Modelling Supply Chain Coordination: An Application of Analytic Hierarchy Process under Fuzzy Environment

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Abstract

Coordination of supply chain of trading partner plays a crucial role in improving overall supply chain performance. For allocating the component or services to trading partner, it would be significant to analyze the supply chain coordination of the trading partner. In order to prioritize supply chain coordination mechanisms the conventional methods are hardly adequate to deal with the imprecise or vague nature of linguistic assessment. To overcome this difficulty, fuzzy multi-criteria decision-making model is proposed. In this study, a fuzzy Analytic Hierarchy Process is applied for prioritization of coordination mechanisms for selected supply chain. A case study of Indian automotive parts manufacturing company is described to illustrate the application of the used method. This paper presents how Fuzzy Analytic Hierarchy Process (FAHP) can be applied to allow for evaluation and prioritization of mechanisms used to coordinate a supply chain. After determining, the coordination criteria that affect the Supply chain partner prioritization, fuzzy AHP method is applied to the problem and results related to the prioritization of coordination mechanisms are presented.

Keywords:

Supply chain coordination, coordination mechanisms, Multi-criteria decision-making, Fuzzy logic, Case study, Fuzzy AHP.

1. Introduction

In a supply chain, trading partners are interconnected to perform various chain activities, which are interdependent, complex and uncertain in nature. To manage these interdependent, complex and uncertain activities have become more and more challenging task in supply chain management that can be resolved by supply chain coordination. A supply chain consists of a number of organizations acting together with each organization dependent on performance of other organizations in the chain.

There are different people, entities and process in a supply chain interacting with each other to achieve supply chain objectives. Each member of supply chain needs to perform specific functions or activities in value addition process.

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Performance of supply chain could be improved if supply chain is integrated and the concerned activities are properly coordinated. Supply chain coordination plays a critical role in integrating different actors of any supply chain resulting in enhancement in its performance. There are number of mechanisms by which the supply chain partners can coordinate with each other. With the global competition, managing uncertainties and complexities to coordinate supply chain is a challenging task.

Prioritization in a supply chain is a multi-criteria decision problem and has important role in chain performance. The conventional methods of partner selection have limitation in dealing with the imprecise or vague nature of linguistic assessment. To overcome this limitation, fuzzy multi-criteria decision-making method is adopted. In this paper, a methodology is proposed to prioritize trading partner based on coordination mechanisms by using multi-criteria decision making in the fuzzy environment. The methodology is demonstrated through a case study of an automotive parts manufacturer in India.

2. Literature Review

The objective of any business organization is to maximize the overall value generated through effective supply chain coordination. The importance of the coordination in a supply chain has been recognized as a key success factor in superior supply chain performances. With better coordination in a supply chain, the efficiency and effectiveness of supply chain performance is expected to improve. To improve the supply chain performance, the coordination in a supply chain should be improved [33]. Supply chain coordination can be defined an identifying interdependent supply chain activities between supply chain members and devise mechanisms for managing those interdependencies. It is the measure of extent of implementation of such aggregated coordination mechanisms, which helps in improving the performance of supply chain in the best interests of participating members [3].

Coordination across supply chain includes integrated planning and control over all inter-organizational processes and activities in the supply chain [34]**.** Main objective of supply chain coordination is to coordinate the independent players to work together as a whole to pursue the common goal of chain profitability in changing market conditions. Coordination is realised when a decision maker in the supply chain, acting rationally, makes decisions that are efficient for the supply chain as a whole [15]. The purpose of coordination in a supply chain is to align all the activities working jointly as a unified system then stimulate the overall supply chain performance [3].

Importance of coordination has been realized by many authors for organizations to streamline supply chain operations, identify interdependencies and mutually define goals, to share risks and rewards, access to resources and to gain competitive advantage ([30], [10], [2]). Coordination mechanisms offer tools to execute supply chain objectives by successfully managing interactions between people, processes, and entities for improving overall system performance ([41],[13],[26]).There are number of mechanisms by which the supply chain partners may coordinate with each other. The appropriate use of coordination mechanisms is expected to increase efficiency and effectiveness in the operations, the actors and the supply chain [32].

