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Analyzing the interaction of factors for flexibility in supply chains

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Abstract

Purpose – In the present scenario of global competition and economic recession, most of the organizations are facing tough challenge to survive in the market because of shortening product life cycle and reducing profit margin. Customers are seeking better design, production and delivery, which have made firms to concentrate on flexibility in supply chains. Therefore, the purpose of this study is to identify major factors and develop a suitable framework for flexibility in supply chains.

Design/methodology/approach – Based on literature review, about 14 factors have been identified. To develop relationship among these factors, a team of five experts from industry and academia was formed. Based on inputs from experts, different relationships are developed among factors to form structural self-interaction matrix (SSIM). Based on this matrix, a flexibility framework is developed by interpretive structural modelling approach.

Findings – Top management commitment, strategy development for flexible SC, application of advance technology and IT tools, information sharing in SC members, trust development among supply chain members have emerged as major driving factors. Logistics and warehouse management, suppliers flexibility, distribution flexibility and manufacturing flexibility have emerged as dependent factors.

Research limitations/implications – Framework developed in this study is based on interpretive structural modelling. This framework can be further validated with some case analysis and empirical findings.

Originality/value – Findings of the study can be useful for industry professionals to develop strategies for flexible supply chains. It will help them in taking new initiatives for making supply chains more responsive and proactive for customers demand.

Keywords Performance, Supply chain management, Flexibility, Product life cycle

Paper type Research paper

1. Introduction

Supply chain is a form of industrial organization that allows buyers and sellers, who are separated by time and space, to progressively add value as products pass from one member of the chain to the next (Hughes, 1994; Handfield and Nichols, 1999). Supply chains are effective networks of firms functioning in a particular product/service value chain (Stevenson, 2007). In the present context of globalization, customer requirements are changing continuously and product life cycle is shortening. Firms have acknowledged the importance of flexibility in meeting customer demands and improving responsiveness

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under uncertain conditions (Vickery *et al.*, 1999). Uncertainty in the supply chains can take many forms, for example, uncertainty regarding the reliability of suppliers, the actions of competitors or the quality of products. One of the key sources of uncertainty in the supply chain relates to the quantities, timings and specifications of end-customer demand and is a key cause of the bullwhip effect (Disney and Towill, 2003). Most literature on manufacturing and supply chain flexibility describes flexibility as a response to, or a means to cope with, uncertainty (Sheffi and Rice, 2005).

Flexibility is typically defined in terms of range, mobility and uniformity, that is, the ability to move from making one product to making another and the ability to perform comparably well when making any product within a specified range (Slack, 1983; Upton, 1995). To meet emerging challenges of dynamic markets, flexibility in whole supply chain has become essential. Flexibility at a particular firm level will not be able to meet market challenges. All members of supply chain, that is, suppliers, manufacturers, distributors and retailers, have to be flexible in their operations. By aligning flexibility with the external environment, organizations can ensure profit and sales performance.

Duclos *et al.* (2003) developed a conceptual model of supply chain flexibility consisting of six components. Lummus *et al.* (2003) have considered five elements such as operational systems, logistics processes, supply network, organizational design and information systems flexibility. Most notably, logistics (processes) flexibility relates to receiving and delivering products as sources of supply and customers change, while supply (network) flexibility refers to the ability to re-configure the supply chain, altering the supply of products in line with demand. Vickery *et al.* (1999) defines that supply chain flexibility comprises of those flexible dimensions that directly impact a firm and are shared among various functions, that is, internal (marketing, manufacturing) or external (suppliers, channel members). Flexibility is most commonly associated with the literature on Manufacturing Flexibility which emerged in the 1980s and 1990s with seminal papers by Slack (1983, 1987), Gerwin (1987, 1993) and Upton (1995). Singh and Sharma (2014) have considered manufacturing, customers and suppliers flexibility as alternatives for improving overall flexibility of supply chains. Chiang *et al.* (2012) have observed that strategic sourcing and firm's strategic flexibility were significantly related to the firm's supply chain agility. According to Gunasekaran *et al.* (2001), flexibility refers to making available the the products/service to meet the individual demand of customers. According to them, this has become possible as a result of the development of such technologies as flexible manufacturing systems, group technology and computer-integrated manufacturing (CIM). In addition, other methods such as single minute exchange of die, as well as information technology (IT) and communication systems facilitate quick response and provide online information. A more detailed conceptual model on supply chain flexibility dimensions has been provided by Duclos *et al.* (2003). According to them, flexibility in the supply chain adds the requirement of flexibility within and between all partners in the chain, including departments within an organization, and the external partners, such as suppliers, carriers, third-party companies and information systems providers.

