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The application of ISM model in evaluating agile suppliers selection criteria and ranking suppliers using fuzzy TOPSIS-AHP methods

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A B S T R A C T

In the present competitive world, the organizations need to endeavor constantly so as to make progress as well as maintaining their current position through employing the appropriate strategies. Organizations surroundings have been undergoing rapid changes among which the different demands and the variety of customers are to be mentioned. The scarce and limited number of sources and facilities are also worth being cited as another example of an important restrictions placed on companies. One way to bring down these problems is employing agile suppliers and outsourcing appropriately. The current study results from two theses completed in the fields of agility and ISM. It begins with identifying the criteria to evaluate agile suppliers. Then these factors are ranked and categorized using the interpretive structural model. The results of this study depict that the delivery speed variable lays on the bottom level of the model outlet with quite high driving power. The delay reduction variable has the same characteristics. Next, using fuzzy hierarchical analysis method, the weight of the agility evaluation criteria of suppliers are measured and put as TOPSIS model input. Finally, six suppliers are rated using fuzzy TOPSIS method. The results of this study shows that the criteria with higher driving power and lower dependence have higher weight in AHP model. It is, therefore, necessary to focus on variables of the first and second level of model in order to increase suppliers' agility. In this study, the weight of data has been determined using hierarchical analysis so as to increase the efficiency of the results of fuzzy TOPSIS technique. At the same time, interpretive structural model has been also employed to interpret the effects of the criteria on suppliers.

1. Introduction

In the past, an organization's products including services or goods used to be bought by customers, and organizations did not have to show any concerns about making any changes or improving their system. As a matter of fact, customers had no choice except to purchase the goods available in the market. However, with the number of manufactures and, as a result, competitors being increased gradually, customers had more freedom to choose and buy whatever suited their preferences among a wide variety of products and organizations offering them. Rapid technological revolution, risk increase, globalization, and privatization expectations are of environmental features with which the current trading organizations are dealing. To succeed in this environment, agility creates a competitive advantage which can be preserved by being famous for innovation and quality. An agile organization makes processes and people compatible with new state-of-the-art technology and accommodates customer's needs based on its quality products and services in a rather short period of time. This certainly would occur when agility was considered a disciplined organizational value and a competitive strategy for managers. In this regard, organizations have to offer the products which can gain customer's satisfaction. Supply chain management and supplier selection process has been given a particular consideration recently. In 1990s a lot of factories were searching for a way to share with suppliers so that they can improve their management efficiency and competitiveness. The supplier and consumer relationship has been seriously considered. Supply chain of a company would be a strong and serious barrier against competitors if there were a long lasting relationship between these two items (Shahaei, 2007). With purchase and supply growth, purchase decisions have become of more importance and since current organizations are more dependent on suppliers, the direct and indirect consequence of feeble decision making appears more serious (De Boer, Labro, & Morlacchi, 2001).

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In most industries, the cost of raw materials and the constituents of the product accounts for the main proportion of price of the finished product (Ghodsypour & O'brien, 1998). In this regard, supply section can play a key role in the performance and efficiency of an organization and has a direct effect on cost minimization, profit making, and flexibility of a company (Ghodsypour & O'brien, 2001). Supply chain is a network which includes all tasks pertinent to goods stream and conversion from raw material to final product stage as well as the corresponding information system. The materials and information are both flowing at the top and bottom of the network and for the supply chain to have a good performance and to gain customer satisfaction, a proper management is needed (Farahani & Asgari, 2007). As a matter of fact, selecting an appropriate collection of suppliers serves a vital function for a company to succeed, on which there has been great emphasis since a long time ago (Zhang, Lei, Cao, To, & Ng, 2003). With the concept of supply chain management having been introduced recently, a majority of researchers, scientists, and managers have found selecting the appropriate supplier and managing it a useful way which can be used to improve supply chain competitiveness (Lee, Ha, & Kim, 2001). Considering a supplier as a supply chain network with the ultimate goal of offering customer's expected product has been introduced and discussed since 2000 (Ali Ahmadi, Tajeddin, & Fatola, 2003). Foreign suppliers contribute to cost minimization, better delivery, and customer satisfaction; in other words, if a company can get in contact with foreign suppliers, it would be one of the most significant duties of the manager to select the supplier. In 1974, Warfield introduced the ISM approach to identify interrelationships between factors from a recommended list (Jindal and Sangwan, 2013; Kannan & Haq, 2007; Kannan, Pokharel, & Sasi Kumar, 2009) This approach was also used to identify the influential role of factors from a recommended list, and it suggested the use of expert opinions based on various management techniques such as brainstorming, nominal technique, etc. to develop a contextual relationship among variables. Attri, Dev, and Sharma (2013) summarized that the ISM technique was an interactive learning process where a set of different and directly related elements are structured into a comprehensive system model. In addition, ISM is a better approach to solve the complexity of relationships with many elements (Mathiyazhagan & Haq, 2013). Similarly, Ansari, Kharb, Luthra, Shimmi, and Chatterji (2013) pointed out that ISM enables individuals or groups to develop a map of the multiple relationships between many elements involved in a complex situation. Generally, ISM is a combination of three modeling languages – words, digraphs, and discrete mathematics – to ensure a solution to a structure of complex issues. This approach is used for an effective decision making process. It is also used traditionally in management studies. The researchers selected this approach because of its benefits; direct and indirect relationships between variables based on situations are revealed far more accurately than individual factors taken in isolation (Cagno, Micheli, Jacinto, & Masi, 2014). In fact, ISM method states that how the factors being studied such as cost, supply chain, innovation, and etc are involved in a company to meet its targets and how they are dependent. That is to say, these features are agility drivers which have been introduced by several different researchers for years. According to the studies done, achieving agility can guarantee the persistence and progress of an organization. These features are explained in details in the agility section. One important aspect of agility is the supply chain section of an organization. If the management section can select the agile and prominent supplier using the appropriate factors and methods, it will be of great help for the organization to achieve its goals. Interpretive structural model is capable of identifying the relationship between criteria which have individual or group dependence on each other. Multi-criterion decision making is one of the research areas in operational and management science which considering various functional needs has been developed rapidly during the current decade. Computers have helped decision making techniques be quite acceptable in all steps of decision making process. Applying computers has had a considerable increase particularly in recent years; therefore, considering mathematical complexities it has become very easy to use multi-criterion decision making methods. Decision making is a way to find the best choice from a set of existing choices. When several criteria are considered in decision making problems, they are called multi-criterion decision making (MCDM) problems (Wang, Lee, & Lin, 2003). Since making decision and selecting agile supplier by an organization is a decision making problem on which several criteria have effect, one of the multi-criterion decision making methods called analytical hierarchical process, AHP, is used in this study. Choy and Lee (2002) introduced a decision making model for suppliers in which the most important suppliers' task are defined in five sections (Choy, Lee, & Lo, 2002). Sarkis and Talluri (2002) have offered a model to evaluate suppliers which has ranked factors based on analytic network process, ANP. Ravi, Shankar, and Tiwari (2005) evaluated and selected the suppliers of a computer network using balance score card and decision making model based on ANP. Ravi et al. (2005) determined eleven barriers to select suppliers in car industry and used ISM methodology to analyze the interaction of these barriers. The details of supplier's selection are introduced by the scientists like Kannan, Haq, Sasikumar, and Arunachalam (2008) and Pokharel and Mutha (2009). Kannan and Haq (2008) used ISM and AHP in a certain environment to determine the ranking and the interaction of different criteria to select a supplier based on his performance.