Therefore, selections of supply chain coordination mechanisms (SCCMs) are essentially have the impact on performance of the whole supply chain. Because of the multidimensional criteria, the selection of appropriate SCCM in a given situation remains a difficult task for supply chain managers. This paper is an attempt to explore various issues pertaining to supply chain coordination and use fuzzy AHP approach to prioritize coordination mechanisms.

To manage vagueness and uncertainty in decision-making, Zadeh [42] proposed fuzzy set theory. Modeling using fuzzy sets has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise [43]. Fuzzy numbers stand for a specific range for a specific value. Due to this specific range, it is easier for the evaluator to indicate his/her preference. The preference of the expert is in many practical cases is uncertain, which makes it difficult to make a numerical comparison [38]. In short, a single linguistic rating will be translated into a fuzzy number consisting of multiple numbers. This way, the linguistic rating is reflected as a range.

Both triangular and trapezoidal fuzzy numbers can be used for fuzzy theory [5]. It is often convenient to use triangular fuzzy numbers (TFN) because of the ease of computation. In present application, it is often convenient to work with triangular fuzzy numbers (TFNs) because of their computational simplicity, and they are useful in promoting representation and information processing in a fuzzy environment. Triangular fuzzy numbers can be defined as a triplet (l, m, u). The parameters l, m, and u respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event and the membership function can be defined by equation (1) (Chang, [9]).

$$\mu_{\mathrm{A}}\left(x\right)=\left\{\begin{array}{ll} 0 & x<l; \\ \dfrac{x-l}{m-l} & l\le x\le m; \\ \dfrac{m-x}{u-m} & m\le x\le u; \\ 0 & x>u. \end{array}\right\} \tag{1}$$

Deng [12] discusses this mathematical representation of a triangular fuzzy number *M* that is depicted by Balli & Korukoglu [5] as shown in Figure 1.

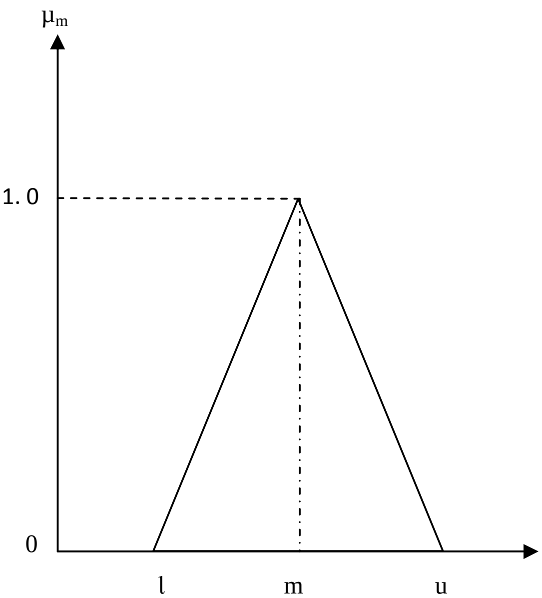

Figure 1: A triangular fuzzy number

3. Overview of methodologies used

Methodology proposed in the present work is an application of Analytic Hierarchy Process under Fuzzy environment. To overcome conventional AHP limitations, Van Laarhoven and Pedrycz [39] proposed Fuzzy Analytic Hierarchy Process, which is the combination of Analytic Hierarchy Process (AHP) and Fuzzy Theory. Fuzzy AHP makes it possible to use linguistic ratings in the calculations by giving it a certain range. It is observed that decision-makers are more positive to give interval judgments than fixed-value judgments [7]. Balli & Korukoglu [5] recognize that fuzziness in AHP contributes by being able to represent vague data. There are numerous studies, which applied the fuzzy AHP in various applications. Chang [9] introduces an approach for handling fuzzy AHP, with the use of triangular fuzzy numbers for pair wise comparison scale of fuzzy AHP, and the use of the extent analysis method for determining synthetic extent values of the pair wise comparisons. Wang and Yang [40] investigate supplier selection in a quantity discount environment using multi objective linear programming, which involve AHP and fuzzy theory. Lee [24] used fuzzy analytic hierarchy process for supplier selection with the consideration of benefits, opportunities, costs and risks. Mehdi [29] used fuzzy AHP for selecting engineering partners. Ramík and Perzina [31] introduced an extension of the AHP with feedback between criteria. Kilincci and Onal [20] utilized Fuzzy AHP approach for supplier selection in a washing machine company. It seems to be first time to use fuzzy AHP approach to prioritize trading partners based on coordination mechanisms criterion. In the research work, Chang's [8] extent analysis on fuzzy AHP is used for selecting trading partners to improve coordination in supply. The outlines of the Chang's extent analysis method on fuzzy AHP used to compute relative weight of the each criterion has been explained in the following section.