With growth in outsourcing, companies are increasingly relying on service providers and sources of supply and realizing the need of management and integration of the whole value chain from vendor to consumer (Fisher, 1997; Lambert *et al.*, 1998; Croom *et al.*, 2000; Jack and Raturi, 2002), blurring the traditional boundaries of the firm. Because of high competence and responsiveness, it has become important to understand how certain organizational conditions enable firms to develop the ability to respond to the change. These conditions have been referred to as "Factors of flexibility" because their presence in the organization appears to support the ability to thrive in uncertain and dynamic environments

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(Dove, 1995; Goldman and Nagel, 1993). According to Vickery *et al.* (1999), flexibility in supply chains may well represent a potential source to improve the company's efficiency and may be a significant measure of supply chain performance. The objectives of this paper are to identify major factors for flexible supply chain management (FSCM) and develop a structural model from an implementation perspective. Organization of this paper is as follows. Section 2 deals with literature review, that is, identification of factors, Section 3 deals with research methodology, that is, interpretive structural modelling (ISM) and Section 4 deals with the results and discussion and finally conclusion.

2. Literature review

There are many factors influencing flexibility in supply chains. These may be related to people, machines and ICT (Vander and Beulens, 2002). Some of the crucial factors for analyzing the interaction of factors for flexibility in supply chains are discussed in this section.

2.1 Top management commitment

According to Kumar *et al.* (2015), top management support is essential for success of any supply chain. Singh (2015) has observed that top management initiatives help in making supply chain responsive and flexible. Jennings and Kenley (1996) have found that total quality management, supply base management, customer-driven corporate policy and other elements of supply chain management are the key strategic options available to achieve competitiveness. Top management commitment plays a key role in implementing different initiatives. However, efforts made by companies to implement these options have not been universally successful and have even failed in many cases to yield the desired results (Griffith, 2006). Regression models introduced by Kola and Latvala (2003) and Yee *et al.* (2005) have identified several factors that directly and positively impact corporate performance. These include the extent to which companies analyze the strategies of competitors and determine future customer requirements and the commitment (Tan *et al.*, 1999).

2.2 Strategy development for flexible supply chain

Managing the supply chains has become very important. Chandra and Kumar (2000) have discussed about the role of planning and coordination in an integrated system in creating a framework for the appropriate structure and better control. Firms are finding that they can no longer compete effectively in isolation of their suppliers or other entities in the supply chain (Spekman *et al.*, 1998). Lummus and Vokurka (1999) have observed that linking a firm's supply chain strategy to its overall business strategy and some practical guidelines can lead to successful supply chain management. Strategic flexibility is the capability of the company to respond quickly to changing competitive conditions to develop and sustain competitive advantage. Strategic flexibility allows the firm in developing future manufacturing strategies, which help them to react swiftly to the changing nature of internal and external conditions.

2.3 Information sharing among supply chain members

Sanchez and Perez (2005) have observed that IT can help supply chain members in improving the performance of supply chain systems. Suarez *et al.* (1996) have derived optimal inventory policies under different information-sharing scenarios. It is also found that information sharing reduces the level of behavioral uncertainty, which, in turn,

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improves the level of trust (Sanchez and Perez, 2005). Jennings and Kenley (1996) have presented a framework for understanding the evolution of buyer–supplier relationships during the past two decades from transaction processes based on arms-length agreements to collaborative processes based on trust and information sharing. Bhadani *et al.* (2016) have observed that organizations should invest in IT and telecommunication systems to improve information flow in supply chains.

2.4 Trust among supply chain partners

The presence of trust among supply chain partners can improve the chances of the supply chain to be flexible (Chan and Chan, 2009). A lack of trust among supply chain partners often results in inefficient and ineffective performance as the transaction costs (verification, inspections and certifications of their trading partners) increase (Singh, 2013). Firm's trust in its supply chain partner is highly associated with both sides' specific asset investments (positively) and behavioral uncertainty (negatively). A partner's reputation in the market should have a positive impact on the trust-building process, whereas partner's perceiving conflicts would lead to negative impact on trust (Gosain *et al.*, 2005).

2.5 Collaborative decision-making by supply chain members

Buyer–supplier relationships play an important role in an organization's ability to respond to dynamic and unpredictable change. If the relationship is too restrictive, then flexibility will be difficult to achieve, and if it is too lenient, then the risk of opportunism will be present. To achieve the objective of collaborative decision-making, buyer–supplier relationship needs to be reviewed from the perspectives of transaction cost theory, strategy-structure theory and resource-based theory of the firm (Clarke and Varma, 1999). Singh (2013) has observed that flexibility in supply chain has the ability to change levels of production rapidly, to develop new products and to respond quickly to competitive threats. This requires managers to find the right balance between committing the resources necessary to carry out a decision and avoiding investment of good money in bad projects (Shimizu and Hitt, 2004).

