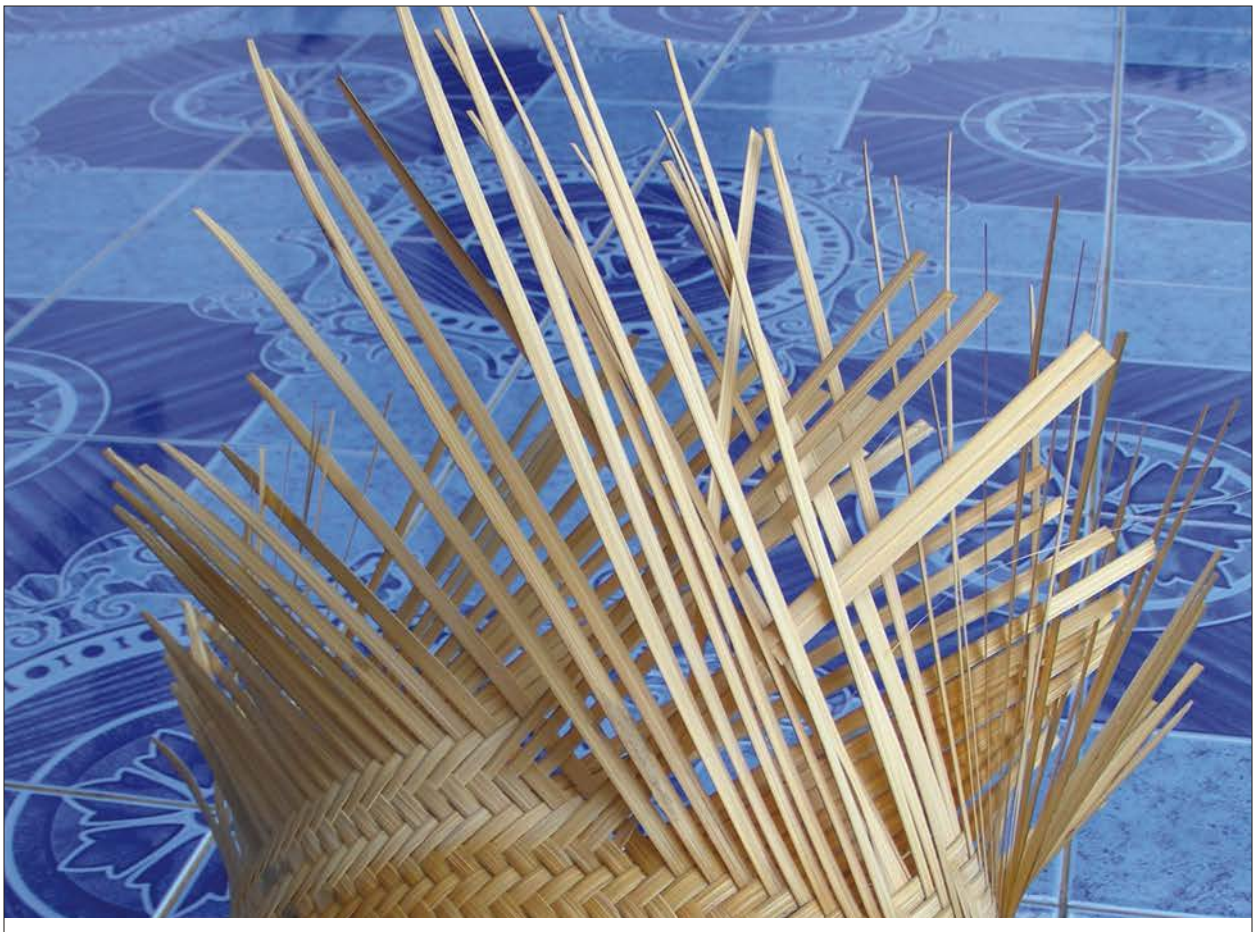

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Barriers to Information Sharing in Supply Chain of Manufacturing Industries

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ABSTRACT

Implementation of supply chain management requires integration of processes between supply chain members in all functional areas, including sourcing, manufacturing and distribution. The need for the successful implementation of information Sharing has been identified as being critical to effective innovation and development of supply chain management at an industry and enterprise level. The objective of this study is to identify and measure the perceived importance of information sharing barriers in supply chain management. The barriers have been categorized into the six main different levels namely managerial, organizational, technological, individual, financial, social and cultural. A questionnaire and interview based research approach was adopted for this purpose to identify perceptions of the most significant barriers to information sharing. It is found that the data collected through questionnaires are sometimes very much ambiguous or vague and insufficient to interpret the significant results. In this study, a fuzzy AHP approach has been used to overcome this kind of deficiency for modeling the rankings of the barriers of information sharing in supply chain management is used. Firstly, the linguistic assessment on barrier is converted into triangular fuzzy numbers. These triangular fuzzy numbers are used to build the comparison matrices of AHP based on pair wise comparison technique. This study has attempted to identify the important and legitimate barriers of information sharing in supply chain management. The findings of this research can be used for developing an evidence based ranking of barriers of information sharing in supply chain.

Key words: Information transfer, Indian manufacturing industry, fuzzy AHP, supply chain management

INTRODUCTION

Information sharing in Supply Chain Management (SCM) is receiving attention among the Indian manufacturing industries for achieving global competitive advantage. Information sharing is a key ingredient for any SCM system (Moberg *et al*., 2002). Information sharing has the potential to offer substantial benefits to supply chain members at several levels. Information sharing improves coordination among supply chain members that leads to high levels of supply chain integration (Jarrell, 1998). Information sharing influences the supply chain performance in terms of total cost and service level (Zhao and Xie, 2002). Information sharing among supply chain members can reduce different kinds of uncertainties related to demand, product and technology that add costs to supply chain processes. The information sharing facilitates to enhance the

efficiency and effectiveness of supply chain as it inherits certain advantages. These advantages include better coordination between different departments, better coordination between supply chain members and better control of the supply chain processes, reduced product design time, shorter production lead-time and stable outputs with consistent quality (Small and Yasin, 1997; Small, 1999; Sun *et al*., 1999).

In view of above, it is of utmost important to identify the parameters of information sharing that influence the effective and efficient operation of supply chain. The advancement of information technology has increased the ease of information flow and has provided many alternatives to share and integrate information. Gil-Garcia *et al*. (2007) reported that different organizations use various types of hardware, software, data standards and programming languages but the task of integrating them could be very challenging.

The identification and recognition of information sharing barriers plays an important role in the success of supply chain operations. Therefore, it is important to identify these information-sharing barriers so that managers may develop strategies in advance to tackle them. In the present study we have tried to explore a number of possible information-sharing barriers and the comprehensive knowledge about these barriers will help senior managers for auditing their strength and weaknesses of their organization.

In this study, an attempt has been made to identify and rank the major barriers that create hindrance to information sharing in Indian Manufacturing industries. A hierarchy structure has been prepared based on information received from questionnaire-interview survey. The Analytic Hierarchy Process (AHP) is a powerful and flexible decision-making technique to help managers for setting up the priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered (Saaty, 1980). AHP is a useful approach for evaluating complex multiple criteria involving subjective judgment of hierarchical structure.