ISM analyzes the relationship between criteria by decomposing them into different levels (Kannan et al., 2009). ISM can be used to analyze the relationship between the features of several variables which are defined for a problem (Jw, 1974). The study carried out by Saxena and Vrat (1992) centers on the ISM function to analyze the relationship between defined variables for cement factory in India. Mandal and Deshmukh (1994) used ISM method to analyze the most important criteria to select the best vendor and the relationship between criteria. Also Sharma (1995) has hierarchically analyzed necessary tasks for a sound production management. Kannan and Haq (2007) have analyzed the criteria and sub criteria needed to select supplier. ISM methodology has few limitations and identifying the relationship between the variables usually depends on the information and the decision maker's acquaintance with the company being studied. Consequently, the individuals' judgment, on the variables can influence the final result (Kumar, Kee, & Manshor, 2009). Despite the wide and successful applications of AHP in a lot of decision making problems, it has always been criticized for its inability in managing uncertainty resulting from relating whole numbers to decision makers' understanding (Deng, 1999). The natural approach to confront the judgments or uncertain decisions is to use fuzzy sets or fuzzy numbers in comparison ratios. In this study, the given framework to analyze and evaluate the agile suppliers includes a number of stages in part of which the fuzzy AHP method has been used to weigh criteria. TOPSIS is a well-known technique for classic MCDM, firstly proposed by Hwang and Yoon. The underlying logic of TOPSIS is ideal and negative ideal solution. The ideal solution is the solution that maximizes benefit criteria and minimizes cost criteria. To sum up, the ideal solution includes all the best values of available criteria while the negative ideal solution is mixture of the worst values of available criteria. The best alternative is the one which has the shortest distance from the ideal solution and the farthest distance from the negative ideal solution. Considering the fact that TOPSIS is a well-known method for classic MCDM, a lot of researchers use it to solve the FMCDM problems. Some researchers have done dis-Fuzzy rates and weights (Yu, 2002). While dis-Fuzzy lead to a loss of some data, some others

(Anand Raj & Nagesh Kumar, 1999; Liang, 1999; Chen, 2000) and supposed that TOPSIS must be generalized in a fuzzy environment. The selection criteria has been evaluated independently and as definite magnitudes in researches thus far been carried out. In addition, certain ranking methods have been applied so as to rank suppliers among which one supplier is being studied.

In the past studies, the ISM model or other decision making methods were single-handedly used while their functions have not ever shown certainly. In the present study begins with leveling the suppliers' evaluation criteria using ISM method and then is followed by weighing each criterion using fuzzy AHP method and ranking the suppliers by TOPSIS method.

2. Agile supplier evaluation criteria

Following the scientific and executive experts meeting, a novel paradigm report entitled "Production Agent Strategy in the 21st Century: Industrial Experts Standpoint" was published and made public by Uacocca institute (Nagel & Dove, 1991). Soon after, the term "agile" came to a common use by all (Gunasekaran, Patel, & Tirtiroglu, 2001).

Several different studies have been conducted in order to identify and to evaluate the organizational agility degree, one of whose main factors is chain supply whose criteria are introduced and explained subsequently. Goldman gives a brief definition of agility in terms of three terms including strategic reaction, pervasive changes, and dominant and outstanding system. He believes that agility is a pervasive and complete reaction to the fundamental changes made in a system governing competitive trading in top economies (Goldman, Nagel, & Preiss, 1995). In the study carried out by Pandey and Garg (2009) entitled "Analysis of the interaction among agile divers in supply chain", thirty six drivers adopted from other studies are introduced, and put into twelve categories. These twelve drivers, which are given for the supply chain to achieve agility, are studied in terms of their interactive effects with the goal of identifying the way these drivers are related. These drivers are as follows

1. Automation (automating or replacing manual production with CAM/CAD).
2. Buyer and vendor interactive reliability and relationship (Simchi-Levi, Kaminsky, Simchi-Levi, & Shankar, 2008).
3. Integration and contribution in production and purchase planning (Fliedner, 2003).
4. Processes integration (Mason-Jones & Towill, 1999).
5. The function of Information and communication technology means.
6. Logistic planning and management (Simchi-Levi et al., 2008).
7. agile production approach (Monden, 2011).
8. Understanding instability (turbulence) of market (Fynes, De Búrca, & Marshall, 2004).
9. Agile and appropriate delivery (Milgate, 2001).
10. Cost minimization (Kumar & Brittain, 1995).
11. Quality improvement (Yasin, Alavi, Kunt, & Zimmerer, 2004).
12. Customer satisfaction (Chan, Qi, Chan, Lau, & Ip, 2003).

In another study on CAM/CAD as a tool to achieve agility, carried out Vinodh, Sundararaj, Devadasan, and Rajanayagam (2009) some of the abilities of agility are studied which have been already noticed by other scientists. Studying the effect of CAM/CAD on organizational agility, this article has introduced the following abilities:

1. Fast production and improvement.
2. Restructuring production process dynamically.
3. Product improvement.
4. Making change for an improved product (Lee & Kim, 1998).
5. Delivery time reduction, product preservation, and response to various demands and new technology (Ismail, Snowden, Poolton, & Reid, 2006).
6. The capability of performing beneficial tasks continuously and replying to unexpected changes.
7. Low rate demands and rather short life cycle of a product (Elkins, Huang, & Alden, 2004).

Production criteria are also introduced in this study which are certainly extracted from other researchers' studies. They are as follows,

1. Production span reduction (Ismail et al., 2006, Onuh, Bennett, & Hughes, 2006)
2. Dynamic structured production process (Lee & Kim, 1998).
3. Production cost minimization (Onuh & Hon, 2001).
4. Restructuring product and minimum cost production (Vokurka & Fliedner, 1998), (Gunasekaran, 1999).
5. Quality improvement (Onuh & Hon, 2001).

3. A review of the background of ISM, AHP, and TOPSIS techniques

Collecting 15 variables to develop a framework to improve agility of supply chain, Agarwal, Shankar, and Tiwari (2006) used interpretive structural model (ISM). The identifying variables are as follows,

1. Market sensitivity.
2. Delivery speed.
3. Data accuracy.
4. Introducing new product.
5. Centralized and collaborative planning.
6. Processes integration.
7. Using information technology tools.
8. Lead time reduction.
9. Service level improvement.
10. Cost minimization.
11. Customer satisfaction.
12. Quality improvement.
13. Uncertainty minimization.
14. Trust development.
15. Minimizing resistance to change.

ISM is a method by which the effect of each variable on other variables can be studied. It is, in fact, a comprehensive approach to improve the agility of supply chain based upon relation, and is employed in order to develop the framework of the agility of supply chain so that the following objectives can be attained. In 2007, Kannan introduced a model called ISM to evaluate and prioritize suppliers. He mixed fuzzy ISM and TOPSIS methods to select suppliers in his study in 2009.

The interpretive structural model can identify the relationship with criteria which are interdependent individually or in group. It analyzes the relationship with criteria through decomposing the criteria into several different levels (Kannan et al., 2009).

ISM steps are described below (adopted from Kannan et al. (2009) and Govindan et al. (2013a)):

Step 1: Variables (SSCM practices) considered for the system under consideration are listed.
Step2: From variables identified in Step 1, a contextual relationship is established among variables to identify which pairs of variables should be examined.

Step 3: A structural self-interaction matrix (SSIM) is developed for variables, indicating pair-wise relationships among the variables of the system under consideration.
Step 4: Reachability matrix is developed from SSIM and the matrix is checked for transitivity. Transitivity of contextual relation is a basic assumption in ISM. It states that if variable A is related to B and B to C, then A is necessarily related to C.
Step 5: The reachability matrix obtained in Step 4 is partitioned into different levels.
Step 6: Based on relationships stated in the reachability matrix, a directed graph is drawn and transitive links removed.
Step 7: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.
Step 8: The ISM model developed in Step 7 is checked for conceptual inconsistency and necessary modifications are made.
The above steps are shown in Fig. 1.