2.6 Application of advance technology and IT tools

Advance technology is a very important factor for all supply chains. Seamen (1995) have observed that applications of IT tools in the food industry have helped in reducing prices of food items consistently. It is widely observed that the key differentiator between the successful and not so successful retailers is primarily in the area of technology. According to Mukhopadhyay (2009), technology can help the organized retailer to lead over the unorganized players, gaining both cost and service advantages. Kärkkäinen (2003) has showed that radio-frequency identification (RFID) processes can be used to carry out continuous monitoring of backroom and shelf inventory, providing automated notification when replenishment is required. Hind (1994) has observed that RFID technology has been applied mainly in the organizational activities such as merchandise classification and tracking, data collection and analysis, production control, product authentication and authority identification. Both technological and design capabilities have a positive effect on technology commercialization. Upton (1995) has observed that the flexibility of the plants depends much more on people than on any technical factor.

According to Singh and Sharma (2014), flexibility in the supply chain can be enhanced by developing technological capabilities by making more investments in advanced technologies and giving more emphasis to human resource welfare-related activities like

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training and education, recruitment policies, providing incentives on job training facilities, multi-skilling of the employees, etc.

2.7 Logistics and warehouse management

The management of the flow and storage of materials and related information across supply chains is the fundamental feature of logistics management. Logistics services influence customers to evaluate firms on factors beyond the physical product. Hannon (2005) has emphasized the need for development of the proper logistics system. A theoretical goal for facility location is identified: every plant should be located at the point of profit maximization (Smykay *et al.*, 1961).

Richmond (2004) and Ahmed *et al.* (2005) have observed that the use of tools such as finite-element analysis (FEA) software can help packaging designers and engineers to study about complex packaging structure and optimize cost and performance effectively. They also observed that millions of dollars can be saved by substituting trial-and-error packaging design with rational math/science-based FEA. Agrawal *et al.* (2015) have felt the need for integrated logistic management for making supply chains more responsive and efficient.

2.8 Revenue and risk sharing

Jennings and Kenley (1996) have observed that risk management has become a critical issue as a result of globalization. Revenue sharing is valuable in vertically separated industries in which demand is either stochastic (unpredictable) or variable (e.g. systematically declining). Unlike two-part tariffs, revenue sharing achieves the best outcome by softening retail price competition without distorting retailers. Supply chain risk management (SCRM) is of growing importance, as the vulnerability of supply chains increases. Fisher (1997), Lambert *et al.* (1998), Croom *et al.* (2000) and Jack and Raturi (2002) have tried to analyze, access and manage risk sources along the supply chain, partly by working closely with suppliers by placing formal requirements on them. It has been observed that risk related to traditional logistics concepts (time, cost, quality, agility and leanness) should be put into the trade-off analysis while evaluating new logistics solutions instead of minimizing risks (Norrman and Jansson, 2004).

2.9 Vendor development

Many supply chains operate with poor forecasting and planning systems and operate with long cycle systems (Agarwal *et al.*, 2014). They also have problems with unreliable inventory control systems, with no stock tracing and poor cost control. This can lead to excess, obsolete stock and eroding customer service levels (Gunasakeran *et al.*, 2000).

Humpherys *et al.* (2005) and Singh *et al.* (2010) have observed that vendor development can help in improving the performance of not only buyers but of vendors also. By vendor development, buying firms can help their vendors in increasing their capabilities and improving their performance. It was found that higher-rated vendors emphasize process management and employee satisfaction to a greater degree than lower-rated vendors (Park *et al.*, 2001). Voss (2013) has observed that purchasing managers prefer to purchase the highest quality product from their suppliers.

2.10 Training of employees

Proper training of employees is considered a very important aspect for implementing new initiatives in a firm. According to Hui (2004), effective strategies and technologies can work to their optimum with proper leadership and trained employees. According to

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Boyer and Pagell (2000), new manufacturing capabilities can be only achieved when companies make infrastructural investments, such as quality leadership, training and empowerment of employees.

2.11 Manufacturing flexibility

The process of choosing appropriate supply chain performance measures is difficult because of the complexity of these systems. Benita (1999) has considered manufacturing flexibility measures for supply chains performance. Singh and Sharma (2014) have observed that manufacturing flexibility is the most important alternative for supply chain flexibility. The availability of methods such as building smaller production units, cellular manufacturing systems, multipurpose machines, material handling and workforce agility has been cited as manufacturing flexibility approaches being integrated from shop floor to plant level (Upton, 1995; Vokurka and O'Leary, 2000). Gerwin (1993) and Upton (1995) have considered different aspect of flexible manufacturing system such as adoption of functions (flexibility in machine, labor, operation functions, logistics) or hierarchical (flexibility at shop-floor, plant and organization level) affecting the range of response towards the product volume and mix changes.