In order to facilitate information sharing in the supply chain for achieving desired goals the major barriers to information sharing have been studied in detail. The available literature on barriers of information sharing in large companies, small to medium industries and public sector organization is scanty. The variations of importance of various barriers have not been given due attention by the authors. However, information-sharing barriers in supply chain have been identified based on review of literature. A targeted literature review was conducted to present the information on the barriers to information sharing in industrial enterprises. It may facilitate the managers to understand the cost associated with these barriers and viability of adopting a successful information sharing system for supply chain. These barriers have been categorized into six perspectives as presented below:

Managerial barriers: These barriers arise because the managers dealing with supply chain do not realize the real benefits of information sharing and do not have confidence in information sharing system (Marsh and Flanagan, 2000). These senior executives do not wish to invest in innovation and culture, conducive to information sharing. Zipf *et al*. (2000) concluded that lack of leadership and managerial direction for information sharing makes the implementation of information sharing extremely difficult. Curry and Moore (2003) have suggested that in order to achieve information sharing culture, support of senior management is required. The emphasis should be given on co-ordinated managerial guidance rather than imposing the hierarchy of top to down leadership. Lack of training and experience and low literacy about the new technology is also considered as one of the barrier of information sharing (Songer *et al*., 2001; Stephenson and

Blaza, 2001; Weippert *et al.*, 2002). Ives *et al.* (2002) have suggested that training and ongoing support with clear guidelines are prerequisite for effective information sharing on all the levels of organizations. Fawcett *et al.* (2008) concluded that lack of trust makes it difficult to share sensitive information because supply chain managers feel that they cannot afford to share sensitive proprietary information without ensuring that how other members of the chain will protect it from misuse. McCarter and Northcraft (2007) and Fawcett *et al.* (2008) noted that past experience of opportunistic behavior of the supply chain members in using the information create hesitation to share the information.

Organizational barriers: Organizational barriers are categorized as those barriers that are originated from attitudes of the organizations towards the implementation of information sharing. These barriers are due to the organizational structure and the groups involved in an information sharing. The process of information sharing may become complicated because of organizational barriers (O'Dell and Grayson, 1998). Information sharing initiatives require radical changes in process and behavior of individuals as well as organizations. Normally the organizations and individuals resist the changes because of structural conflicts and managerial practices of different organization in supply chain. The delay to address these embedded barriers lead to disappointment and failures. Organizational factors that are deeply embedded in institutional and professional realities also create barriers to inter-organizational information sharing. Tsai (2002) reported that organizations with centralization in strong hierarchical structure have a significant negative impact on sharing of information in a supply chain. The interests of employees to share information are greatly reduced when they do not enjoy the freedom due to limited autonomy and when they are required to seek permission from their superior for every decision. Willem and Buelens (2007) have mentioned that horizontal departmentisation in bureaucracy could also constitute barriers for information sharing. Gil-Garcia *et al.* (2007) found that the complexity of information sharing gradually increases from the organizational level to the inter-organizational level. Small to medium organizations associated in supply chain feel that information sharing is suited only to big companies and that it is an additional financial burden that will not bring any major returns on investment to their businesses.

The organizations with high level of bureaucracy and strict administrative control lack the information sharing spirit in supply chain (Bures, 2003). Researchers (Milward, 1982; Tsai, 2002; Willem and Buelens, 2007) are of the view, that formal rules, guidelines, procedures and regulation could be some barriers to information sharing as well. They have also reported that less formalized organization structure and voluntary information sharing arrangements can lead to more flexible and open interactions among employees and seem to create more beneficial environment for information sharing in supply chain. Barson *et al.* (2000) has concluded that some organizations fear of losing company stability/market position in case they share technical information with other chain members. Caudle *et al.* (1991) has shown that without support from the top management, an innovation in information sharing system is less likely to be adopted. Top management support has been consistently found to play an important role in the adoption and implementation of information sharing systems and is treated as organizational barrier.

Financial barriers: Financial constraints are a key barrier to Information sharing in supply chain. Cost considerations are the prime challenges to support the infrastructure and man-power requirements of information system. Information and technological systems require more funds

because without this efficient information sharing cannot take place in supply chain. Large amount of financial resources are needed for redesigning internal organizational and technical processes, changing traditional and fundamental product distribution channels, customer service procedures and training of staff to achieve efficient information sharing in supply chain (Motwani *et al.*, 2000). Cragg *et al.* (2002) has reported that lack of resources inhibits organizations to adopt information sharing using information technology. It is because of difficulties in raising finance to invest in information sharing systems (Damaskopoulos and Evgeniou, 2003).

Clark and Hammond (1997) reported that implementation of transparent information sharing system become very expensive in supply chain with many members. They have concluded that most chain members such as retailers show unwillingness to invest in sophisticated infrastructure for using information technology tools for the purpose of ordering and business processing. The financing of feasibility studies, systems design and management efforts to start up new supply chain communication channels becomes a substantial barrier to implement the efficient information sharing system (Lee and Whang, 2000). Love *et al.* (2001) regarded the high initial investment and running cost of maintenance of an information sharing system in supply chain as financial barriers. They have reported that the cost of specialized man-power and training of personnel as basic obstacle to information sharing. Chong and Pervan (2001) identified initial setup cost as one of the major barrier for information sharing system. Most of the small to medium organizations do not have sufficient finances to employ consultants to help the implementation of information sharing systems (Soriano *et al.*, 2002).

Technological barriers: The advancement of information technology has increased the ease of information sharing and has provided better methods to share and integrate information. Technological linkages across organizational units as well as up and down the supply chain are particularly critical to sharing information. Study has shown that complexity of a technology is a major factor that affects the adoption of information sharing (Newcomer and Caudle, 1991). Different organizations may use various types of hardware, software, data standards and definitions, as well as programming languages and the task of integrating them could be very challenging. Hoffman and Mehra (2000) stated that the technological factors can cause the failure of any information system in supply chain so that technological barriers need to be tackled at the earliest. Premkumar and Ramamurthy (1995) concluded that if the technology is simple to use, it is easier to adopt and other characteristics such as functionality, reliability and accessibility influence the users to use the technology for information sharing. Monczka and Morgan (1997) termed poor IT infrastructure as a barrier in the supply chain integration. However, poor IT infrastructure may be attributed to lack of funds and lack of awareness and commitment of top management about the use of IT tools in a supply chain (Bender, 2000; Kilpatrick and Factor, 2000). The deployment of IT tools in a supply chain is also not free from barriers. Some of these barriers are due to lack of trust in information technology tools, fear of information system breakdown etc. (Kwan, 1999; Ayers, 2000; Zhao and Xie, 2002; Li, 2000; Agarwal and Shankar, 2003). Dawes (1996) found that differences in level of the technological capabilities of chain members may be an important barrier in participation in inter-organizational information systems. Lack of ability of professionals to maintain adequate levels of knowledge and expertise due to fast pace of rapidly and radically changing technology used in information sharing system is one of the major barrier of information sharing (Dawes, 1997; Holden *et al.*, 2003).