This model can be used so as to analyze and identify the relationship among specific variables which define a problem or an issue (Sage 1977; Warfield 1974). In the study carried out by Saxena et al. (1992), the ISM method is applied to analyze the relationship among the defined variables for the cement factory in India. Mandal et al. (1994) used the ISM method to analyze the most important criteria to select the best vendor and to identify the relationship among criteria. Also, Sharma et al. (1995) has conducted a study on hierarchical analysis of required tasks to achieve a sound production management. In 2007, Kannan and Haq analyzed the criteria and sub-criteria to select the supplier using ISM method. ISM methodology has few limitations. Detecting the relation among the variables usually depends on the decision maker's knowledge and familiarity with the firm to be studied; consequently, the bias of the person who is judging the variables man influence the final result (Kumar et al., 2009).

Decisions are categorized into two groups including decision making based on several different criteria and decision making based on several different objectives. The MCDM method is usually used to select the best choice whose criteria may be in contradiction. The MODM, which stands for multi objective decision making, can focus on several contradictory objectives simultaneously and finds the best solution by mathematical planning method (Farahani & Asgari, 2007). The MODM takes account of the relative excellence of the objectives and their relationship to criteria (Yang & Hung, 2007). The MADM is employed to select the best choice out of the proposed choices (Farahani & Asgari, 2007). The MADM is a descriptive approach for its objective criteria. The MADM method aims at selecting the best choice and at the same time achieving the most satisfaction (Yang & Hung, 2007). The mixed methods, the distance methods, and relative excellence methods are among the common MCDM methods to be mentioned (Pomerol & Barba-Romero, 2000). Belton and Stewart (2002) introduced a categorization in three groups; in first group, the criteria evaluation model is used based upon the multi criteria function theory and analytical hierarchical process, AHP; the second group is a non-ranking categorization in which the ineffective choices are eliminated using non-ranking comparison; the third group is the selection technique model according to the most ideal TOPSIS choice. Of the most outstanding MCDM methods, the AHP method could be mentioned, which first estimates the relationship among criteria weight and then total value of each choice based on the obtained weight (Saaty, 1980, 1996). The AHP method, compared to the other MCDM methods, is more widely used for multi-criteria decision making, usually with better results (Saaty, 1996). TOPSIS in another method of MCDM which selects the best choice based on the minimum distance to the positive ideal and the maximum distance to the negative ideal for each choice. See Yoon article for any further details about TOPSIS method (Hwang & Yoon, 1981). The AHP and TOPSIS are able to give result, merely, in the event that there are certain conditions with accurate information. However, in case of not having access to accurate information, comparative method is the best decision making method (Farahani, SteadieSeifi, & Asgari, 2010). The AHP is one of the strongest decision making method to prioritize the criteria (Işıklar & Büyüközkan, 2007). In one study conducted by Wu (2010) TOPSIS method has been applied to rank an appropriate strategy in the article, the ANP has been used to calculate input weights (Wu, Lin, & Lee, 2010). The fuzzy AHP is one of the strongest decision making methods to prioritize the criteria (Işıklar & Büyüközkan, 2007). A great deal of numerical studies has been done in which the fuzzy AHP is used to solve different management problems. Chou and Chang (2008) used the fuzzy analytical process and judgment matrix to evaluate people's perception. Pan (2008), applied fuzzy AHP method to select the appropriate bridge construction. In 2008, Cakir and Canbolat proposed an inventory classification system based on fuzzy AHP. Also, Wang and Chen (2008) applied fuzzy linguistic preference relations to construct a pairwise comparison matrix with additive reciprocal property and consistency. Sambasivan and Fei (2008), evaluated the factors and sub-factors critical to a successful implementation of environmental management system. Sharma, Moon, and Bae (2008) used the AHP method to optimize delivery network design. Bana e Costa and Vansnick (2008), studied the priority vector in the AHP method. Ali Khatami Firouzabadi, Henson, and Barnes (2008), applied the AHP method in order to address the selection problem from the point of view of an individual stockholder. Kuo, Tzeng, and Huang (2007) proposed a solution to select the appropriate location in fuzzy environment. In 2009, Gumus employed the AHP and TOPSIS method for hazardous waste transportation. TOPSIS views a MADM problem with m alternatives as a geometric system with m points in the n-dimensional space of criteria (Sun, 2010).

This method selects the best alternative based on the concept that the chosen alternative should have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution (Wang & Chang, 2007). It has often been difficult for the decision makers to assign a precise performance rating to an alternative for the attribute under consideration. In this case, it is worthwhile to use fuzzy numbers for evaluation. TOPSIS method has also been used based on fuzzy numbers (Kuo et al., 2007; Yang & Hung, 2007). Fuzzy TOPSIS method is convenient for solving group and multi criteria decision making problems (Sun, 2010). In using TOPSIS method, the mathematical correlations which are derived from the study conducted by Feyzioğlu, & Nebol (2008) have been applied. In recent years, fuzzy TOPSIS was developed for ranking different fields. In 2008, Lin and Chang used fuzzy TOPSIS for order selection and pricing of supplier when order exceeds production capacity. Chen and Tsao (2008) also extended fuzzy TOPSIS based on interval-valued fuzzy sets in decision analysis. Büyüközkan, Feyzioğlu, and Nebol (2008) identified the strategic main and sub-criteria of alliance partner selection and the best alternative using AHP and fuzzy TOPSIS. Abo-Sinna, Amer, and Ibrahim (2008) employed multi objective large scales nonlinear programming problem with block angular structure to determine the order preference. Wang and Chang (2007) used fuzzy TOPSIS to help the Air Force Academy in Taiwan choose optimal initial training aircraft in a fuzzy environment. In 2007, Li developed a compromise ration methodology for fuzzy multi attribute decision making which is the best part of decision making system. Using fuzzy hierarchical TOPSIS, Kahraman, Çevik, Ates, and Gülbay (2007) proposed a model for multi criteria evaluation of robotic industry. Benitez, Çevik, et al. (2007) proposed a fuzzy TOPSIS approach to evaluate the dynamism of the service quality of three hotels in Gran Canaria

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Island. Wang and Elhag (2006) introduced the fuzzy TOPSIS based on α level sets and linear programming solution procedures. Chen, Lin, and Huang (2006) employed fuzzy TOPSIS approach in order to select supplier in the supply chain system.

4. Research method

Choosing a research method depends on the objective and the nature of the research subject and its implementation facilities. Therefore, the research method can be selected when the nature of the subject as well as the objectives and its broadness is identified. Mixed research method is frequently used in a study. Miller believes that the research orientation layout can be distinctively divided into three areas including fundamental, practical and evaluation.

The nature of a research subject means the researcher goes in search of the consequences of the solution to the social problems or the outcome of the prevailing measures and the research objective is to conduct an accurate social study on the consequence of a program which is applied for a social problem (Miller, Boehlje, & Dobbins, 2001). In the current study library survey method are applied to collect the required information. Data collection was through the questionnaire about the study of the conceptual relationship between attributes and the questionnaire about pairwise comparison as well as the questionnaire about the evaluation of agility level of suppliers; the respondent community includes the managers and the production heads of several industrial organizations manufacturing polyethylene products and couplings. The questionnaires on the evaluation of the agility level of suppliers are also completed by experts in logistic and procurement sections of the organization.

The current study is developmental. The research method in this survey is descriptive and analytical. This study begins with identifying the factors affecting the supplier selection and then is followed by leveling the factors using ISM model. Finally, the fuzzy TOPSIS and AHP methods are employed for the purpose of ranking suppliers.

5. Contextual model of the research

The primary conceptual model of this research is created, as shown in Fig. 5.1 based on the studies carried out and introduced here, based on which the variables of the evaluation of the agile suppliers are derived using the research literature. Next, these variables are rated by establishing a contextual correlation matrix and an interaction matrix. Lastly, a digraph is presented. The first phase known as ISM comes to the end here. In the second phase, the weight of each factor is identified using pairwise comparison matrix and the method which are interpreted in the corresponding section and ranking of the suppliers are done through TOPSIS technique in the end. It is also worth mentioning that considering the cited reasons, all calculations are performed in a fuzzy environment (see Fig. 5.2).