2.12 Supplier flexibility

It examines suppliers' ability to change as per market demands. Even though there has been a tremendous amount of research on the topic of flexibility, most of it has been confined to intra-firm flexibility concerns. JIT practices can help firms in achieving flexibility by reducing impediments of change. Gunasekaran *et al.* (2001) have observed that computer integrated manufacturing can help SMEs to reduce lead time and increase flexibility, reliability and customer service. Duclos *et al.* (2003) have identified opportunities for future cross-functional research that can build theoretical foundation and lead to more effective formulation of supply chain strategies. Girubha *et al.* (2016) have observed that selection of sustainable suppliers are crucial for ensuring success of supply chains.

2.13 Distribution flexibility

Distribution flexibility is used to guide organizations to measure and improve supply chain responsiveness and organizational performance. The research is carried out to identify that agile supply chain distribution enhances organizational performance. The critical distribution practices of supply chains that make supply chains agile are collaborative distribution, order commitment, distribution flexibility and inventory management. These practices have a significant impact on organizational performance (Khan *et al.*, 2009). Changes in overall warehouse locations, distribution of products among the warehouses, transportation network and mode of transportation can emphasize the supply chain performance significantly.

Chan and Chan (2009) conducted a number of simulation studies to investigate the effects on these two characteristics of the distributed supply chain, that is, flexibility and adaptability, which are subjected to uncertainty. Their research mainly focused on demand uncertainty and quality flexibility.

2.14 Flexible supply chain

To meet dynamic market requirements in terms of lead time, volume and variety, flexible supply chain is essential. Flexibility in supply chains represents a potential means of

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improving a company's efficiency and is one of significant measures of supply chain performance. Tummala *et al.* (2007) conducted a case study to identify important factors that are necessary for successful implementation of supply chain management (SCM) in an organization. Singh and Sharma (2015) have developed a TISM-based framework to evaluate flexibility index of a supply chain.

All above discussed factors for FSCM have been summarized in Table I.

3. Research methodology

The concept of interpretive structural modeling (ISM) has been used for modeling factors of FSCM. The basic idea of ISM is to decompose a complicated system into several subsystems (elements) by using practical experience of experts and their knowledge. The ISM process transforms unclear, poorly articulated mental models of systems into visible, well-defined models. Singh *et al.* (2007) have applied ISM for modeling of critical success factors for implementation of advanced manufacturing technologies in organizations. Bhadani *et al.* (2016) have used ISM for investment decision in the Indian mobile service sector. Steps involved in the ISM methodology are as follows:

SN	Factors	References
1	Top management commitment	Bhadani *et al.* (2016), Kumar *et al.* (2015), Singh (2015), Griffith, (2006), Yee *et al.* (2005), Kola and Latvala (2003), Tan *et al.* (1999), Jennings and Kenley (1996)
2	Strategy development for flexible SC	Singh and Sharma (2015), Kumar *et al.* (2015), Chandra and Kumar (2000), Spekman *et al.* (1998), Lummus *et al.* (2003)
3	Information sharing in SC members	Bhadani *et al.* (2016), Chan and Chan (2009), Sanchez and Perez (2005), Suarez *et al.* (1996), Jennings and Kenley (1996), Duncan (1995)
4	Trust development among SC members	Singh, (2013), Chan and Chan (2009), Gosain *et al.* (2005)
5	Collaborative decision-making by SC members	Hoyt and Huq (2000), Laura, (2001) Clarke and Varma, (1999)
6	Application of advance technology and IT tools	Bhadani, *et al.* (2016), Mukhopadhyay (2009), Kärkkäinen (2003), Seamen (1995), and Hind (1994)
7	Logistics and warehouse management	Agrawal *et al.* (2015), Sharma and Bhat (2012b) Ralston *et al.* (2013), Hannon (2005), Smykay *et al.* (1961), Richmond (2004) and Ahmed *et al.* (2005)
8	Revenue and risk sharing	Sharma and Bhat (2012a), Jack and Raturi (2002), Norrman and Jansson (2004), Jennings and Kenley (1996), Fisher (1997); Lambert *et al.* (1998); Croom *et al.* (2000)
9	Vendor development	Bansal *et al.* (2014), Humpherys *et al.* (2005), Voss, (2013), Park *et al.* (2001), Gunasakeran *et al.* (2000)
10	Training of employees	Singh *et al.* (2007), Hui (2004), Boyer and Pagell (2000)
11	Manufacturing flexibility	Singh and Sharma (2014), Sharma and Bhat (2013), Benita (1999), Upton (1995); Gerwin (1993); Upton (1995)
12	Supplier flexibility	Girubha *et al.* (2016), Singh and Sharma (2014), Duclos *et al.* (2003), Leslie *et al.* (2003), Gunasekaran *et al.* (2001);
13	Distribution flexibility	Agrawal *et al.* (2015), Khan *et al.* (2009), Chan and Chan (2009)
14	Flexible supply chain	Singh and Sharma (2015), Sharma and Bhat (2014), Chan and Chan (2009) Tummala *et al.* (2007), Christopher and Peck (2004)