Individual barriers: Barriers originating from behavior and actions of either individuals or groups within or between various business functions are considered individual barriers. Information is scattered among individuals and across groups or among group members. The information that other chain members might need may be available with any of individual or group in the chain. Constant *et al.* (1994) concluded that organizations' effort to encourage and facilitate the sharing of information by investing in collaborative information and communication technology becomes useless if employees are not willing to share the information. They have also stated that individuals are more willing to share information when they are happy in their organizations and unsatisfied individuals always hesitate or refuse to share information. They have suggested that it is important to explore people's attitudes toward sharing information and to see whether there are significant factors that can influence people's attitudes. Many employees are reluctant to share and contribute their own information to shared databases (Cress *et al.*, 2006). Thorpe and Mead (2001) concluded that some individuals may feel that they are already having existing overload of information sharing. Information overload is described as having more relevant information than one can assimilate (Butcher, 1998). Johnson and Payne (1985) demonstrated that information overload can even worsen the effectiveness of decisions because more information sometimes only confuses and distracts the decision maker. Szulanski (1996) has reported that one of the major barriers for sharing information is lack of motivation that can lead to many different hindrances. Individuals feel that power, ownership and privilege of possessing crucial information are lost when they share the information. Some employees regard information as a symbol of power (Kolekofski and Heminger, 2003). Sharing information is viewed as losing power and social influence among Ardichvill *et al.* (2003). These factors inhibits information sharing and can result in something that has termed as information pathologies e.g. preservation of information from co-workers to show superiority (Jarvenpaa and Staples, 2000). Pendlebury *et al.* (1998) has cited lack of training as one of the barriers to information sharing. In his study, the majority of respondents have reported that no formal training was provided with regard to the use of the information communication systems.

Childhouse and Towill (2003) has presented evidences of interference by the human element in supply chain. In his study, he has reported that several managers quietly expressed that their problems in implementing better information sharing system were rooted in individuals, not the technological impasses. These managers emphasized that it is often easier to resolve technical issues than to manage the most intractable challenges of behavioral issues. Fears and attitudes of staff is also an important group of barriers to sharing of information. Employees are afraid of making mistakes and/or feared being exposed or ridiculed on sharing wrong information (Stevens, 2000). Individuals may feel that they may be blamed in case they shared incorrect or ambiguous information. They also fear of penalty if the information is wrongly interpreted. Fear of becoming redundant and losing importance after sharing information is also a human barrier in information sharing (Love *et al.*, 2001).

Social-cultural barriers: Kamal and Themistocleous (2006) regarded misinterpretation or misuse of shared information as one of the barriers of inter-organizational information sharing. The proprietary information shared with collaborators may be either intentionally or unintentionally revealed to competitors. Bures (2003) has regarded lack of coherence between the personal intents of employees and the organization missions as one of the barriers to information sharing. According

to Curry and Moore (2003), one of the major barriers to information sharing is the failure to recognize the cultural gap between different stakeholders within an organization. Working methods, techniques and corporate culture may vary from organization to organization and this may become a barrier of information sharing in supply chain. The information culture within an organization must be conducive to information management. This means a culture that secures the support, enthusiasm and co-operation of staff and management alike (Curry and Moore, 2003). Low level of technological literacy of some participating individuals and supply chain members is also treated as another barrier for implementing information sharing (Stewart *et al.*, 2004). There may be difference of opinions among different departments due to differences in their working style. Lack of harmonious environment and lack of commitment/involvement of employees is also a major social barrier for information sharing in supply chain (Songer *et al.*, 2001). Jarvenpaa and Staples (2000) stated that information sharing can be promoted through cultural norms within the organization, on an organizational basis as well as on departmental basis. Connelly and Kelloway (2003) supported the effect of organizational culture on employees' attitudes towards information sharing. Lin (2006) found that employee's perceptions on organization's cooperativeness and the fairness of organizational procedures have a significant effect on their willingness to share information at the workplace.

RESEARCH METHODOLOGY

Fuzzy AHP approach: In conventional AHP, the pair wise comparisons for each level with respect to the barriers of information sharing are conducted using a nine-point scale. Each pair wise comparison indicates an estimate of the priorities of the compared barriers. The pair wise comparison ratios are in crisp real numbers. Even though the discrete scale of 1-9 has the advantages of simplicity and easiness for use but it does not take into account its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-makers perception to exact numbers (Deng, 1999). Importance of different barriers of information sharing always contains ambiguity and multiplicity of the meaning. These descriptions are usually linguistic and vague. It may also be recognized that human assessment on qualitative attributes is always subjective and thus imprecise. Chan *et al.* (2007) has reported that most decision-makers tend to give assessments based on their knowledge, past experience and subjective judgments. Zadeh (1965) have also stated that as the complexity of a system increases the ability to make precise and significant statements diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics. Therefore, conventional AHP seems to be inadequate for this work to generate importance weights for the ranking of barriers of information sharing.

In order to model this kind of uncertainty in human preference, Fuzzy sets can be incorporated with the pair wise comparison as an extension of AHP. Since fuzziness and vagueness are common characteristics in many decision-making problems, the Fuzzy AHP approach allows a more accurate description of the decision-making process (Ayag and Ozdemir, 2006). The fuzzy AHP method in the decision making process can be applied to many different areas due its accuracy. Kahraman *et al.* (2003) used fuzzy AHP to select the best supplier firm providing the most satisfaction for the attributes determined. Murtaza (2003) has presented a fuzzy version of AHP to risk assessment problem. The use of fuzzy methodology allows the decision maker to incorporate both qualitative and quantitative data into the decision model. For this reason, decision makers

usually feel more confident to give interval judgments rather than fixed value judgments. The fuzzy theory also allows use of mathematical operators and computer programming in the fuzzy domains.

Fuzzy set theory: The fuzzy set theory allows the membership functions to operate over the range of real numbers [0, 1]. A fuzzy set is characterized in terms of membership function and all the information about a fuzzy set is described by its membership function. The membership function maps elements (crisp inputs) in the universe of discourse (interval that contains all the possible input value) to elements degrees of membership) within a certain interval which is usually [0, 1]. Then, the degree of membership specifies the extent to which a given element belongs to a set or is related to a concept. The most commonly used range for expressing degree of membership is the unit interval [0, 1]. If the value assigned is 0, the element does not belong to the set (it has no membership). If the value assigned is 1, the element belongs completely to the set (it has total membership). Finally, if the value lies within the interval [0, 1], the element has a certain degree of membership (it belongs partially to the fuzzy set). A fuzzy set contains elements that have different degrees of membership in it. The main characteristic of fuzziness is the grouping of individuals into classes that do not have sharply defined boundaries (Hansen, 2005). The fuzzy number can represent the uncertain comparison judgment (Leung and Cao, 2000).