Chang's Extent Analysis

Let $X=\{x_1,x_2,x_3,....,x_n\}$ an object set, and $G=\{g_1,g_2,g_3,.....g_n\}$ be a goal set. According to the method of Chang's [8] extent analysis, each criterion is taken and extent analysis for each goal g_i; is performed, respectively. Therefore, m extent analysis values for each criterion can be obtained by using following notation (Kahraman [19]);

$M_{g_i}^1, M_{g_i}^2, M_{g_i}^3, M_{g_i}^4, M_{g_i}^5, ...M_{g_i}^m$, where g_i is the goal set $(i=1,2,3,4,5,......,n)$ and $M_{g_i}^j$ $(j=1,2,3,4,5,......m)$, All are Triangular Fuzzy Numbers *(TFNs)*. The steps of Chang's extent analysis are illustrated as the following, from equation 2-9.

Step1: The value of fuzzy synthetic extent value *(S_i)* with respect to the i^{th} criterion is defined as

$$S_i=\sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1} \qquad (2)$$

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

$$\sum_{j=1}^{m} M_{g_i}^j=\left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \qquad (3)$$

Where l is the lower limit value, m is the most promising value and u is the upper limit value and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1}$ Perform the "fuzzy addition operation" of $M_{g_i}^j$ $(j=1,2,3,4,5,......m)$ values as given below $\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j=\left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$ and then the inverse of the vector is computed; such as

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \qquad (4)$$

Step 2: As $M_1=(l_1,m_1,u_1)$ and $M_2=(l_2,m_2,u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2=(l_2,m_2,u_2)\geq M_1=(l_1,m_1,u_1)$ is defined as

$$V(M_2\geq M_1)=\sup_{y\geq x}\left[\min\left(\mu_{M_1}(x),\mu_{M_2}(y)\right)\right] \qquad (5)$$

x and y are the values on the axis of membership function of each criterion. This expression can be equivalently written as given in equation below:

$$V(M_2\geq M_1)=\begin{cases}1, & if \quad m_2\geq m_1,\\ 0, & if \quad l_1\geq u_2,\\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)} & otherwise\end{cases}$$

……….. (6)

To compare M_1 and M_2; we need both the values of V ($M_2 \geq M_1$) and V ($M_1 \geq M_2$)

Step 3.The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i $(i = 1, 2, 3, 4, 5, ..., k)$ can be defined by

$$V\ (M\geq M_1,\ M_2,\ M_3,\ M_4,\ M_5,\ M_6,\ ......,\ M_k)$$

$$=V\ [(M\geq M_1) and (M\geq M_2) \text{and} (M\ \geq M_3)$$
$$\text{and}(M\geq M_4) and\ ....\ and\ (M\geq M_k)]$$

$$=min\ V(M\ \geq M_i),\ i\ =\ 1,\ 2,\ 3,\ 4,\ 5,\ ......,\ k.$$

………… (7)

Assume that $d'(C_i)=\min\ V(S_i\geq S_k)$ for $k\ =1,\ 2,\ 3,\ 4,\ 5,\ ......,\ n;\ k\neq i.$ then the weight vector is given by

$$W'=\left[d'(C_1),d'(C_2),d'(C_3),d'(C_4),d'(C_5),..........,d'(C_n)\right]^T$$

………… (8)

Where $C_i\left(i = 1, 2, 3, 4, 5, 6, \ldots, n\right)$ are n elements

Step 4: Via normalization, the normalized weight vectors are given in equation 9,

$$W = \begin{bmatrix} d\left(C_1\right), d\left(C_2\right), d\left(C_3\right), d\left(C_4\right), d\left(C_5\right), \ldots \\ \ldots\ldots, d\left(C_n\right) \end{bmatrix} \quad \ldots\ldots\ldots (9)$$

Where W is non-fuzzy numbers, and d is the coordinate of highest intersection point D between μ_{M_1} and μ_{M_2} (see Figure 2).