5.1. A review of TOPSIS and AHP, and fuzzy calculation

An explanation of the fuzzy number used here seems necessary prior to studying ranking and weighting method. In the current study, linguistic terms have been used instead of certain numbers so as to determine the weight of variables as well as ranking alternatives. The linguistic terms given in Table 5.1 are meant to compare the importance of the criteria.

In Table 5.2 linguistic variables denoting supplier preference to each other are presented.

In the current study, fuzzy numbers are given in all stages in order to prevent any ambiguity caused by uncertainty in making decisions. Pairwise comparisons in AHP are used in Table 5.1 to show the result. A triangular fuzzy number, shown as $\tilde{A} = (l,m,u)$, has the following membership function. In the current study, the selected membership function for fuzzy numbers is shown in Fig. 5.1.

Two variables are used in triangular fuzzy numbers: confidence variable and optimism variable. The confidence variable, α, indicates the decision maker confidence degree in his prioritizing and judgment. Having defined α, the triangular fuzzy number is defined as follows (Ayağ & Özdemir, 2009):

$$\mu F(X) = \begin{Bmatrix} 0, & \chi < \imath \\ \chi - \imath/m - \imath, & \imath \leqslant \chi \leqslant m \\ u - \chi/u - m, & m \leqslant \chi \leqslant u \\ 0, & \chi > u \end{Bmatrix} \quad (5.1)$$

$$\forall \alpha \in [0,1] M\alpha = [\imath^{\alpha}, u^{\alpha}] = [(m - \imath)\alpha + \imath, -(u - m)\alpha + u] \quad (5.2)$$

Also, the optimism variable, μ, can be used to estimate the degree of success. The higher degree of μ is an indication of the higher degree of optimism. As it is shown by the following formula, the optimism index is a linear convex combination (Lee & Adviser-Tonkay, 1995).

$$\tilde{a}_{ij}^{\alpha} = \mu a_{iju}^{\alpha} + (1 - \mu) a_{ijl,}^{\alpha}, \quad \forall \mu \in [0,1] \quad (5.3)$$

Therefore, the following matrix is obtained through pairwise comparisons.

$$\tilde{\mathrm{A}} = \begin{bmatrix} 1 & \tilde{a}_{12}^{\alpha} & \cdots & \cdots & \tilde{a}_{1n}^{\alpha} \\ \tilde{a}_{21}^{\alpha} & 1 & \cdots & \cdots & \tilde{a}_{2n}^{\alpha} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \tilde{a}_{n1}^{\alpha} & \tilde{a}_{n2}^{\alpha} & \cdots & \cdots & 1 \end{bmatrix} \quad (5.4)$$

After composing pairwise comparisons, the vector of indexes weight is calculated among which λ_{max} is largest value of the matrix:

$$Aw = \lambda_{max} w \quad (5.5)$$

After generating all matrixes of pairwise comparison between criteria and sub criteria, consistency ratio (*CR*) shall be calculated as:

$$CR = \frac{CI}{RI} \quad (5.6)$$

Consistency index (*CI*) indicates the offset degree from consistency which is obtained as following,

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5.7)$$

where n is the size of matrix of pairwise comparison and *RI* is random consistency index or average weight index produced randomly which can be found from the corresponding table (Saaty, 1980). If the obtained *CR* is less than 0.1, the comparisons made will be acceptable. Otherwise, the comparisons must be drawn based upon more accurate data by more experienced people:

$$D = \begin{matrix} & F_1 & F_2 & \dots & F_j & \dots & F_n \\ A_1 & f_{11} & f_{12} & \dots & f_{1j} & \dots & f_{1n} \\ A_2 & f_{21} & f_{22} & \dots & f_{2j} & \dots & f_{2n} \\ \vdots & \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ A_i & f_{i1} & f_{i2} & \dots & f_{ij} & \dots & f_{in} \\ \vdots & \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ A_m & f_{m1} & f_{m2} & \dots & f_{mj} & \dots & f_{mn} \end{matrix} \quad (5.8)$$

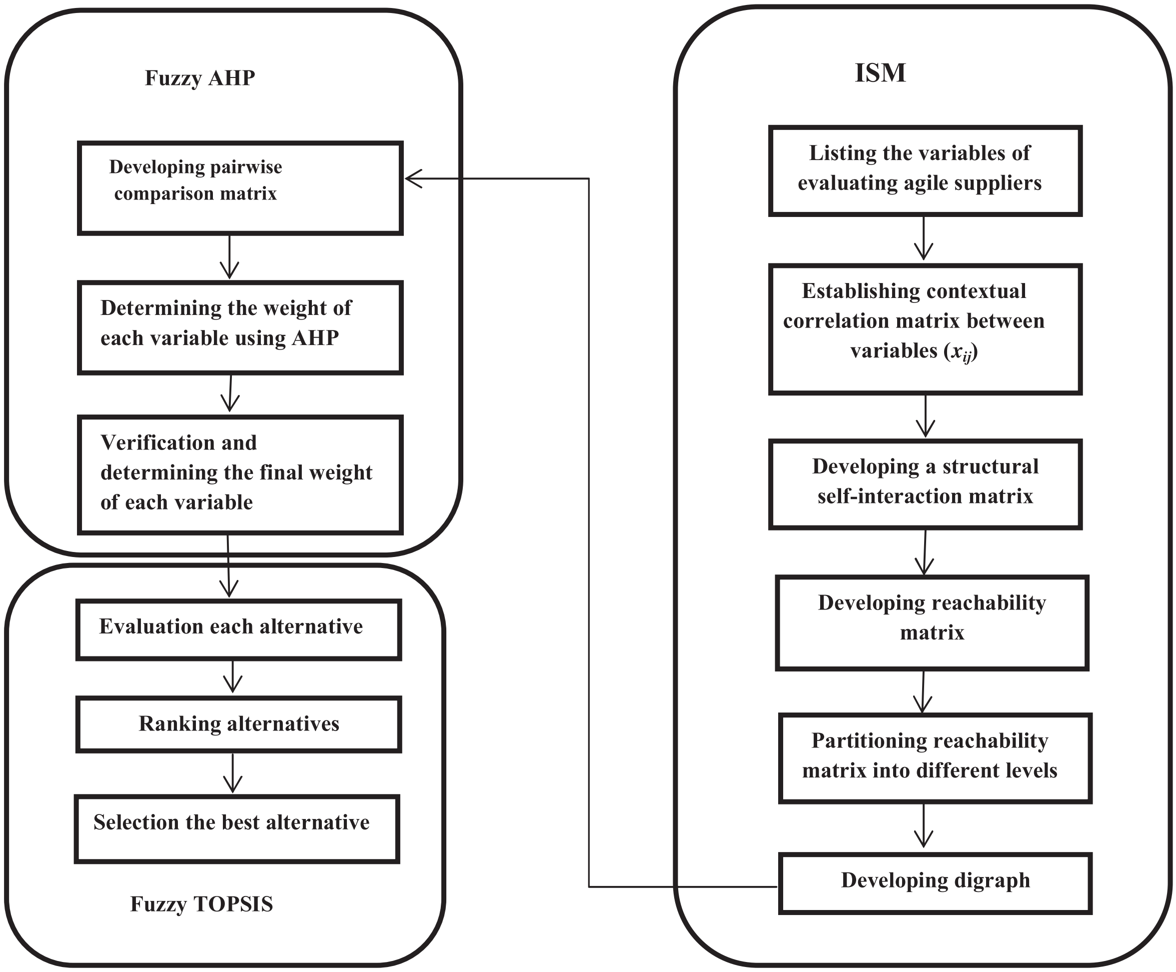

Fig. 5.1. The contextual model of the research.