Table I. Factors for flexible supply chain management (FSCM)

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- Identification of factors: The elements of the system are identified which are relevant to the problem or issue and then finalized with a group problem-solving technique like brainstorming sessions.
- Contextual relationship: From the factors identified in Step 1, a contextual relationship is identified among factors. A structural self-interaction matrix (SSIM) is prepared based on pair-wise comparison of factors of the system under consideration.
- Reachability matrix is developed from the SSIM, and it is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a Factor A is related to B and B is related to C, then A is necessarily related to C.
- The reachability matrix obtained in Step 3 is converted into the canonical matrix format by arranging the elements according to their levels.
- From the canonical matrix form of the reachability matrix, a directed graph is drawn by means of vertices or nodes and lines of the edges and the transitive links are removed based on the relationships given above in the reachability matrix.

The resultant digraph is converted into an ISM, by replacing factors nodes with the statement.

3.1 Structural self-interaction matrix

ISM methodology suggests the use of expert opinion in developing the contextual relationship among the factors. To develop a relationship among these factors, a team of five experts from industry and academia was formed. All experts were having more than ten years of experience. Three members were from industry and two members from academia. The majority view was considered as final decision. Based on the opinion of experts, Table I is developed. Four symbols are used to denote the direction of the relationship between the criterion (*i* and *j*):

V: Criterion *i* will help to achieve criterion *j*;
A: Criterion *j* will be achieved by criterion *i*;
X: Criterions *i* and *j* will help to achieve each other; and
O: Criterions *i* and *j* are unrelated.

The following statements would explain the use of the symbols V, A, X and O in SSIM (Table II):

- Factor 1 helps achieve Factor 2. This means that factor, namely, "Top management commitment", will help to achieve factor "Strategy development for flexible SC". Thus, the relationship between Factors 1 and 2 is denoted by "V" in the SSIM.
- Factor 3 can be achieved by Factor 6, that is, Factor 6, namely, "Application of Advance technology and IT Tools" would help to achieve Factor 3, that is, "Information sharing among SC members". Thus, the relationship between these factors is denoted by "A" in the SSIM.
- Factors 4 and 3 help achieve each other. Factor 4, namely, "Trust development among SC members", and Factor 3, namely, "Information sharing in SC members", help achieve each other. Thus, the relationship between these factors is denoted by "X" in the SSIM.

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SN	Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Top management commitment		V	V	V	V	V	V	V	V	V	V	V	V	V
2	Strategy development for flexible SC			V	V	V	V	V	V	V	V	V	V	V	V
3	Information sharing among SC members				X	V	A	V	V	V	V	V	V	V	V
4	Trust development among SC members					V	O	V	V	V	O	O	V	V	V
5	Collaborative decision-making by SC members						A	V	X	V	V	V	V	V	V
6	Application of advance technology and IT tools							V	O	V	V	V	V	V	V
7	Logistics and warehouse management								A	A	A	V	V	V	V
8	Revenue and risk sharing policies									V	O	V	V	V	V
9	Vendor development										A	V	V	V	V
10	Training of employees											V	V	V	V
11	Manufacturing flexibility												X	X	V
12	Supplier flexibility													X	V
13	Distribution flexibility														V
14	Flexible supply chain														

Notes: Here for i< j; A: Factors j leads to Factors i; V: Factors i leads to Factors j; X: Factors i and j lead to each other; O: No relationship between i and j

Table II. Structural self-interaction matrix (SSIM)

- No relationship exists between trust development among SC members (Factor 4) and application of advance technology and IT tools (Factor 6), and hence, the relationship between these factors is denoted by "O" in the SSIM.

3.2 Reachability matrix

The SSIM is transformed into a binary matrix, called the initial reachability matrix by replacing V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following. Initial reachability matrix is given in Table III:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.

SN	Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Top management commitment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Strategic development for flexible SC	0	1	1	1	1	1	1	1	1	1	1	1	1	1
3	Information sharing in SC members	0	0	1	1	1	0	1	1	1	1	1	1	1	1
4	Trust development among link partners	0	0	1	1	1	0	1	1	1	0	0	1	1	1
5	Collaborative decision-making by SC members	0	0	0	0	1	0	1	1	1	1	1	1	1	1
6	Application of advance technology and IT Tools	0	0	1	0	1	1	1	0	0	1	1	1	1	1
7	Logistics and warehouse management	0	0	0	0	0	0	1	0	0	0	1	1	1	1
8	Revenue and risk sharing policies	0	0	0	0	1	0	1	1	1	0	1	1	1	1
9	Vendor development	0	0	0	0	0	0	1	0	1	0	1	1	1	1
10	Training of employees	0	0	0	0	0	0	1	0	1	1	1	1	1	1
11	Manufacturing flexibility	0	0	0	0	0	0	0	0	0	0	1	1	1	1
12	Supplier flexibility	0	0	0	0	0	0	0	0	0	0	1	1	1	1
13	Distribution flexibility	0	0	0	0	0	0	0	0	0	0	1	1	1	1
14	Flexible supply chain	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table III. Initial reachability matrix