A fuzzy number is a special fuzzy set $F = \{(x, \mu_F(x)), x \epsilon R\}$ where x takes it values on the real line, R: $-8<x<+8$ and $\mu(x)$ is a continuous mapping from R to the closed interval [0, 1]. A triangular fuzzy number denoted as $\tilde{M} = (a, b, c)$, where $a \le b \le c$ has the following triangular type membership function (Fig. 1):

$$\mu_F(x) = \begin{cases} 0 & x < a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ \dfrac{c-x}{c-b} & b \le x \le c \\ 0 & x > c \end{cases} \quad (1)$$

In this study, triangular fuzzy numbers, $\tilde{1}$ to $\tilde{9}$, have been used to represent subjective pair wise comparisons of barriers of information sharing. Boender *et al.* (1989) stated that the triangular approximation of fuzzy operations provides fuzzy solutions with much smaller spread than trapezoidal membership functions as proposed by Buckley (1985). A character tilde "~" is placed above a symbol if the symbol represents a fuzzy set. In order to take the imprecision of human qualitative assessments into consideration; the five triangular fuzzy numbers are defined with the corresponding membership function as shown in Fig. 2 and Table 2.

Alternatively, by defining the interval of confidence level α, the triangular fuzzy number is characterized as:

$$\begin{aligned} &\forall \alpha \in [0,1] \\ &\tilde{M}_\alpha = [a^\alpha, c^\alpha] = [(b-c)a + a, -(c-b)a + c] \end{aligned} \quad (2)$$

The α-cut values and index of optimism μ incorporated into Fuzzy AHP matrix take care of the accuracy of the measurement. α-cut is known to incorporate the experts or decision maker (s)

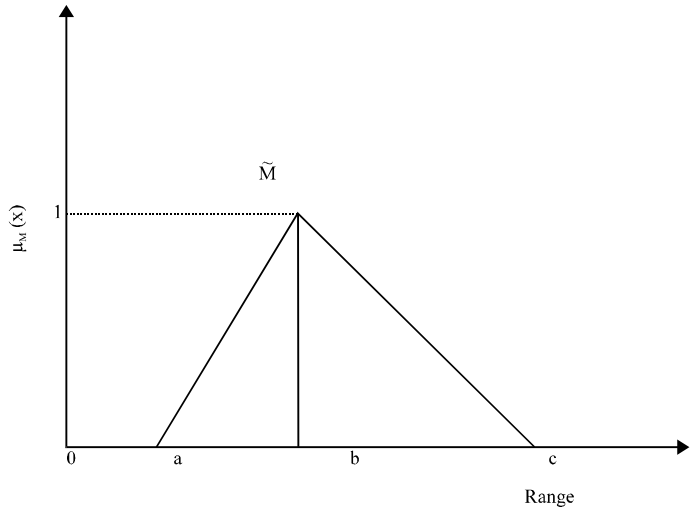

Fig. 1: Triangular fuzzy number

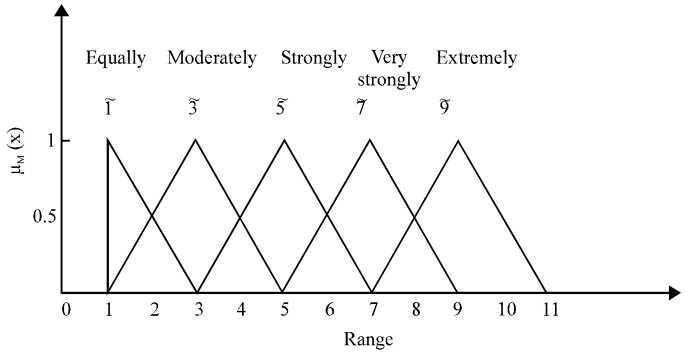

Fig. 2: The membership function of triangular fuzzy number

confidence over his/her preference or the judgments. It will yield an interval set of values from a fuzzy number. For example, $\alpha = 0.5$ will yield a set $\alpha_{0.5} = (2, 3, 4)$. The operation is presented by using Table 2 and Fig. 3.

Computational procedure of fuzzy AHP: The AHP method is also known as an eigenvector method. It indicates that the eigenvector corresponding to the largest eigen-value of the pair wise comparisons matrix provides the relative priorities of the factors and preserves ordinal preferences among the alternatives. This means that if an alternative is preferred to another, its eigenvector component is larger than that of the other. A vector of weights obtained from the pair wise comparisons matrix reflects the relative performance of the various factors. In the Fuzzy AHP, triangular fuzzy numbers are utilized to improve the scaling scheme in the judgment matrices and interval arithmetic is used to solve the fuzzy eigenvector (Cheng and Mon, 1994). The computational procedure of this approach has been summarized as follows:

- **Step 1:** Construct the hierarchy structure model
- **Step 2:** Comparing the relative strength score: Triangular fuzzy numbers ($\tilde{1}$ $\tilde{3}$ $\tilde{5}$ $\tilde{7}$ and $\tilde{9}$) are used to indicate the relative strength of each pair of elements in the same hierarchy

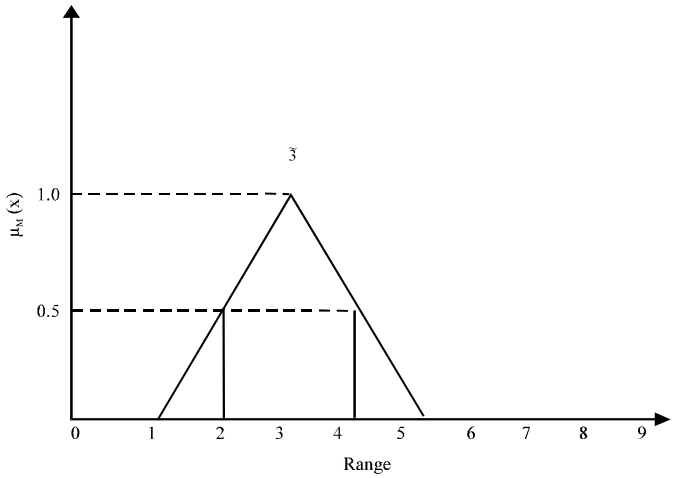

Fig. 3: α-cut operation on triangular fuzzy number

- **Step 3:** Constructing the fuzzy comparison matrix: By using triangular fuzzy numbers, via pair wise comparison, the fuzzy judgment matrix $\tilde{A}$ (α_{ij}) is constructed as given below:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{\alpha}_{12} & \tilde{\alpha}_{13} & \cdots & \tilde{\alpha}_{1(n-1)} & \tilde{\alpha}_{1n} \\ \tilde{\alpha}_{21} & 1 & \tilde{\alpha}_{23} & \cdots & \tilde{\alpha}_{2(n-1)} & \tilde{\alpha}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \tilde{\alpha}(n-1)1 & \tilde{\alpha}(n-1)2 & \tilde{\alpha}(n-1)3 & \cdots & 1 & \tilde{\alpha}(n-1)n \\ \tilde{\alpha}_{n1} & \tilde{\alpha}_{n2} & \tilde{\alpha}_{n3} & \cdots & \tilde{\alpha}_{n(n-1)} & 1 \end{bmatrix} \quad (3)$$

where $\tilde{\alpha}_{ij} = 1$, if i equal to j and $\tilde{\alpha}_{ij} = \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ or $\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1}$ if i is not equal to j