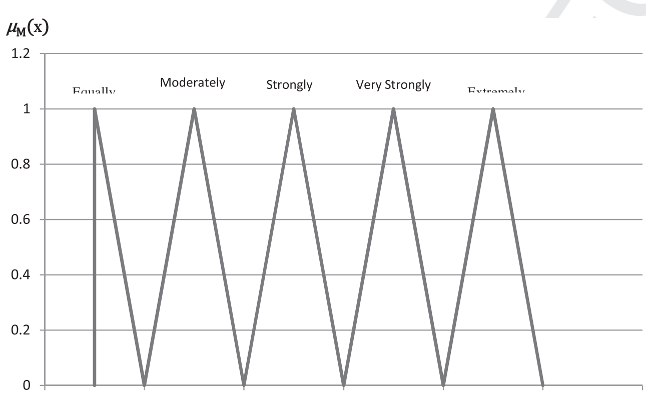

Fig. 5.2. Triangular membership function for linguistic values.

After the weight of the criteria is calculated using the above-mentioned method, a matrix is formed comprised of m rows and n columns with each column denoting an evaluation index and each row a supplier. This matrix depicts the comparisons completed using linguistic variables in Table 5.2 as following.

Then the established matrix is normalized. There are different normalizing methods, two of which are given here. In the first method, the values are normalized through dividing each value by square root of value square summation whose formula (5.9), is given.

In the second method, each value in a column is divided by its Maximum value. After normalizing the data, a normalized weighted matrix is established for which the obtained data of the matrix must be multiplied by the weight vector calculated by AHP method. Assuming ω is the weight vector, the calculation method is as shown in 10;

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \quad (5.9)$$

$$\upsilon_{ij} = \omega_i r_{ij} \quad (5.10)$$

The positive and negative ideal alternatives can be defined based upon the obtained matrix,

Table 5.1
Linguistic terms for pairwise comparisons to show their importance (Gumus, 2009).

Fuzzy number	Linguistic variable	Fuzzy number scale
1	Equal	(1,1,1)
2	Weak advantage	(1,2,3)
3	Not bad	(2,3,4)
4	Preferable	(3,4,5)
5	Good	(4,5,6)
6	Very good	(5,6,7)
7	Fairly good	(6,7,8)
8	Absolute	(7,8,9)
9	Perfect	(8,9,10)

Table 5.2
Linguistic variables for the rating of suppliers (Sun, 2010).

Linguistic variables	Corresponding triangular Fuzzy numbers
Very poor	(0,1,3)
Poor	(1,3,5)
Fair	(3,5,7)
Good	(5,7,9)
Very good	(7,9,10)

$$\upsilon_i^{*-} = \begin{cases} \max\limits_{1\leqslant j\leqslant n}\{\upsilon_{ij}\} & (f_i \in F^2) \\ \min\limits_{1\leqslant j\leqslant n}\{\upsilon_{ij}\} & (f_i \in F^1) \end{cases} \quad (5.11)$$

$$\upsilon_i^{*+} = \begin{cases} \max\limits_{1\leqslant j\leqslant n}\{\upsilon_{ij}\} & (f_i \in F^1) \\ \min\limits_{1\leqslant j\leqslant n}\{\upsilon_{ij}\} & (f_i \in F^2) \end{cases} \quad (5.12)$$

As it is shown in the above functions, the ideals can be calculated using the maximum and the minimum of an index. However, in some articles, the positive ideal is considered as weight matrix and the negative ideal as zero. After the ideals are calculated, separation measures of each alternative from ideal solution and the summation of distances are calculated.

$$D^{*+}(x_j) = \sqrt{\sum_{i=1}^{m}(\upsilon_{ij} - \upsilon_i^{*+})^2} \quad (5.13)$$

$$D^{*-}(x_j) = \sqrt{\sum_{i=1}^{m}(\upsilon_{ij} - \upsilon_i^{*-})^2} \quad (5.14)$$

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]} \quad (5.15)$$

$$C^*(x_j) = \frac{D^{*-}(x_j)}{D^{*+}(x_j) + D^{*-}(x_j)} \quad (5.16)$$

And finally, using the obtained values, *CCj* coefficient for each alternative is identified based on which they are ranked.

As it is mentioned, the alternative with higher *CCj* is more desirable.

6. Findings

To conduct the current survey, the criteria to evaluate the agility of suppliers are derived using the literature and the experts' views (this is done in the third writer's thesis). In this section, the agile supplier evaluation criteria are briefly discussed.

6.1 *Delivery speed* from the perspective of market is defined as the ability to quickly meet delivery target (Agarwal et al., 2006; Jayaram, Droge, & Vickery, 1999). Delivery speed refers to the ability to deliver a product or a service faster than other competitors. This definition includes the ability to produce the new product, reducing time to bring new product to market, and delivery time reduction (Agarwal, Shankar, & Tiwari, 2007; Calantone & Dröge 1999).

6.2 *Lead time reduction,* time management is one of the most important issues existing in an organization. Time management includes innovation improvement and increasing efficiency. Reducing the wasted time improves the performance of an organization (Agarwal et al., 2007).

6.3 *Cost minimization* helps an organization be able to achieve a higher efficiency through appropriate methods. Cost management within an organization aims at finding appropriate solutions in order to reduce the cost with the help of suppliers and vendors (Agarwal et al., 2006; Cooper, Lambert, and Pagh, 1997). The traditional cost management system is unable to identify the proper methods for cost minimization due to not identifying intangible variables (Agarwal et al., 2006, 2007).

6.4 *Quality improvement* is the most important requirement of an organization to succeed in a competitive marketplace. This is the suppliers and customers who determine quality improvement criteria (Agarwal et al., 2006, 2007). Developing an efficient relationship between supplier and consumer is the most significant action taken regarding quality improvement by comprehensive quality management system (Agarwal et al., 2006; Gunasekaran & McGaughey 2003). As Ware et al. (1998) said, quality improvement can reduce cost and increase the efficient use of resources, and improve the process performance in supply chain.

6.5 *Information technology tools* are needed to transfer the appropriate data and information and to keep managers knowledge updated for convenient decision making. This technology has thus decreased errors and increased the managers' confidence in the existing data (Agarwal et al., 2006; Lee & Kim 2000).

6.6 *Price* is one of the most efficient factors in selection.

6.7 *Minimizing uncertainty*; organizations always encounter with a dynamic environment including customers' and raw material supplier's demand (Agarwal et al., 2006; Prater, Biehl, & Smith, 2001). In 1999, Mason-Jones, and Towill (1999) considered uncertainty minimization as the most important action that can be taken to increase the competitive advantage.

6.8 *Logistic* (*procurement* and transportation) is of particular importance to a supplier because it can greatly affect reaction speed and satisfaction.

6.9 *Customer satisfaction*, nowadays, plays an essential role in the success of organizations. The supply chain strategy must take action in terms of customer satisfaction, otherwise its action will be useless and costly (Agarwal et al., 2006; Gunasekaran & McGaughey 2003). The supply chain must be in close contact with customers to improve efficiency (Agarwal et al., 2006; Lee & Billington 1992). The customer satisfaction is defined based upon the expectation from purchased product (Agarwal et al., 2006; Agarwal, Erramilli, & Dev, 2003).

6.10 *Data accuracy* is one important factor which is defined as the accuracy of the data used by managers in making decision (Zhu, Toth, Wobus, Richardson, and Mylne, 2002). Data accuracy plays an effective role in predicting demands correctly because it leads to maintaining of product (Agarwal et al., 2006; Lee, Kim, Cha, Lee, & Kim, 1997).

6.11 First, a 10 by 10 matrix comprised of attributes was created to establish structural self-interaction matrix, after which the managers were provided with. The managers completed the matrixes based on the following principles.

For each ((*i*,*j*)), the relationship between this two variables is studied in the following framework.

V: variable *i* will helps to achieve the variable *j*
A: variable *i* will be achieved only by the variable *j*.
X: both *i* and *j* help will help achieve each other.
O: variables *i* and *j* are unrelated.