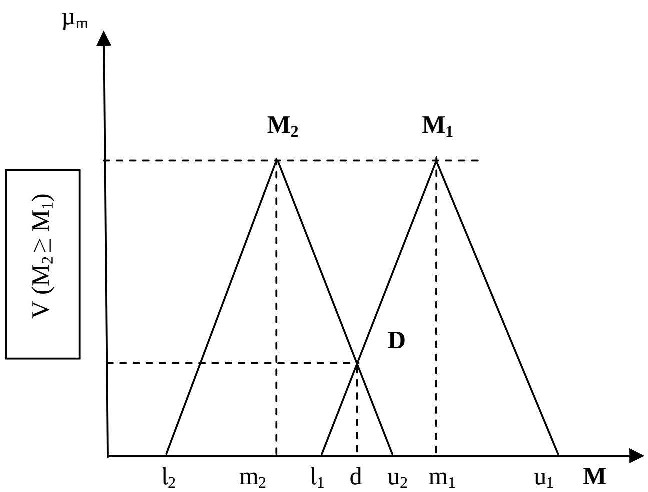

Figure 2: The Intersection between Two TFNs (Chang, 1996)

4. Identification of decision-making criterions

To manage the dependencies between supply chain members some means and mechanisms of coordination are required. A coordination mechanism is a set of methods used to manage interdependencies between organizations. To gain competitive advantage and to increase organizational performance, the challenges to the organization is how to select the appropriate coordination mechanism to manage organizational dependencies. Coordination mechanisms, which are tools to address particular coordination problems and effectively managing interactions between people, processes, and entities that interact in order to execute supply chain objectives ([13], [41], [26]). Li and Wang [26] define coordination mechanism is an operational plan, which coordinate the operations and improve overall system profit. The knowledge of coordination mechanism has positive impacts on supply chain performance.

Supply chain coordination mechanism can handle the challenge arise from dependencies and conflicts between chain members, and motivate the supply chain members to take decisions that are optimal for the whole chain [41]. Coordination mechanisms provide a system for supply chain members to collectively create value and achieve improved supply chain performance.

Supply chain coordination mechanisms manage the dependencies and uncertainties between supply chain members that may improve the performance of supply chain. A coordination mechanism is a set of methods used to manage interdependencies between organizations [41]. Coordination mechanisms provide tools for effectively managing interactions between people, processes, and entities that interact in order to execute common goals. From the review of literature Plans and schedules, Standardization of rules, Flexibility, Contracts, Information sharing, joint decision making, Risk and reward sharing, Resource sharing, Quantity discount, Flexible return policies, Incentive mechanisms, Credit scheme, Effective communication, Joint cost minimization, Collective learning, Knowledge sharing, Uses of Electronic Data Interchange (EDI), Order coordination, Performance monitoring, and Scheduling of frequent meetings with stakeholders are identified coordination mechanisms. As a result of, factor analysis and discussion with experts, four important coordination mechanisms are identified and defined in the following section as our decision-making criteria. These are Joint decision making (JDM), Information sharing (IS), Use of information tools (UIT) and Resource Sharing (RS).

4.1 Joint Decision Making (JDM)

Joint decision-making is to involve supply chain members in decision-making and to delegate to the member with the best negotiating position to lead the relevant decision-making. Joint decision-making helps in resolving conflicts among supply chain members and handles exceptions in case of any future uncertainty.

According to Chopra and Meindle [10] member's behaviour like trust, cooperation, reliability and commitments are key parameters of successful joint decision making which result in proper distribution of risk and rewards. Das [11] discussed the role of Joint decision making to improve coordination. Joint considerations of cost, inventory holding costs, collaborative planning, costs of different processes, frequency of orders, coordinated order quantity, product development are some joint decision-making activities to improve the performance of supply chain ([16], [14],[6],[17],[21]).

Some joint decision making initiatives can be taken to perform activities jointly to reduce uncertainties. These initiatives are efficient consumer response, vendor managed inventory, collaborative design and development, and joint ordering may help in joint decision-making.