- **Step 4:** Estimating the degree of optimism for $\tilde{A}$

Degree of satisfaction for the judgment matrix $\tilde{A}$ is estimated by the index of optimism μ. The larger value of the index μ indicates the higher degree of optimism. The index of optimism is a linear convex combination defined (Lee *et al.*, 1999) as:

$$\hat{\alpha}_{ij}^{\alpha} = \mu\alpha_{iju}^{\alpha} + (1-\mu)\alpha_{ijv}^{\alpha}, \quad \forall\mu \in [0,1] \quad (4)$$

While α is fixed, the following crisp judgment matrix can be obtained after setting the index of optimism, μ, in order to estimate the degree of satisfaction.

$$\tilde{A} = \begin{bmatrix} 1 & \hat{\alpha}_{12}^{\alpha} & \cdots & \hat{\alpha}_{1n}^{\alpha} \\ \hat{\alpha}_{21}^{\alpha} & 1 & \cdots & \hat{\alpha}_{2n}^{\alpha} \\ \cdots & \cdots & \ddots & \vdots \\ \hat{\alpha}_{n1}^{\alpha} & \hat{\alpha}_{n2}^{\alpha} & \cdots & 1 \end{bmatrix} \quad (5)$$

- **Step 5:** Solving fuzzy eigen-value

A fuzzy eigen-value, λ is a fuzzy number solution to:

$$\tilde{A}\tilde{x} = \tilde{\lambda}\tilde{x} \tag{6}$$

where, $\tilde{A}$ is n by n fuzzy matrix containing fuzzy numbers $\tilde{\alpha}_{ij}$ and $\tilde{x}$ is a non-zero n by 1 fuzzy vector containing fuzzy number $\tilde{x}_i$. To perform fuzzy multiplications and additions by using the interval arithmetic and α-cut, the equation $\tilde{A}\tilde{x} = \tilde{\lambda}\tilde{x}$ becomes equivalent to:

$$[a_{i1l}^{\alpha} x_{1l}^{\alpha}, a_{1u}^{\alpha}] \oplus .... \oplus [a_{inl}^{\alpha} x_{nl}^{\alpha}, a_{inu}^{\alpha} a_{nu}^{\alpha}] = [\lambda x_{il}^{\alpha}, \lambda x_{iu}^{\alpha}]$$

where, $\tilde{A} = [\tilde{a}_{ij}]$, $\tilde{x}^t = (\tilde{x}_1, ..., \tilde{x}_n)$

$$\tilde{a}_{ij}^{\alpha} = [a_{ijl}^{\alpha}, a_{iju}^{\alpha}], \tilde{x}_i^{\alpha} = [x_{il}^{\alpha}, x_{iu}^{\alpha}], \quad \lambda^{\alpha} = [\lambda_l^{\alpha}, \lambda_u^{\alpha}] \tag{7}$$

For $0<\alpha\leq 1$ and all i, j where I = 1, 2,... .., n and j = 1, 2,... .., n

- **Step 6:** Determining the weights for criteria

The eigen-value method can be used for calculating the eigenvector or weight vector for each pair-wise matrix. The eigenvector is calculated by fixing the μ value and identifying the maximal eigen-value (Saaty, 1980).

Normalization of the matrix of paired comparisons and calculation of priority weights (approximate attribute weights) are done before calculating α max. The consistency ratio for each of the matrices and overall inconsistency for the hierarchy are calculated in order to control the results of this method. The deviations from consistency are expressed by the following equation:

$$CI = \frac{\lambda max - n}{n - 1} \tag{8}$$

where, CI is consistency index.

The Consistency Ratio (CR) is used to estimate directly the consistency of pair wise comparisons. The CR is computed by using Eq. 9. RI is the average index for randomly generated weights. The value of RI has been obtained depending upon the rank of matrix (Saaty, 1980):

$$CR = \frac{CI}{RI} \tag{9}$$

If the CR is less than 0.10, the comparisons are acceptable, otherwise not. If the consistency test is not passed, the decision maker is required to revise the original values in the pair wise comparison matrix.

EVALUATION OF HIERARCHY FOR INFORMATION SHARING BARRIERS

Building the initial hierarchy model and its criteria: Initially more than 100 attributes for information sharing barriers were proposed based on review of literature. An initial hierarchy model of information sharing barriers was developed and after that, experts were asked to review the hierarchy model for the sake of feasible application in supply chain management. Eight experts

from areas of academics, finance and production and material management were selected. An interview with the eight experts was arranged to review the initial information sharing barriers hierarchy. Interviews helped in for direct discussion with the experts and the hierarchy model was immediately revised at the same time during the discussion. A description brochure of criteria was also given to the eight experts to check whether these descriptions in the information sharing barriers hierarchy were understandable. After revising both the hierarchy and descriptions of criteria, a hierarchy Information sharing barriers model was developed (Table 1).

Table 1: List of main criteria and sub criteria for barriers for information sharing

Main criterion	Criterion code	Sub criterion
Managerial barriers	MB 1	Lack of perceived benefits of information sharing
	MB 2	Lack of trust and of confidence in information sharing system
	MB 3	Lack of leadership and managerial direction
	MB 4	Conservative business practices
	MB 5	Lack of accuracy and credibility of information source
	MB 6	Opportunistic behavior of the chain members
	MB 7	Undefined roles and responsibilities of different members of the chain
	MB 8	Poor Targeting of Information
Organizational barriers	OB 1	Poor infrastructural facilities for information sharing
	OB 2	Fear of losing company stability and market position
	OB 3	Lack of top management support
	OB 4	Formal rules, guidelines and procedures and regulation
	OB 5	Centralization of hierarchical structure slows down information sharing
	OB 6	Lack of long-term relationship among chain member
	OB 7	Lack of corporate culture for information sharing
Financial barriers	FB 1	Lack of resources for system design costs
	FB 2	Lack of resources for cost of hardware
	FB 3	Lack of resources for software cost
	FB 4	Lack of resources for operational expenditure
	FB 5	Financial constraints for high cost of maintenance
	FB 6	Cost of specialized manpower and training
Technological barriers	TB 1	Data and information Security
	TB 2	Incompatibility of information system with process functions
	TB 3	Lack of technical support for maintenance of IT systems
	TB 4	Lack of efficiency and effectiveness of Information system
	TB 5	Sophisticated and complex technology for information sharing
	TB 6	Rapidly changing technology
Individual barriers	IB 1	Fear of penalty if the shared information is misused
	IB 2	Reluctance by unsatisfied individuals to share information
	IB 3	Fear of loss of intellectual property ownership
	IB 4	Fear of embarrassment for sharing incorrect information .information
	IB 5	Information overload for gathering and reporting information
	IB 6	Lack of rewards and incentives for information sharing
Social-cultural barriers	SCB 1	Different values, cultural and linguistic environment
	SCB 2	Lack of computer literacy among staff
	SCB 3	Lack of support, encouragement motivation to adopt new technology
	SCB 4	Employee with diverse missions, goals and priorities
	SCB 5	Lack of commitment/involvement of employees
	SCB 6	Difference in levels of education, skill and experience of employees
	SCB 7	Lack of willingness and sharing spirit among employees

Table 2: Definition and membership function of fuzzy numbers (Ayag and Ozdemir, 2006)