If the (i,j) entry is V in matrix SSIM, then in the reachability matrix the (i,j) entry will become one and (j,i) entry will become zero. If the (i,j) entry in SSIM is A, the in the reachability matrix the (i,j) entry will become zero and the (j,i) entry will become one. If the (i,j) entry is x, then in the reachability matrix the (i,j) entry will become one and the (j,i) entry will become one. If the (i,j) entry is O, the in the reachability matrix the (i,j) and (j,i) entries will become zero (see Table 6.1).

Reachability matrix is composed using structural self-interaction matrix as it is shown in the following table. If the correlation is as V, the $(i,j) = 1$ and $(j,i) = 0$; If the correlation is as A, then $(i,j) = 0$ and $(j,i) = 1$; If the correlation is as X, then $(i,j) = (j,i) = 1$; If the correlation is as O, then $(i,j) = (j,i) = 0$. Using these correlations, the reachability matrix given in Table 6.2 is composed.

Having composed the reachability matrix, reachable and antecedent sets are defined and then their intersection is obtained. That is, reachable set is a set in which the criteria of rows are one and antecedent set is a set which the criteria of columns are one. Based on transitory in mathematic logic, if $(i,j) = 1$ and $(j,k) = 1$, then $(i,k) = 1$. That is to say the criteria having indirect impact on other criteria are considered and the two variables which are correlated after applying this logic are shown as *1.

In Table 6.3 considering transition relation, if i and j are related and j and k are also related, then i and k are related. Therefore, some elements will become *1. Also the obtained matrix will be partitioned into different levels and antecedent set will be obtained for each criterion. Having composed the reachability matrix, reachable and antecedent sets are defined and then their intersection is obtained. That is, reachable set is a set in which the rows are the criteria transitory having obtained the intersection of these sets, the next column of the table will be filled. The elements for which the reachability and intersection sets are the same are the top-level elements.

The reachability set consists of the element itself and other elements, which it may help to achieve, whereas the antecedent set consists of the element itself and other elements, which may help achieving it. Then the intersection of these sets is derived for all the elements. The elements for which the reachability and intersection sets are same are the top-level elements in the ISM hierarchy. The top-level elements of the hierarchy would not help to achieve any other element above their own level in the hierarchy. Once top-level elements are identified, it is separated out from the rest of the elements. Then, the same process is repeated to find the next level of elements. In Table 6.4 the element 8 (transportation) and element 10 (data accuracy) are found at level 1. Thus, they will be removed in Table 6.5.

After removing elements 8 and 10 from Table 6.5 next table is obtained in which reachable and antecedent sets and their intersection are determined. By comparison, the interact column and reachable set in second level, prioritization of elements including element 7 (uncertainty minimization) and element 9 (customer satisfaction) are done the process is repeated for seven times till Table 6.6.

Table 6.1
Structural self-interaction matrix (criteria comparison matrix).

1	2	3	4	5	6	7	8	9	10	JI
–	O	V	V	O	O	V	X	O	O	1
–	–	V	X	X	X	V	A	A	X	2
–	–	–	V	O	X	V	X	O	O	3
–	–	–	–	V	V	X	X	X	O	4
–	–	–	–	–	O	X	O	O	O	5
–	–	–	–	–	–	V	V	V	V	6
–	–	–	–	–	–	–	V	O	V	7
–	–	–	–	–	–	–	–	O	O	8
–	–	–	–	–	–	–	–	–	V	9
–	–	–	–	–	–	–	–	–	–	10

Table 6.2
Reachability Matrix.

10	9	8	7	6	5	4	3	2	1	J I
0	0	1	1	0	0	1	1	0	1	1
1	0	0	1	1	1	1	1	1	0	2
0	0	1	1	1	0	1	1	0	0	3
0	1	1	1	1	1	1	0	1	0	4
0	0	0	1	0	1	0	0	1	0	5
1	1	1	1	1	0	0	1	1	0	6
1	0	1	1	0	1	1	0	0	0	7
0	0	1	0	0	0	1	1	1	1	8
1	1	0	0	0	0	1	0	1	0	9
1	0	0	0	0	0	0	0	1	0	10

Table 6.3
Modified reachability matrix (final reachability matrix).

10	9	8	7	6	5	4	3	2	1	J I
*1	*1	1	1	*1	*1	1	1	0	1	1
*1	*1	*1	1	1	1	1	1	1	0	2
0	*1	1	1	1	*1	1	1	0	0	3
*1	1	1	1	1	1	1	0	1	0	4
*1	*1	*1	1	*1	1	0	0	1	0	5
1	1	1	1	1	0	0	1	1	0	6
1	0	1	1	0	1	1	0	0	0	7
0	0	1	0	0	0	1	1	1	1	8
1	1	0	0	0	0	1	0	1	0	9
1	0	0	0	0	0	0	0	1	0	10

Table 6.4
The first iteration to determine top level in hierarchical ISM.

Level	Intersection	Reachable set	Reachable set	Element
	1, 8	1, 8	1, 3, 4, 5, 6, 7, 8, 9, 10	1
	2, 4, 5, 6, 8, 9, 10	2, 4, 5, 6, 8, 9, 10	2, 3, 4, 5, 6, 7, 8, 9, 10	2
	3, 6, 8	1, 2, 3, 6, 8	3, 4, 5, 6, 7, 8, 9	3
	2, 4, 7, 8, 9	1, 2, 3, 4, 7, 8,9	2, 4, 5, 6, 7, 8, 9, 10	4
	2, 5, 7	1, 2, 3, 4, 5, 7	2, 5, 6, 7, 8, 9, 10	5
	2, 3, 6	1, 2, 3, 4, 5, 6	2, 3, 6, 7, 8, 9, 10	6
1	4, 5, 7	1, 2, 3, 4, 5, 6, 7	4, 5, 7, 8, 10	7
	1, 2, 3, 4, 8	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4, 8	8
1	2, 4, 9	1, 2, 3, 4, 5, 6, 9	2, 4, 9, 10	9
	2, 10	1, 2, 4, 5, 6, 7, 9, 10	2, 10	10

Using these levels, a diagram called "developed ISM model to improve supply chain agility" will be drawn in such a way that elements 8 and 10 characterized as the top level are put at the first level of diagram and other elements are likewise put in the other level of the diagram. This diagram is shown in Fig. 6.1.

Considering the above tables and figures and using prioritized levels of elements and reachability matrix, the driving and dependence digraph in reachability matrix is obtained. That is first level is attributed to the largest and last level to the smallest number.

The clusters in Fig. 6.2 are defined as follows

First cluster includes the variables that have weak driving power and dependence. These variables most likely separate from system because they weak links to that system.

Second cluster includes the variables that have weak power but strong dependence. Uncertainty minimization (7) and transportation (8) fall into this cluster.

Third cluster includes the variables that have strong driving power and dependence. Cost minimization (3), quality improvement (4), information technology tools (5), price (6) which are called linkage variables fall into this cluster.

Table 6.5
The second iteration in hierarchical ISM.

Level	Intersection	Reachable set	Reachable set	Element
	1	1	1, 3, 4, 5, 6, 7, 9	1
	2, 4, 5, 6, 9	2, 4, 5, 6, 9	2, 3, 4, 5, 6, 7, 9	2
	3, 6	1, 2, 3, 6	3, 4, 5, 6, 7, 9	3
	2, 4, 7, 9	1, 2, 3, 4, 7, 9	2, 4, 5, 6, 7, 9	4
	2, 5, 7	1, 2, 3, 4, 5, 7	2, 5, 6, 7, 9	5
	2, 3, 6	1, 2, 3, 4, 5, 6	2, 3, 6, 7, 9	6
2	4, 5, 7	1, 2, 3, 4, 5, 6, 7	4, 5, 7	7
2	2, 4, 9	1, 2, 3, 4, 5, 6, 9	2, 4, 9	8

Fourth cluster include the variables with strong driving power and weak dependence. Delivery speed (1) and lead time reduction (2) are of key variables which are at the lowest level of diagram.