4.2 Information Sharing (IS)

Objective of information sharing is to provide relevant, timely, and accurate information to coordinate physical and financial flow that affect the organizational performance. Lee [25] states that, to coordinate material, information, and financial flows, companies must have access to information reflecting their accurate supply chain picture all the times. Sharing of Information across the various functional departments of an organisation, supplier and customer organisations is also improve decision-making in supply chain. Information sharing should target on providing accurate and good-quality information for the decision makers. Shared information provides the visibility of the operations in supply chain processes, such as customer demand, product-related data, costs-related data, process-related data, and performance metrics so on [35]. The customer sharing the demand data with the supplier enables the supplier to schedule and utilize the resources more efficiently [35]. Information sharing between the supply chain members is essential for a responsive supply chain [36].

Information sharing is a challenging task that requires willingness and a high degree of trust among supply chain partners [1]. According to Lee [25], coordination of information sharing, is an attempt to make relevant, accurate and timely information available to the decision-makers.

Sharing of information between supply chain members helps to reduces lead-time, reduces the supply chain costs, reduces the demand variability, enhances responsiveness and improves the service level [4]. Lack of information sharing lead to operational inefficiencies that increase operational costs and additional coordination costs of supply chain [26]. Information sharing helps to facilitate coordination between supply chain members. Information sharing in supply chain refers to the usage of information technology by a manufacturer with the purpose of enhancing communication with suppliers and customers in areas such as order tracking, knowledge management, and collaboration services. Hence, supply chain member may improve coordination by adopting superior information systems.

4.3 Use of Information Technology (UIT)

Information technology helps to link the point of production seamlessly with the point of delivery or purchase. Use of Information technology makes company information systems compatible by accessing information pertaining to the supply chain activities like planning, monitoring and estimating the lead times. Due to recent advances in Information technology, make possible firms, to quickly exchange products, information and funds and utilize collaborative methods to optimize supply chain operations ([18], [27],[28],[22]).

Liu [27]states that use of information technology enhance communication, which helps members of supply chain to review and monitor past and current performance and estimate demand of certain products need to be produced and to manage workflow system. Use of Information technology, also support sales, distribution and customer service processes, procurement, order fulfilment processes, and strengthen the relationships along the supply chain, exchanging data, and making joint decisions.

4.4 Resource sharing (RS)

Resource sharing is the cooperation among independent but related firms to share resources and capabilities to meet their customers' most extraordinary needs. It is a particular degree of relationship among chain members as a means to share resources that result in higher business performance than would be achieved by the firms individually [23].

5. Case application of Proposed Model

The effectiveness of the proposed methodology is discussed through a case study conducted for an Indian automotive part manufacturing company. The management of company has decided to incorporate coordination criterion into their trading partner prioritization process. To evaluate the performance of partners four coordination criterions are considered these are Joint decision-making (JDM), Information sharing (IS), Use of information tools (UIT) and Resource Sharing (RS).

Linguistic and subjective evaluations take place in questionnaire form. Each linguistic variable has its own numerical value in the predefined scale. In classical AHP, these numerical values are exact numbers whereas in fuzzy AHP method they are intervals between two numbers with most likely value. As the nature of the human being, linguistic values can change from person to person. In these circumstances, considering the fuzziness will provide less risky decisions. Triangular fuzzy numbers (TFNs) have been used for pair wise comparison of the criterion to know the importance of the criterions. Criterions are prioritized by using fuzzy AHP method. After obtaining the weights for each criterion, they are normalized and called the final importance degrees or weights for the hierarchy level. The final weights of criteria from fuzzy AHP have been to prioritize supply chain coordination criteria.

5.1 Determination of Priority Weights for Decision Criterions

The objective of using fuzzy AHP is to determine important weight of the coordination criterions. Pair wise comparison matrix that matches linguistic statement of data is formed by the questionnaire, filled by the team of experts. If the numbers of decision makers are more than one, a group matrix will be obtained by calculating geometric average of fuzzy numbers for all samples. Following steps explained the method of determining priority weights for decision criterions.

Step 1: A panel of three experts from the case company is selected as per their experience in the area of supply chain management and role in the company.

Step 2: Four criterions; Joint decision-making (JDM), Information sharing (IS), Use of IT tools (UIT) and Resource sharing (RS) have been identified as the supply chain coordination mechanisms. These are shown in Figure 3.

