	0.0000	0.0000	0.0000	0.0000	0.0000	0.1621
C1	Flexibility in delivery	0.0420	0.0400	0.0420	0.0000	0.1250	0.2083	0.0000	0.0000	0.0417	0.1875	0.1667	0.1875
C2	Delivery time	0.0060	0.0800	0.0060	0.2500	0.3750	0.0417	0.0000	0.0000	0.2083	0.0625	0.0833	0.0625
D1	Power equipment and capacity	0.1606	0.5195	0.0533	0.0000	0.0000	0.0000	0.0000	0.0000	0.1324	0.2125	0.2731	0.0701
D2	Power infrastructure	0.4688	0.1341	0.5333	0.0000	0.0000	0.0000	0.0000	0.0000	0.2287	0.1136	0.0694	01324
D3	Professional and technical knowledge can	0.1059	0.0346	0.4096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0701	0.0613	0.1162	0.0701
D4	Power financial	0.0255	0.0726	0.2446	0.2500	0.2500	0.2500	0.5000	0.5000	0.0701	0.1142	0.0423	0.2287

Table 11- functional super matrix of advantages

		A1	A2	A3	B1	B2	B3	C1	C2	D1	D2	D3	D4
A1	Outsourcing	0.1942	0.1942	0.1942	0.1942	0.1942	0.1942	0.1942	0.1942	0.1942	0.1942	0.1942	0.1942
A2	Company(A)	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.2285	0.0285	0.0285	0.0285	0.0285
A3	Company(B)	0.0233	0.0233	0.0233	0.0233	0.0233	0.233	0.0233	0.0233	0.0233	0.0233	0.0233	0.0233
B1	Adaption with specification	0.0891	0.0891	0.0891	0.0891	0.0891	0.0891	0.0891	0.0891	0.0891	0.0891	0.0891	0.0891
B2	The average time to replace items returned	0.0578	0.0578	0.0578	0.0578	0.0578	0.0578	0.0578	0.0578	0.0578	0.0578	0.0578	0.0578
B3	Quality management systems	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312
C1	Flexibility in delivery	0.0884	0.0884	0.0884	0.0884	0.0884	0.0884	0.0884	0.0884	0.0884	0.0884	0.0884	0.0884
C2	Delivery time	0.0835	0.835	0.0835	0.0835	0.0835	0.0835	0.0835	0.0835	0.0835	0.0835	0.0835	0.0835
D1	Power equipment and capacity	0.0709	0.0709	0.709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709
D2	Power infrastructure	0.1139	0.1139	0.1139	0.1139	0.1139	0.1139	0.1139	0.1139	0.1139	0.1139	0.1139	0.1139
D3	Professional and technical knowledge can	0.0524	0.0524	0.0524	0.0524	0.0524	0.0524	0.0524	0.0524	0.0524	0.0524	0.0524	0.0524
D4	Power financial	0.1670	0.1670	0.1670	0.1670	0.1670	0.1670	0.1670	0.1670	0.1670	0.1670	0.1670	0.1670

Table 12- options priorities with reference to the indicators of advantages

Options	Ideal Priority	Normal Priority	Initial Priority
In sourcing	1.0000	0.7720	0.1879
Company(A)	0.1059	0.0817	0.0199
Company(B)	0.1895	0.1463	0.0356

We mean by the primary preference as the first three numbers of the first column of the limiting super matrix. The normal preference is obtained by dividing each primary preference by the whole primary preferences. The ideal preference is also obtained by dividing each normal preference on the largest normal preference.

It is evident from the above table that the insourcing of the project related to the rum under the engine, gains the largest profit for the company; also outsourcing the project to company B, gains the minimum amount of profits for the company.

Because of the high quantity of data and calculations, we only present the final normal output of the four models.

Table 14- the final normal priorities of options

outsourcing		insourcing	Product's name
B firm	A firm		
0.1579	0.0759	0.7662	Rum under the engine
0.2969	0.6175	0.0856	Supporter of the back shield
0.5286	0.3364	0.1350	Supporter of the front shield
0.1220	0.2297	0.6483	Left and right glass elevators

The above table takes into account the BOCR indicators simultaneously and determines the desirability of each option. The numbers within the table have been obtained using $bB + oO - cC - rR$ formula. The small letters are the ideal preferences of the options in the domains of profits, opportunities, costs, and risks. Capital letters, on the other hand, show the preferences of the effective indicators in the domains of profits, opportunities, costs, and risks for all models. Based on this we can conclude that in the case of the rum below the engine, the best option is insourcing its production. Also, it is better to outsource the production of the supportive set of the back shield to company A. outsourcing of the production of the supportive set of front shield is offered to company B, and the best option for producing glass escalators of right and left, is insourcing them.

8-summary and conclusion

As it was evident, the majority of the past decision-making models of insourcing and outsourcing has not considered this issue comprehensively and in a multidimensional way, and has only tried to solve the problem using a few qualitative or quantitative criteria. From another point of view, few models have been proposed related to decision-making in the case of determining insourcing of the production activities. Also, no method was found to be applicable in the fuzzy environment.

So, in this research, we tried by presenting a new eclectic multi-criteria model of decision-making, make decisions about insourcing and outsourcing of production activities in cases of uncertainty based on various qualitative and quantitative criteria. In fact, this model can answer two questions simultaneously: the first question is that which activities should be insourced or outsourced? And the second is that to whom it should be handed over?

From a structural point of view, this model, this is based on the combination of ANP and DEMATEL in the fuzzy environment, in addition to making clear the vague points and uncertainties of the linguistics expressions of the decision-makers, solve one of problems of ANP method which is studying a large number of even comparisons to obtain the importance weights of those criteria which have internal dependencies.

Also, this model can calculate the amount of profits, opportunities, risks, and costs related to outsourcing and insourcing of the production activity, and make the decision-making process easier.

Considering the comprehensiveness of the criteria in this model, it can be used in the case of insourcing or outsourcing of every kind of product and also various decision-making options can be entered to the model according to the situations and priorities of the companies.

In the future researches, work can be done on a model which answers this question: if the score of more than one company was positive, according to differing criteria like capacity, number of personnel, and costs, to what extent each of the companies can take part in the project.

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