Intensity of importance	Fuzzy number	Definition	Membership function
1	$\tilde{1}$	Equally important/preferred	(1, 1, 3)
3	$\tilde{3}$	Moderately more important/preferred	(1, 3, 5)
5	$\tilde{5}$	Strongly more important/preferred	(3, 5, 7)
7	$\tilde{7}$	Very strongly more important/preferred	(5, 7, 9)
9	$\tilde{9}$	Extremely more important/preferred	(7, 9, 11)

Table 3: Sample questionnaire for pair-wise comparison of the relative criteria

Criterion A	$\tilde{9}$	$\tilde{7}$	$\tilde{5}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{7}$	$\tilde{9}$	Criterion B
Lack of perceived benefits of information sharing							*			Lack of trust and of confidence in information
								*		Lack of leadership and managerial direction
				*						Conservative business practices
								*		Lack of accuracy and credibility of information source
				*						Opportunistic behavior of the chain members

Table 4: Fuzzy comparison matrix for the major criteria

Attributes	Managerial	Organizational	Financial	Technological	Individual	Social-cultural
Managerial	1	$\tilde{5}^{-1}$	$\tilde{7}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}$	$\tilde{5}$
Organizational	$\tilde{5}$	1	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{5}$
Financial	$\tilde{7}$	$\tilde{5}$	1	$\tilde{1}$	$\tilde{5}$	$\tilde{7}$
Technological	$\tilde{7}$	$\tilde{3}$	$\tilde{1}^{-1}$	1	$\tilde{3}$	$\tilde{7}$
Individual	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1	$\tilde{3}$
Social-Cultural	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{7}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	1

Fuzzy comparison matrices: A Fuzzy AHP technique to evaluate the attributes of barriers of information sharing in supply chain has been presented in this study. About twenty-five professionals working at responsible positions from the various manufacturing industries of India were interviewed to evaluate the information sharing barriers hierarchy model. The aim of the interaction was to understand their opinions on three aspects: (i) Weight judgments of the Information sharing barriers (ii) Their attitude toward the FAHP approach used by this study and (iii) their suggestions in general.

All barriers have been structured into different hierarchical levels before performing the pair wise comparison of barriers to information sharing in supply chain management (Table 1). After constructing a hierarchy, the decision-makers were asked to express the preference $(\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9})$ by pair-wise comparing of the relative importance of each criterion using triangular fuzzy numbers by separate questionnaire to estimate their relative importance in relation to the element at the immediate proceeding level. The sample questionnaire is shown in Table 3.

After finalizing the assessment of relative importance by the experts for the information sharing barriers selection model, the fuzzy comparison matrixes for major and sub criterions are prepared and shown in Table 4-10.

After finalizing the assessment of relative importance by these experts for the Information sharing barriers selection model, the triangular membership function and α-cuts were used to convert the subjective judgments of the experts to become fuzzy judgments. After that, a degree of optimism for the experts was estimated by the index of optimism μ. All initial individual fuzzy

Table 5: Fuzzy comparison matrix for sub criteria of managerial barriers

Attributes	MB 1	MB 2	MB 3	MB 4	MB 5	MB 6	MB 7	MB 8
MB 1	1	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}$
MB 2	$\tilde{7}$	1	$\tilde{5}$	$\tilde{9}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{9}$
MB 3	$\tilde{3}$	$\tilde{5}^{-1}$	1	$\tilde{5}$	$\tilde{1}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}$
MB 4	$\tilde{3}^{-1}$	$\tilde{9}^{-1}$	$\tilde{5}^{-1}$	1	$\tilde{7}^{-1}$	$\tilde{7}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}$
MB 5	$\tilde{5}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{7}$	1	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{9}$
MB 6	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{7}$	$\tilde{3}$	1	$\tilde{1}$	$\tilde{9}$
MB 7	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{7}$	$\tilde{3}$	$\tilde{1}^{-1}$	1	$\tilde{9}$
MB 8	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$	$\tilde{7}^{-1}$	$\tilde{3}^{-1}$	$\tilde{9}^{-1}$	$\tilde{9}^{-1}$	$\tilde{9}^{-1}$	1

Table 6: Fuzzy comparison matrix for sub criteria of organizational barriers

Attributes	OB 1	OB 2	OB 3	OB 4	OB 5	OB 6	OB 7
OB 1	1	$\tilde{5}$	$\tilde{5}^{-1}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$
OB 2	$\tilde{5}^{-1}$	1	$\tilde{9}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$
OB 3	$\tilde{5}^{-1}$	$\tilde{9}$	1	$\tilde{7}$	$\tilde{3}$	$\tilde{3}$	$\tilde{7}$
OB 4	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{7}^{-1}$	1	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$.
OB 5	$\tilde{3}$	$\tilde{7}$	$\tilde{3}^{-1}$	$\tilde{7}$	1	$\tilde{3}^{-1}$	$\tilde{5}$
OB 6	$\tilde{5}$	$\tilde{7}$	$\tilde{3}^{-1}$	$\tilde{5}$	$\tilde{1}^{-1}$	1	$\tilde{3}$
OB 7	$\tilde{1}^{-1}$	$\tilde{5}$	$\tilde{7}^{-1}$	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1

Table 7: Fuzzy comparison matrix for sub criteria of financial barriers

Attributes	FB 1	FB 2	FB 3	FB 4	FB 5	FB 6
FB 1	1	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$
FB 2	$\tilde{3}^{-1}$	1	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$	$\tilde{7}^{-1}$
FB 3	$\tilde{5}$	$\tilde{7}$	1	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
FB 4	$\tilde{3}$	$\tilde{5}$	$\tilde{3}^{-1}$	1	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$
FB 5	$\tilde{7}$	$\tilde{9}$	$\tilde{3}$	$\tilde{5}$	1	$\tilde{3}$
FB 6	$\tilde{5}$	$\tilde{7}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}^{-1}$	1

Table 8: Fuzzy comparison matrix for sub criteria of the technological barriers

Attributes	TB 1	TB 2	TB 3	TB 4	TB 5	TB 6
TB 1	1	$\tilde{3}$	$\tilde{7}^{-1}$	$\tilde{9}$	$\tilde{9}$	$\tilde{5}$
TB 2	$\tilde{3}^{-1}$	1	$\tilde{5}^{-1}$	$\tilde{9}$	$\tilde{7}$	$\tilde{3}$
TB 3	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	1	$\tilde{5}$	$\tilde{5}$	$\tilde{3}$
TB 4	$\tilde{9}^{-1}$	$\tilde{9}^{-1}$	$\tilde{5}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{7}^{-1}$
TB 5	$\tilde{9}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	1	$\tilde{5}^{-1}$
TB 6	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{7}$	$\tilde{5}$	1

Table 9: Fuzzy comparison matrix for sub criteria of individual barriers

Attributes	IB 1	IB 2	IB 3	IB 4	IB 5	IB 6
IB 1	1	$\tilde{1}$	$\tilde{7}$	$\tilde{3}$	$\tilde{5}$	$\tilde{7}$
IB 2	$\tilde{1}^{-1}$	1	$\tilde{7}$	$\tilde{3}$	$\tilde{5}$	$\tilde{9}$
IB 3	$\tilde{7}^{-1}$	$\tilde{7}^{-1}$	1	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$
IB 4	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}$	1	3	$\tilde{5}$
IB 5	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{3}^{-1}$	1	$\tilde{3}$
IB 6	$\tilde{7}^{-1}$	$\tilde{9}^{-1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	1