Step 3: The experts were asked to give the relative weight to each criterion according to the linguistic variable as per Table 1, (Togla [37]).

Table 1: Values of Triangular Fuzzy Numbers

Statement	TFN	Reciprocal TFN
Absolute (A)	(7/2, 4, 9/2)	(2/9,1/4,2/7)
Very strong (VS)	(5/2, 3, 7/2)	(2/7,1/3,2/5)
Fairly strong (FS)	(3/2, 2, 5/2)	(2/5,1/2,2/3)
Weak (W)	(2/3, 1, 3/2)	(2/3,1,3/2)
Equal (E)	(1, 1, 1)	(1,1,1)

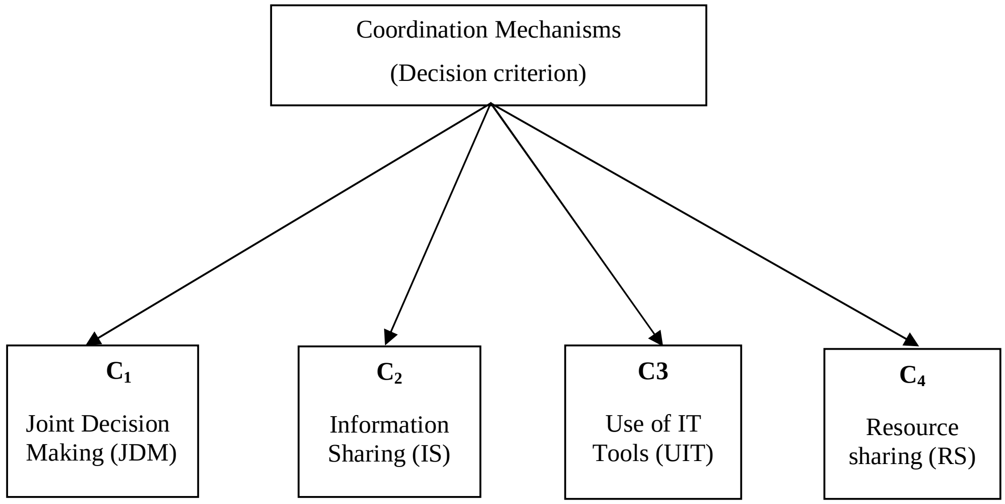

Figure 3: The Hierarchy of the Supply Chain Coordination Criterions

After the criterions have been determined as given in Figure 3, a questionnaire has been prepared to determine the importance levels of these criterions. To evaluate the questions, experts only select the related linguistic variable according to Table 1; these are illustrated in Table 2.

Table 2: Pair wise Comparisons of Criterions via Linguistic Variables

		C_1	C_2	C_3	C_4
C_1	E1	E	E	W	FS
	E2	E	W	FS	W
	E3	E	W	FS	VS
C_2	E1		E	W	FS
	E2		E	FS	FS
	E3		E	VS	FS
C_3	E1			E	E
	E2			E	W
	E3			E	W
C_4	E1				E
	E2				E
	E3				E

Further, for calculations they are converted into the corresponding triangular fuzzy numbers (refer Table 3 and Table 4).

Table 3: Pair Wise Comparisons of Selection Criterions via TFNs

		C_1	C_2	C_3	C_4
C_1	E1	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)
	E2	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)	(2/3,1,3/2)
	E3	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)	(5/2,3,7/2)
C_2	E1	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)
	E2	(2/3,1,3/2)	(1,1,1)	(3/2,2,5/2)	(3/2,2,5/2)
	E3	(2/3,1,3/2)	(1,1,1)	(5/2,3,7/2)	(3/2,2,5/2)
C_3	E1	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)
	E2	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(1,1,1)	(2/3,1,3/2)
	E3	(2/5,1/2,2/3)	(2/7,1/3,2/5)	(1,1,1)	(2/3,1,3/2)
C_4	E1	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(1,1,1)	(1,1,1)
	E2	(2/3,1,3/2)	(2/5,1/2,2/3)	(2/3,1,3/2)	(1,1,1)
	E3	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(2/3,1,3/2)	(1,1,1)

Table 4: Pair Wise Comparisons of Selection Criteria's (Modified)