7. Ranking using fuzzy TOPSIS and AHP

After using ISM, effective factors will weigh by AHP. To do so, a 10 by 10 matrix was established whose row and column include the identified variables in this survey. Then, the managers did pair-wise comparison using the matrixes. The pair-wise comparison values are obtained using the values given in Table 5.1 in the fuzzy form. Finally, all matrixes became a single equivalent matrix so that the geometric averages of all values were calculated and the resulting matrix was used for the rest of calculations. Next, the average geometric values of each row was calculated and using dis-fuzzy or BNP, each variable was weighed. These calculations are shown in Table 7.1.

7.1. BNP = [(U1 – L1) + (M1 – L1)/3] + L1 (Sun et al., 2010)

As shown in Table 17.1 delivery speed variable is of the greatest importance. It is worth mentioning that the consistency comparison matrix of this matrix was analyzed in order to verify the accuracy of the results. In this method, using eigenvector which is proposed by Saaty (Asgharpour, 2006), the data transfer matrix was composed, eighth of which had the considered properties. Then, using this matrix, the values of maximum element, consistency index (*CI*), consistency rate (*CR*), and random index were obtained from Saaty Table. The vector of the calculated weights are given in Tables 7.2 and 7.3 using eigenvector and calculated values.

As the obtained value of *CR* is less than 0.1, it can be said that comparison matrixes are of good consistency (Asgharpour, 2006). As shown in the table above, the obtained weights using eigenvector also rank indices as former methods; however, these weights are more precise.

Table 6.6
Levels of agility variables of supply chain.

Level	Intersection	Reachable set	Reachable set	Element
7	1, 8	1, 8	1, 3, 4, 5, 6, 7, 8, 9, 10	1
7	2, 4, 5, 6, 8, 9, 1	2, 4, 5, 6, 8, 9, 10	2, 3, 4, 5, 6, 7, 8, 9, 10	2
6	6, 8, 3	1, 2, 3, 6, 8	3, 4, 5, 6, 7, 8, 9	3
5	2, 4, 7, 8, 9	1, 2, 3, 4, 7, 8, 9	2, 4, 5, 6, 7, 8, 9, 10	4
4	2, 5, 7	1, 2, 3, 4, 5, 7	2, 5, 6, 7, 8, 9, 10	5
3	2, 3, 6	1, 2, 3, 4, 5, 6	2, 3, 6, 7, 8, 9, 10	6
2	4, 5, 7	1, 2, 3, 4, 5, 6, 7	4, 5, 7, 8, 10	7
1	1, 2, 3, 4, 8	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4, 8	8
2	2, 4, 9	1, 2, 3, 4, 5, 6, 9	2, 4, 9, 10	9
1	2, 10	4, 5, 6, 7, 9, 10, 1, 2	2, 10	10

In the next section, six suppliers are ranked from agility perspective using obtained weights by AHP method for each index. In this regard, a matrix is first established whose first column includes evaluation criteria of agile suppliers and whose row is comprised of six agile suppliers. It should be mentioned that polling about these suppliers is done using fuzzy numbers in Table 5.2. Therefore, a couple of managers who are in contact with the suppliers have filled these matrixes and the geometrical average of their views is then calculated. The next step is normalization of the obtained data using Saaty method. Then, the weighted normalized matrix is established using the obtained weight vector which is shown in Table 7.4.

The next step will be defining positive ideal and negative ideal vectors. In this survey, weight vector is considered as positive ideal vector and zero vector as negative ideal vector because while normalizing data, coefficient vector is multiplied by a value less than one and as a result has a smaller value. Subsequently, matrix of closeness to positive and negative ideal is composed and ranked by using those alternatives. It is worth mentioning that calculation of the distance to ideal value was done once through the calculation approach for non-fuzzy data and another time through the calculation approach for fuzzy data (Amiri 2010; Dağdeviren, Yavuz, & Kılınç, 2009). In using non-fuzzy data, the corresponding data are subtracted from the ideal value and finally ten obtained values which are non-fuzzy are summed. In case of fuzzy data, each parameter corresponding to the fuzzy number is subtracted from the ideal value to obtain ten fuzzy numbers for negative ideal. Then, using fuzzy number method the summation of these numbers is calculated which a non-fuzzy number is. The results of calculation shows that the relative distance to ideal value gives different values for the alternatives in both methods but their ranking in both fuzzy and non-fuzzy methods provides the same values. The final results from non-fuzzy and fuzzy calculations are given in Tables 7.5 and 7.6.

In Table 7.6, the distances to ideal value are calculated by fuzzy distance method while in Table 7.5 they are calculated by normal and discontinuous fuzzy number method. As it is seen, the values of ranking are the same and this proves that if a value becomes non-fuzzy, then again its results can be reliable.

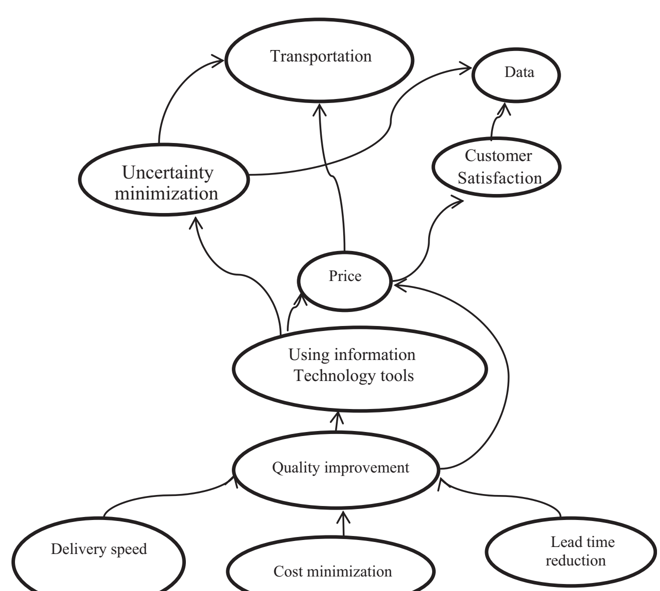

Fig. 6.1. ISM base model of the variables for improving supply chain agility after removing indirect link.

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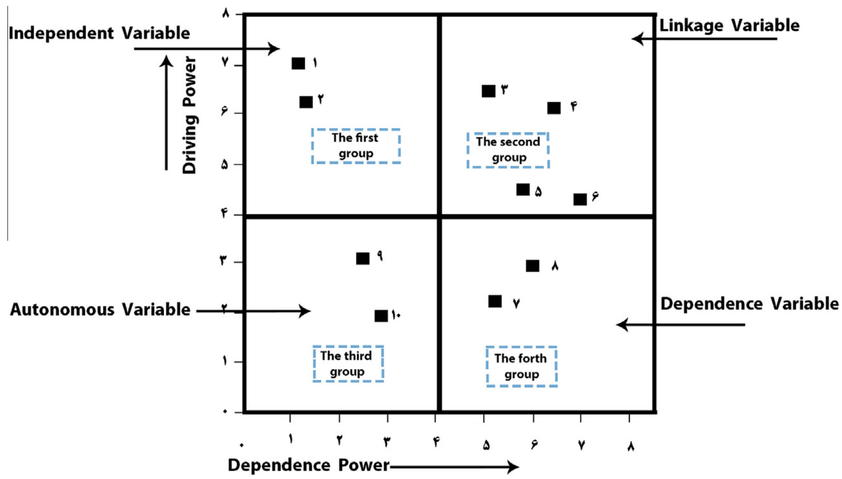

Fig. 6.2. clusters of variables for improving supply chain agility.

Table 7.1
The values of calculated weights in AHP method.