Table 10: Fuzzy comparison matrix for sub criteria of social and cultural barriers

Attributes	SCB 1	SCB 2	SCB 3	SCB 4	SCB 5	SCB 6	SCB 7
SCB 1	1	$\tilde{3}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$
SCB 2	$\tilde{3}^{-1}$	1	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{9}^{-1}$	$\tilde{9}^{-1}$	$\tilde{9}^{-1}$
SCB 3	$\tilde{5}$	$\tilde{5}$	1	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
SCB 4	$\tilde{5}$	$\tilde{5}$	$\tilde{3}$	1	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
SCB 5	$\tilde{5}$	$\tilde{9}$	$\tilde{5}$	$\tilde{3}$	1	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$
SCB 6	$\tilde{7}$	$\tilde{9}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}$	1	$\tilde{1}^{-1}$
SCB 7	$\tilde{5}$	$\tilde{9}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}$	$\tilde{1}$	1

comparison matrices based on triangular membership function and α-cuts were formulated. The lower limit and upper limit of the fuzzy numbers with respect to α are defined using Eq. 2:

$$\tilde{1}_\alpha = [1, 3-2\alpha], \qquad \tilde{1}_\alpha^{-1} = \left[\frac{1}{3-2\alpha}, 1\right]$$

$$\tilde{3}_\alpha = [1+2\alpha, 5-2\alpha] \qquad \tilde{3}_\alpha^{-1} = \left[\frac{1}{5-2\alpha}, \frac{1}{1+2\alpha}\right]$$

$$\tilde{5}_\alpha = [3+2\alpha, 7-2\alpha] \qquad \tilde{5}_\alpha^{-1} = \left[\frac{1}{7-2\alpha}, \frac{1}{3+2\alpha}\right]$$

$$\tilde{7}_\alpha = [5+2\alpha, 9-2\alpha] \qquad \tilde{7}_\alpha^{-1} = \left[\frac{1}{9-2\alpha}, \frac{1}{5+2\alpha}\right]$$

$$\tilde{9}_\alpha = [7+2\alpha, 11-2\alpha] \qquad \tilde{9}_\alpha^{-1} = \left[\frac{1}{11-2\alpha}, \frac{1}{7+2\alpha}\right]$$

The α-cut values and index of optimism μ incorporated into fuzzy AHP matrix take care of the accuracy of the service quality measurement. The values α = 0.5 and μ = 0.5 are used in this case study. By putting α = 0.5 in the above expression and then putting the value of fuzzy numbers in the Table 4-10 fuzzy comparison matrices are obtained for main criterion and sub criterion. For example, Fuzzy Comparison Matrix (FCM) for the determinants (α = 0.5, μ = 0.5) main criterion is given below:

$$\text{FCMmain}(\alpha = 0.5 \text{ and } \mu = 0.5) = \begin{bmatrix} 1 & \left[\frac{1}{6}, \frac{1}{4}\right] & \left[\frac{1}{8}, \frac{1}{6}\right] & \left[\frac{1}{8}, \frac{1}{6}\right] & [2,4] & [4,6] \\ [4,6] & 1 & \left[\frac{1}{6}, \frac{1}{4}\right] & \left[\frac{1}{4}, \frac{1}{2}\right] & [2,4] & [4,6] \\ [6,8] & [4,6] & 1 & [1,2] & [4,6] & [6,8] \\ [6,8] & [2,4] & \left[\frac{1}{2}, 1\right] & 1 & [2,4] & [6,8] \\ \left[\frac{1}{4}, \frac{1}{2}\right] & \left[\frac{1}{4}, \frac{1}{2}\right] & [6,8] & \left[\frac{1}{4}, \frac{1}{2}\right] & 1 & [2,4] \\ \left[\frac{1}{6}, \frac{1}{4}\right] & \left[\frac{1}{6}, \frac{1}{4}\right] & \left[\frac{1}{8}, \frac{1}{6}\right] & \left[\frac{1}{8}, \frac{1}{6}\right] & \left[\frac{1}{4}, \frac{1}{2}\right] & 1 \end{bmatrix}$$

Equation 3 is used to transform fuzzy group comparison matrix into group crisp comparison matrix and from that the importance weights of major criteria of information sharing barriers are obtained (Table 11).

Table 11: Final priority of information sharing barriers

Main criterion	Major criterion Wt.	Criterion code	CR	Ratio weight	Final weight	Survey mean	Final score	Rank
Managerial barriers	0.0877	MB 1	0.0801	0.0471	0.0041	2.2315	0.0092	33
		MB 2		0.3435	0.0301	2.8367	0.0855	9
		MB 3		0.0849	0.0074	2.4545	0.0183	26
		MB 4		0.0268	0.0024	2.2021	0.0052	36
		MB 5		0.1154	0.0101	2.6543	0.0269	23
		MB 6		0.1899	0.0167	2.7155	0.0452	16
		MB 7		0.1754	0.0154	2.6060	0.0401	18
		MB 8		0.0171	0.0015	2.0541	0.0031	38
Organizational barriers	0.1475	OB 1	0.0665	0.0842	0.0124	3.7518	0.0466	15
		OB 2		0.0250	0.0037	2.9870	0.0110	31
		OB 3		0.0413	0.0061	2.6520	0.0161	28
		OB 4		0.2092	0.0309	4.2121	0.1300	8
		OB 5		0.1708	0.0252	2.9820	0.0751	13
		OB 6		0.4025	0.0594	3.7450	0.2223	5
		OB 7		0.0671	0.0099	2.6340	0.0261	24
Financial barriers	0.3574	FB 1	0.0854	0.0488	0.0174	2.4128	0.0421	17
		FB 2		0.0299	0.0107	2.6087	0.0279	21
		FB 3		0.1810	0.0647	2.1081	0.1364	7
		FB 4		0.1012	0.0362	2.2524	0.0814	11
		FB 5		0.3975	0.1421	3.6543	0.5191	1
		FB 6		0.2416	0.0864	3.2824	0.2835	3
Technological barriers	0.3129	TB 1	0.0899	0.4478	0.1401	3.2340	0.4531	2
		TB 2		0.2582	0.0808	2.9860	0.2412	4
		TB 3		0.0803	0.0251	2.6540	0.0667	14
		TB 4		0.0254	0.0080	2.2040	0.0175	27
		TB 5		0.0432	0.0135	2.3450	0.0317	19
		TB 6		0.1451	0.0454	3.9023	0.1772	6
Individual barriers	0.0657	IB 1	0.0803	0.3525	0.0232	3.6028	0.0834	10
		IB 2		0.3241	0.0213	3.6587	0.0779	12
		IB 3		0.0572	0.0038	2.7222	0.0102	32
		IB 4		0.1502	0.0099	2.8541	0.0282	20
		IB 5		0.0838	0.0055	2.6236	0.0145	30
		IB 6		0.0322	0.0021	2.4421	0.0052	37
Social-cultural barriers	0.0289	SCB 1	0.0879	0.0454	0.0013	2.2435	0.0029	39
		SCB 2		0.0226	0.0007	2.3658	0.0015	40
		SCB 3		0.0754	0.0022	2.6893	0.0059	35
		SCB 4		0.0994	0.0029	2.7123	0.0078	34
		SCB 5		0.1862	0.0054	2.9865	0.0161	29
		SCB 6		0.2733	0.0079	3.1052	0.0245	25
		SCB 7		0.2977	0.0086	3.2365	0.0278	22