	C_1	C_2	C_3	C_4
C_1	(1,1,1) (1,1,1) (1,1,1)	(1,1,1) (2/3,1,3/2) (2/3,1,3/2)	(2/3,1,3/2) (3/2,2,5/2) (3/2,2,5/2)	(3/2,2,5/2) (2/3,1,3/2) (5/2,3,7/2)
C_2	(1,1,1) (2/3,1,3/2) (2/3,1,3/2)	(1,1,1) (1,1,1) (1,1,1)	(2/3,1,3/2) (3/2,2,5/2) (5/2,3,7/2)	(3/2,2,5/2) (3/2,2,5/2) (3/2,2,5/2)
C_3	(2/3,1,3/2) (2/5,1/2,2/3) (2/5,1/2,2/3)	(2/3,1,3/2) (2/5,1/2,2/3) (2/7,1/3,2/5)	(1,1,1) (1,1,1) (1,1,1)	(1,1,1) (2/3,1,3/2) (2/3,1,3/2)
C_4	(2/5,1/2,2/3) (2/3,1,3/2) (2/7,1/3,2/5)	(2/5,1/2,2/3) (2/5,1/2,2/3) (2/5,1/2,2/3)	(1,1,1) (2/3,1,3/2) (2/3,1,3/2)	(1,1,1) (1,1,1) (1,1,1)

Step 4: Fuzzy important weight of the criterions are calculated by taking geometric mean of the responses of the experts [24].This is shown in Table 5.

Table 5: Fuzzy Geometric Mean of Pair Wise Comparison

	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(0.763,1,1.310)	(1.145,1.587,2.109)	(1.357,1.817,2.359)
C_2	(0.763,1,1.310)	(1,1,1)	(1.357,1.817,2.359)	(1.5,2.0,2.5)
C_3	(0.474,0.630,0.873)	(0.424,0.550,0.737)	(1,1,1)	(0.763,1,1.310)
C_4	(0.424,0.550,0.737)	(0.400,0.500,0.667)	(0.763,1,1.310)	(1,1,1)

Step 5: Crisp relative important weight (priority vector) for identified criterions are calculated by using the extent analysis method proposed by Chang [9] as explained previously in this paper), by equations number 2 to 9. The fuzzy values of paired comparison are converted to crisp value via the Chang's extent analysis as follows.

To determine fuzzy combination expansion for each one of the criteria, first we calculate $\sum_{j=1}^{m} M_{g_i}^{j}$ value for each row of the matrix.

C_1 = (1+0.763+1.145+1.357, 1+1+1.587+1.817, 1 +1.310+2.109+2.359)

= (4.265, 5.404, 6.778)

C_2 = (0.763+1+1.357+1.5, 1+1+1.817+2.0, 1.310 +1+2.359+2.5)

= (4.620, 6.817, 7.169)

C_3 = (0.474+0.424+1+0.763, 0.630+0.550+1+1, 0.873 +0.737+1+1.310)

= (2.661, 3.180, 3.920)

C_4 = (0.424+0.400+0.763+1, 0.550+0.500+1+1, 0.737 +0.667+1.310+1)

= (2.587, 3.050, 3.714)

The $\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}$ value is calculated as:

(4.265, 5.404, 6.778) $\oplus$ (4.620, 6.817, 7.169) $\oplus$ (2.661, 3.180, 3.920) $\oplus$ (2.587, 3.050, 3.714)

= (14.133, 18.451, 21.581)

Then calculate the $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ value

$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ = (1/21.581, 1/18.451, 1/14.133)

= (0.046, 0.054, 0.071)

The value of fuzzy synthetic extent (S_i) with respect to i^{th} criteria (i = 1, 2, 3, 4) is calculated as:

S_1 = (4.265, 5.404, 6.778) $\otimes$ (0.046, 0.054, 0.071)

= (0.196, 0.292, 0.481)

S_2 = (4.620, 6.817, 7.169) $\otimes$ (0.046, 0.054, 0.071)

= (0.213, 0.368, 0.509)

S_3 = (2.661, 3.180, 3.920) $\otimes$ (0.046, 0.054, 0.071)

= (0.122, 0.172, 0.278)

S_4 = (2.587, 3.050, 3.714) $\otimes$ (0.046, 0.054, 0.071)

= (0.119, 0.162, 0.264)

Now the V values (preference order) are calculated by using these vectors.

$$V(s_1 \geq s_2) = \frac{0.213 - 0.481}{(0.292 - 0.481) - (0.368 - 0.213)} = 0.779$$

; V ($S_1 \geq S_3$) = 1; V ($S_1 \geq S_4$) = 1.