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- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

3.3 Level partitions

After considering transitivity effect, final reachability matrix is given in Table IV. From the final reachability matrix, the reachability and antecedent set for each factor are found. The reachability set consists of the element itself and other elements, which it may help achieve, whereas the antecedent set consists of the element itself and the other elements, which may help in achieving it. Then the intersection of these sets is derived for all elements. The element for which the reachability and intersection sets are same is the top-level element in the ISM hierarchy. The top-level element of the hierarchy would not help achieve any other element above their own level. Once the top-level element is identified, it is separated out from the other elements. Then, the same process finds the next level of element. This process continues till the levels of each element are found. All iterations for identification of levels of different factors are shown in Tables V to XII. These identified levels help in building the digraph and final model.

4. Results and discussion

Results have been discussed in two parts. The first part will try to develop ISM-based framework for flexible supply chains and the second part will try to classify the factors based on driving and dependence power derived from final reachability matrix, that is, Table IV.

4.1 Formation of ISM-based framework

Based on levels derived from different iterations and relations in final reachability matrix (Table IV), the structural framework is generated by means of vertices or nodes and lines of

SN	Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	D.P
1	Top management commitment	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
2	Strategy development for flexible SC	0	1	1	1	1	1	1	1	1	1	1	1	1	1	13
3	Information sharing in SC members	0	0	1	1	1	0	1	1	1	1	1	1	1	1	11
4	Trust development among SC members	0	0	1	1	1	0	1	1	1	1*	1*	1	1	1	11
5	Collaborative decision-making by SC members	0	0	0	0	1	0	1	1	1	1	1	1	1	1	9
6	Application of advance technology and IT tools	0	0	1	1*	1	1	1	1*	0	1	1	1	1	1	11
7	Logistics and warehouse management	0	0	0	0	0	0	1	0	0	0	1	1	1	1	5
8	Revenue and risk sharing policies	0	0	0	0	1	0	1	1	1	1*	1	1	1	1	9
9	Vendor development	0	0	0	0	0	0	1	0	1	0	1	1	1	1	6
10	Training of employees	0	0	0	0	0	0	1	0	1	1	1	1	1	1	7
11	Manufacturing flexibility	0	0	0	0	0	0	0	0	0	0	1	1	1	1	4
12	Supplier flexibility	0	0	0	0	0	0	0	0	0	0	1	1	1	1	4
13	Distribution flexibility	0	0	0	0	0	0	0	0	0	0	1	1	1	1	4
14	Flexible supply chain	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Dependence	1	2	5	5	7	3	10	7	9	8	12	13	13	14	109

Notes: D.P. - Driving power; * - Transitivity effect

Table IV. Final reachability matrix

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Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1	1	
2	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2	2	
3	2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 6	2, 3, 4	
4	2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 6	2, 3, 4	
5	5, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 8	5, 8	
6	3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14	1, 2, 6	6	
7	7, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	7	
8	5, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 8	5, 8	
9	7, 9, 11, 12, 13, 14	1, 2, 3, 4, 5, 8, 9, 10	9	
10	7, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 8, 10	10	
11	11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	11, 12, 13	
12	11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	11, 12, 13	
13	11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	11, 12, 13	
14	14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	14	I

Table V.
Iteration 1

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1	1	
2	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 2	2	
3	2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 6	2, 3, 4	
4	2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4	2, 3, 4	
5	5, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 8	5, 8	
6	3, 6, 7, 8, 10, 11, 12, 13	1, 2, 6	6	
7	7, 11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	7	
8	5, 7, 8, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 8	5, 8	
9	7, 9, 11, 12, 13	1, 2, 3, 4, 5, 8, 9, 10	9	
10	7, 9, 10, 11, 12, 13	1, 2, 3, 4, 5, 6, 8, 10	10	
11	11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	11, 12, 13	II
12	11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	11, 12, 13	II
13	11, 12, 13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	11, 12, 13	II

Table VI.
Iteration 2

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1	1	
2	2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2	2	
3	2, 3, 4, 5, 7, 8, 9, 10	1, 2, 3, 4, 6	2, 3, 4	
4	2, 3, 4, 5, 7, 8, 9, 10	1, 2, 3, 4	2, 3, 4	
5	5, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 8	5, 8	
6	3, 6, 7, 8, 10	1, 2, 6	6	
7	7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	7	III
8	5, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 8	5, 8	
9	7, 9	1, 2, 3, 4, 5, 8, 9, 10	9	
10	7, 9, 10	1, 2, 3, 4, 5, 6, 8, 10	10	