For example Group Crisp Comparison Matrix A for (GCCM) ($\mu = 0.5$) for main criteria is:

$$\text{Matrix A} = \begin{bmatrix} 1 & 0.2083 & 0.1458 & 0.1458 & 3 & 5 \\ 5 & 1 & 0.2083 & 0.375 & 3 & 5 \\ 7 & 3 & 1 & 1.5 & 5 & 7 \\ 7 & 3 & 0.75 & 1 & 3 & 7 \\ 0.375 & 0.375 & 0.2083 & 0.375 & 1 & 3 \\ 0.2083 & 0.2083 & 0.1458 & 0.1458 & 0.375 & 1 \end{bmatrix}$$

Eigen-values of the matrix 'A' have been calculated as follows by solving the characteristic equation of A, det (A–λI) = 0:

$\lambda_1 = 6.5452$ $\lambda_2 = -0.18+2.0245i,$ $\lambda_3 = -0.1178-2.0245i$
$\lambda^4 = -0.3673$ $\lambda_5 = -0.0711+0.3372i$ $\lambda_6 = -0.0711-0.3372i$

As the value of λ_1 is the largest, the corresponding eigenvectors of A can be calculated as follows by substituting the λ_1 in to the equation, AX = λX:

$$X_1 = (0.1621, 0.3228, 0.7036, 0.5958, 0.1268, 0.0588)^T$$

After normalization, the importance weights of the dimensions (criterion) can be determined as shown below:

Normalized weight for main criteria = (0.0877, 0.1475, 0.3574, 0.3129, 0.0657, 0.0289)

The Consistency Ratio (CR) has been computed using equation 8 and 9.
Here CR of the matrix A can be calculated as:

$$CR = \frac{CI}{RI}$$

and:

$$CI = \frac{\lambda max - n}{n-1}$$

Here λmax =6.5452, n = 6 for matrix A, then:

$$CI = \frac{6.5452 - 6}{6-1} = 0.10904$$

RI = 1.24, then:

$$CR = \frac{CI}{RI} = 0.087935$$

For matrix A, CR<0.1, so this comparison of main criteria is acceptable.

The subjective judgments for the information sharing barriers hierarchy model have been analyzed by consistency ratio and if the subjective judgments of the experts were found to be inconsistent, they were requested to repeat the pair-wise comparison processes until the criterion of consistency test was not fulfilled. It was found that CR for the entire main as well as sub criteria of barriers to be less than 0.1 and all the fuzzy comparison matrices were found to be consistent.

By following the similar calculations, fuzzy comparison matrices for sub criteria were transformed into crisp comparison matrices and their major criterion weight, Consistency Ratio

(CR), ratio weight for Managerial, Organizational, Financial, Technological, Individual and Social-Cultural Barriers were calculated using computer program and results are shown in Table 11.

A survey was carried out on Likert scale 1-5 to obtain the views of the different executives in Indian industries on importance of these barriers. The means of survey data has been calculated for different barriers of information sharing under study. The priority weight of each barrier has been calculated by multiplying the importance weight of each barrier obtained by FAHP method and the survey mean score of each barrier. Final ranking of different barriers has been shown in the Table 11.

RESULTS AND DISCUSSION

Based on literature review and discussions with academicians, practitioners and executives from industries, six main barriers were of considerable importance. The analysis shows that financial, technological and organizational barriers are of prime importance (Table 11). The financial barriers were found to be of highest importance in order among them with weight of 0.3574 followed by technological barriers with weight of 0.3129 in order among all of them. Further, it can be seen that about 50% of information sharing problem arises due these two barriers only.

It can be observed from the Table 11 that the financial barrier viz. 'Financial constraint for high cost of maintenance' (FB-5) is having highest rank in the list. Information sharing in many organizations is often initiated on an ad-hoc basis and the continuing growth of the initiatives is not always nurtured by financial support. 'Data and information security' (TB-1) from the technological perspective list is ranked at number two. Threat to information security requires on-line firewalls and adequate security. This shows that the supply chain managers are not ready to loose sensitive information to their competitors by sharing information. 'Cost of specialized manpower and training' (FB-6) under financial sub criterion is third barrier in the list. Sometimes cost of training and man-power in the field of information technology becomes barrier to get professionals with adequate level of expertise.

The fourth important barrier from analysis under the technological perspective list is 'Incompatibility of information system with process functions' (TB-2). It is required that participating organizations need to have compatible infrastructures to exchange information to obtain greater utility.

'Lack of top management support' (OB-6) which is sub criterion of the organizational barrier, is at fifth rank in the final list. The top management should demonstrate commitment to the information sharing activities at par with other organizational goals by integrating all the members of the supply chain. The sixth rank in the list has been assigned to 'Rapidly changing technology' (TB-6) under the category of technological barriers. The challenges of learning the technology are complicated by the nature and pace of technological developments since past two decades. 'Lack of financial support for cost of software' (FB-3) is ranked at seventh position. 'Centralization of hierarchical structure' (OB-4) slows down information sharing and this barrier from the analysis is ranked at eighth position followed by 'Lack of trust and of confidence in information sharing system' (MB-2) and 'Fear of penalty if the shared information is misused' (IB-1) are placed at 9th and 10th rank respectively. Rest all other barriers with final weights shown in the table are having very less priority weight so they do not need much attention by management.

CONCLUSION

This study has attempted to identify the important and legitimate barriers of information sharing in supply chain management based on the review of research articles. Total 40 barriers

were identified and Fuzzy AHP technique has been used to analyze the ranking of different barriers. This methodology explicitly handles vague and ambiguous data and has been used to improve the imprecise ranking of most significant barriers to information sharing. The barriers have been ranked according to their final score based on importance weight of each barrier obtained by FAHP methodology and the survey mean score of each barrier. The crucial barriers found in the study are financial, technological and organizational barriers for integration of information sharing with supply chain in the Indian manufacturing industry. The 'financial constraints for high cost of maintenance' under the category of financial barrier was found to be of highest importance in order is and followed by 'Data and information security' as technological barrier. 'Cost of specialized manpower and training' has been found to be third financial barrier in order of the list.

The findings of this study can be used for developing an evidence based ranking of barriers of information sharing in supply chain. Adaptation of fuzzy numbers was found to be helpful for managers to have freedom of judgment while responding to the questionnaires of the rating of information sharing barriers during this study. The barriers to information sharing have been generalized and may be inadequate or very specific for some specific industries. This methodology may found to be helpful for managers to arrive at critical barriers for their industries.

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