Ranking elements	The weight of each variable (w)	Numerical weight	BNP	Ranking
Uncertainty minimization	0.045, 0.062, 0.091	0.069	0.066	9
Customer satisfaction	0.054, 0.075, 0.105	0.081	0.078	7
Lead time minimization	0.063, 0.092, 0.128	0.098	0.094	4
Cost minimization	0.100, 0.151, 0.215	0.162	0.155	2
Delivery speed	0.133, 0.198, 0.287	0.216	0.206	1
Data accuracy	0.049, 0.069, 0.100	0.076	0.073	8
Price	0.093, 0.139, 0.211	0.155	0.148	3
Transportation	0.042, 0.061, 0.089	0.067	0.064	10
Information technology tools	0.054, 0.076, 0.114	0.085	0.081	6
Quality improvement	0.054, 0.078, 0.113	0.085	0.082	5

Table 7.2
The indices of consistency calculation.

Maximum Landa	10.58976086
CI	0.065528985
RI	1.49
CR	0.043979184

Table 7.3
Calculated weights using eigenvector in AHP, method.

Ranking indices	Weight of each index
Uncertainty minimization	0.06459449
Customer satisfaction	0.075821798
Lead time minimization	0.092518029
Cost minimization	0.147319998
Delivery speed	0.193196094
Data accuracy	0.068830476
Price	0.140281657
Transportation	0.062017105
Information technology tools	0.077245555
Quality improvement	0.078174799

8. Discussion and conclusion

In the knowledge age, the successful organizations are the ones which rapidly run novel strategies based on competitive advantages, and learning from market and customers they modify and improve their processes and customers if necessary. In the current study, first, the factors influencing agile supplier are given in different levels using interpretive structural model and then are given in a driving power and dependence graph.

The result of this process helps suppliers choose a more efficient way to increase the degree of their agility and competitive ability. In 2009, Kannan et al. has conducted a research which is relatively similar to this study but with different results; this could be possibly because of using AHP. ISM method results show that delivery time and lead time minimization variables are of the most important factors influencing suppliers' agility. There is cost minimization factor in the next level. With taking a look at the graph of agility variable clusters, it can be seen that delivery time and lead time minimization variables are of high driving power whereas customer satisfaction and data accuracy variable have the minimum driving power and dependence. Also, the variables in linkage cluster have both high driving power and high dependence degree.

Delivery speed is among the factors, which was given the most importance in evaluating suppliers in the study by Agarwal et al. (2007), and accordingly, placing this variable in the first level of a JSM Model and its strong driving power depicts the significance of this index in terms of suppliers' agility in the present study. The same is true of the variable of delay reduction time or JIT, because Muduli, Govindan, Barve, Kannan, and Geng (2013) pointed out the vitality of this variable in distinguishing the excelling supplier in their study in 2007. Similarly, the result of this study shows that this variable is placed in the first level of ISM and is of particular significance. The customer satisfaction and uncertainty minimization variables, which were introduced in the studies carried out by Gunasekaran (2003) and Prater et al. (2001), are considered as dependent variables in higher levels in this study. Correspondingly, the results of those studies which

Table 7.4
Weighted normalized fuzzy decision matrix.

	First supplier	Second supplier	Third supplier	Fourth supplier	Sixth supplier	Seventh supplier
Uncertainty minimization	0.013, 0.033, 0.078	0.017, 0.038, 0.076	0.017, 0.037, 0.074	0.015, 0.034, 0.071	0.014, 0.033, 0.068	0.014, 0.033, 0.068
Customer satisfaction	0.021, 0.046, 0.088	0.026, 0.053, 0.096	0.018, 0.042, 0.093	0.026, 0.052, 0.096	0.024, 0.050, 0.092	0.025, 0.051, 0.094
Lead time minimization	0.029, 0.065, 0.119	0.019, 0.047, 0.094	0.029, 0.063, 0.115	0.020, 0.049, 0.097	0.021, 0.051, 0.099	0.024, 0.055, 0.104
Cost minimization	0.057, 0.118, 0.215	0.049, 0.108, 0.201	0.055, 0.117, 0.213	0.038, 0.090, 0.176	0.038, 0.091, 0.176	0.053, 0.113, 0.184
Delivery speed	0.064, 0.139, 0.265	0.039, 0.098, 0.204	0.068, 0.144, 0.271	0.062, 0.135, 0.259	0.046, 0.112, 0.225	0.059, 0.132, 0.253
Data accuracy	0.015, 0.037, 0.074	0.022, 0.039, 0.078	0.015, 0.036, 0.074	0.017, 0.039, 0.078	0.025, 0.050, 0.094	0.018, 0.041, 0.081
Price	0.049, −0.13, 0.204	0.029, 0.073, 0.156	0.035, 0.083, 0.172	0.045, 0.097, 0.193	0.041, 0.092, 0.186	0.051, 0.106, 0.207
Transportation	0.017, 0.037, 0.074	0.018, 0.033, 0.068	0.018, 0.038, 0.076	0.016, 0.037, 0.073	0.017, 0.038, 0.075	0.019, 0.040, 0.079
Information technology tools	0.019, 0.043, 0.090	0.018, 0.042, 0.089	0.024, 0.042, 0.089	0.029, 0.058, 0.112	0.023, 0.049, 0.099	0.027, 0.055, 0.108
Quality improvement	0.023, 0.050, 0.098	0.015, 0.039, 0.080	0.020, 0.046, 0.091	0.020, 0.046, 0.091	0.028, 0.057, 0.108	0.021, 0.046, 0.092

Table 7.5
Ranking of alternatives by non-fuzzy calculation method.

CCj	First supplier	Second supplier	Third supplier	Fourth supplier	Sixth supplier	Seventh supplier
Value	0.6676	0.6547	0.7230	0.7117	0.6988	0.7344
Ranking	5	6	2	3	4	1

Table 7.6
Ranking of alternatives by fuzzy calculation method.

CCj	First supplier	Second supplier	Third supplier	Fourth supplier	Sixth supplier	Seventh supplier
Value	0.6682	0.6533	0.7206	0.7103	0.6977	0.7330
Ranking	5	6	2	3	4	1

presented these variables as that of suppliers' optimism and evaluation, proves the validity of results in this study.

In increasing suppliers' agility through developing these variables their degree of independence must be considered. This is to say that with a partial increase in one of these variables, no change can be seen in suppliers' agility. These variables must change at the same time with other variables from the same cluster and independent variables. Therefore, ISM model firstly focuses on delivery time and lead time minimization variables. In what follows, AHP method is used to determine the weight of each index so that it would be possible to categorize several suppliers from agility perspective using TOPSIS method. Upon considering decision making as a wide issue, fuzzy environment is used in this study.

After providing pairwise comparisons, their consistency is evaluated which proves that the value of 0.043 is true for certain rate of the consistency of pairwise comparison matrix. Considering the obtained weights and ranking these factors in terms of their weight, it could be seen that delivery time index is of higher weight and importance in this method. The second variable in this method is cost minimization. Weight ranking resulting from AHP method is similar to results from ISM ranking. Then using fuzzy TOPSIS, six suppliers are ranked and the results were given. In this ranking, two methods known as fuzzy calculation and ideal distance, and non -fuzzy calculations are used with the same ranking results. In this regard, it can be said that in this study mathematical calculations in a non-fuzzy environment for the purpose of ranking does not have considerable impact on the result with the distance to the ideal value being calculated different. Considering the stated results, it can be seen that organizations can use the above method in order to select supplier and concentrate on driving power variables derived in interpretive structural model to increase the suppliers' efficiency and agility.

It is worth mentioning that the results of AHP model confirms those of ISM model inasmuch as the values of weight for each variable implies its importance which is to some extent shown in ISM model.

Future recommendations:

1. In future studies, ISM model can be also used in fuzzy manner and all calculations can do using fuzzy method.
2. This study has been carried out in a manufacturing company, and it may lead to different results if performed for service organizations.
3. In the present study, indices were selected according to experts and quality methods while the Meta-heuristics method must be employed for data collection in order to reduce the experts and decision makers errors.

9. Uncited reference

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