Table VII.
Iteration 3

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Table VIII.
Iteration 4

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 8, 9, 10	1	1	
2	2, 3, 4, 5, 6, 8, 9, 10	1, 2	2	
3	2, 3, 4, 5, 8, 9, 10	1, 2, 3, 4, 6	2, 3, 4	
4	2, 3, 4, 5, 8, 9, 10	1, 2, 3, 4	2, 3, 4	
5	5, 8, 9, 10	1, 2, 3, 4, 5, 6, 8	5, 8	
6	3, 6, 8, 10	1, 2, 6	6	
8	5, 8, 9, 10	1, 2, 3, 4, 5, 6, 8	5, 8	
9	9	1, 2, 3, 4, 5, 8, 9, 10	9	IV
10	9, 10	1, 2, 3, 4, 5, 6, 8, 10	10	

Table IX.
Iteration 5

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 8, 10	1	1	
2	2, 3, 4, 5, 6, 8, 10	1, 2	2	
3	2, 3, 4, 5, 8, 10	1, 2, 3, 4, 6	2, 3, 4	
4	2, 3, 4, 5, 8, 10	1, 2, 3, 4	2, 3, 4	
5	5, 8, 10	1, 2, 3, 4, 5, 6, 8	5, 8	
6	3, 6, 8, 10	1, 2, 6	6	
8	5, 8, 10	1, 2, 3, 4, 5, 6, 8	5, 8	
10	10	1, 2, 3, 4, 5, 6, 8, 10	10	V

Table X.
Iteration 6

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 8	1	1	
2	2, 3, 4, 5, 6, 8	1, 2	2	
3	2, 3, 4, 5, 8	1, 2, 3, 4, 6	2, 3, 4	
4	2, 3, 4, 5, 8	1, 2, 3, 4	2, 3, 4	
5	5, 8	1, 2, 3, 4, 5, 6	5	
6	3, 6	1, 2, 6	6	
8	5, 8	1, 2, 4, 5, 6, 8	5, 8	VI

Table XI.
Iteration 7

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6	1	1	
2	2, 3, 4, 5, 6	1, 2	2	
3	2, 3, 4, 5	1, 2, 3, 4, 6	2, 3, 4	
4	2, 3, 4, 5	1, 2, 3, 4	2, 3, 4	
5	5	1, 2, 3, 4, 5, 6	5	VII
6	3, 6	1, 2, 6	6	

the edges. If there is a relationship between the factors i and j, then this is shown by an arrow which points from i to j. This graph is called a directed graph or digraph. After removing the transitivities as described in ISM methodology, the digraph is finally converted into ISM as shown in Figure 1. Top management is at the bottom of framework, that is, major driving factor. It helps in strategy formulation for application of advanced

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technologies and developing trust in supply chains. Trust among members of supply chain helps in collaborative decision-making and in sharing of revenue and risks. These initiatives help in developing vendors, thereby improving flexibility in manufacturing and distribution and finally flexible supply chains. Flexible supply chains help organizations in meeting dynamic market requirements.

4.2 Classification of factors

Based on the driving power and the dependence, these factors for flexible supply chain management have been classified into four clusters, that is, (i) Autonomous, (ii) Dependent, (iii) Linkages, and (iv) Drivers. These factors are shown in Figure 2.

4.2.1 Cluster I: Weak driving power and weak dependence. This group is called autonomous or excluded factors. They appear quite out of line with the system. However, a

Factor	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 6	1	1	XI
2	2, 3, 4, 6	1, 2	2	X
3	2, 3, 4	1, 2, 4, 6	2, 3, 4	VIII
4	2, 3, 4	1, 2, 3, 4	2, 3, 4	VIII
6	3, 6	1, 2, 6	6	IX