V ($S_2 \geq S_1$) =1; V ($S_2 \geq S_3$) = 1; V ($S_2 \geq S_4$) =1;

$$V\left(s_3 \geq s_1\right) = \frac{0.196 - 0.278}{(0.172 - 0.278) - (0.292 - 0.196)} = 0.406$$

;

$$V\left(s_3 \geq s_2\right) = \frac{0.213 - 0.278}{(0.172 - 0.278) - (0.368 - 0.213)} = 0.249$$

; V ($S_3 \geq S_4$) =1

$$V\left(s_4 \geq s_1\right) = \frac{0.196 - 0.264}{(0.162 - 0.264) - (0.292 - 0.481)} = 0.782$$

$$V\left(s_4 \geq s_2\right) = \frac{0.213 - 0.264}{(0.162 - 0.264) - (0.368 - 0.213)} = 0.198$$

$$V\left(s_4 \geq s_3\right) = \frac{0.122 - 0.264}{(0.162 - 0.264) - (0.172 - 0.122)} = 0.934$$

The priorities of weights are calculated by using

$$d'(C_1) = \min\left(0.779, 1, 1\right) = 0.779$$

$$d'(C_2) = \min\left(1, 1, 1\right) = 1$$

$$d'(C_3) = \min\left(0.406, 0.249, 1\right) = 0.249$$

$$d'(C_4) = \min\left(0.782, 0.198, 0.934\right) = 0.198$$

$$W' = \left(0.779, 1, 0.249, 0.198\right)$$

After normalization, priority weight with respect main goal for all four criterions are determined, which is given as, $W = \left(0.350, 0.449, 0.112, 0.089\right)$

$$\begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{bmatrix} = \begin{bmatrix} 0.350 \\ 0.449 \\ 0.112 \\ 0.089 \end{bmatrix}$$

6. Result and Discussion

The conventional methods of decision-making have limitation in dealing with the imprecise or vague nature of linguistic assessment. Decision makers faces uncertainties from subjective perceptions and experiences in the decision making process. To overcome this limitation, fuzzy multi-criteria decision-making method has been adopted in this research work. Here an approach of the Fuzzy AHP is used to prioritize the supply chain coordination criterions. Fuzzy AHP is applied to calculate the relative weights of each criterion. The suggested methodology has been applied with the help of real life case study.

The case study deals with ranking of four coordination criterions in a leading automobile parts manufacturing company. As a result, of Fuzzy AHP Information sharing between the trading partners is determined as the most important criterion for coordination, because this criterion has highest weight priority. Joint decision-making ranked second important criterion followed by information sharing.

7. Limitations and Future Scope of the Research Work

To prioritize different coordination criterions an approach of fuzzy AHP is applied in this paper. Prioritization is done for criteria identified through literature survey, and case studies. Testing and validation of the models is limited to the experiences from the case company. The values for pair wise comparisons in fuzzy AHP depend on the knowledge of the decision-makers. The scores stating the relationship among criterions were obtained in an interview with experts. The effectiveness of the result depends on the opinion of experts. In order to improve the result, more number of experts can be interviewed. The proposed method can be applied to other multi-criteria decision making problems like personnel selection, software selection, machine selection and project selection.

8. Conclusion

The Supply chain coordination mechanism prioritization is a crucial strategic decision for long-term survival of the firm, because the profitability of a firm and customer satisfaction is directly proportional to the effectiveness of selection process. It have been observed from the literature that decision makers faces the uncertainties from subjective perceptions and experiences in the decision making process. By using Fuzzy AHP uncertainty and vagueness can be effectively handled and reached to a more effective decision. In this paper, a multi criteria decision-making model has been developed and presented in a fuzzy environment for prioritization of coordination mechanisms. The fuzzy approach capable of capturing vagueness associated with subjective perception of decision makers has been applied. The model is useful in solving the practical problem, because vagueness and imprecision can be effectively handled in this model. If the criteria and alternatives are clearly defined, the present model can be adopted in any Industry.

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