Table XII. Iteration 8

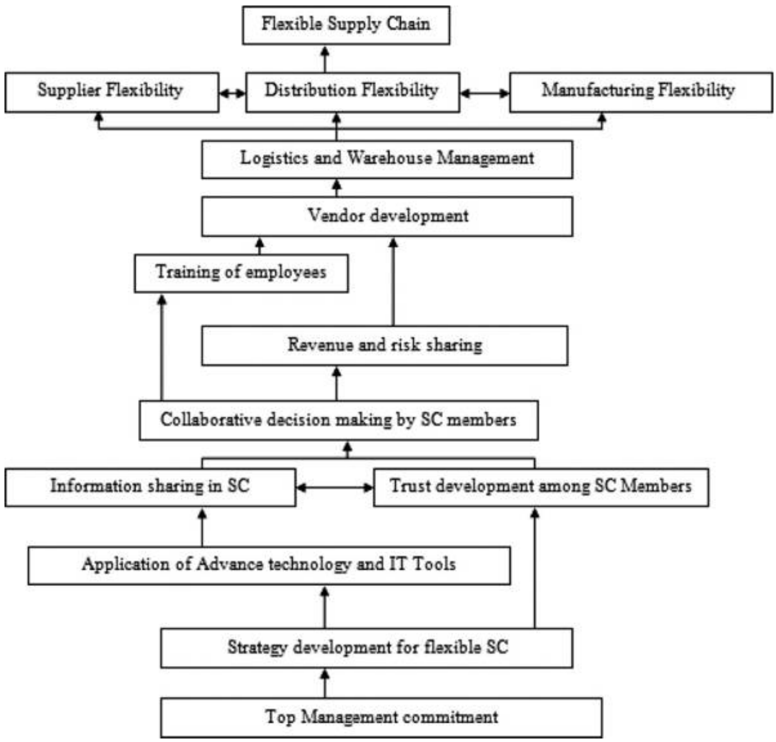

Figure 1. ISM-based framework for factors of flexible supply chain management

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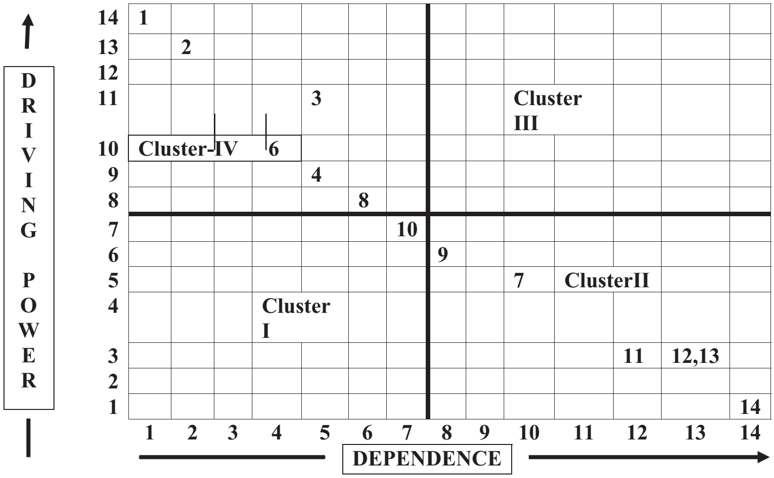

Figure 2.
Classification of factors

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distinction may be drawn within this group between the disconnected factors situated near the axis's origin, whose evolution, therefore, seems to be rather excluded from the system's global dynamics and secondary levers. These factors are located in the south-west frame. The analysis reveals that Factor 10, that is, training of employees comes under this category (Figure 2).

4.2.2 Cluster II: Weak driving power and strong dependence. These factors are called dependent factors or result-oriented factors. These factors, located in the south-east frame of the chart, are at the same time little influent and very dependent. So they are especially sensitive to the evolution of influent factors. In this study, Factors 7,9,11,12,13,14, namely, logistics and warehouse management, vendor development, supplier flexibility, distribution flexibility, manufacturing flexibility, flexible supply chain management fall in this cluster (Figure 2). This finding implies that flexible supply chain management can be analyzed in terms of these results-oriented factors.

4.2.3 Cluster III: Strong driving power and strong dependence. These factors are at the same time very influencing and very dependent. They are also called linkages factors. These factors are situated in the north-east frame of the chart and are unstable. Any action on these indicators will have impact on others and feedback effect on themselves which may amplify or support the initial pulse. These are usually unstable factors. In the present study, there is no factor in this cluster (Figure 2).

4.2.4 Cluster IV: Strong driving power and weak dependence. These factors are altogether very influential and very less dependent on others. These factors are located in the north-west frame of the diagram (Figure 2) and known as drivers of the system. Most of the dependent factors or results dimensions depend on these factors. "Top management commitment" (Factor 1)," Strategy development for flexible SC" (Factor 2), "Information sharing in SC members" (Factor 3), "Trust among SC members" (Factor 4), "Application of advance technology" (Factor 6), "Collaborative decision making" (Factor 5) and "Revenue and risk sharing policies" (Factor 8) are the factors in this zone and are ranked as independent factors as they are having the strong driving power.

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5. Conclusion

This study has tried to identify the different factors for flexible supply chain management. Total 14 factors are identified from the literature. Then ISM approach is applied to develop a framework based on relationships among different factors. Based on driving and dependence power different factors are classified into four clusters, that is, (i) Autonomous, (ii) Dependent, (iii) Linkages and (iv) Drivers.

It is observed from ISM framework, that top management commitment is a major driver for developing effective strategies to improve flexibility in supply chain. Strategies should focus on application of advanced IT systems to improve information flow and trust among supply chain partners. Information flow and mutual trust among supply chain members will help in collaborative decision-making to provide effective training for employees and for developing a mechanism to share the revenue and risk among supply chain partners. By taking these initiatives, organizations can improve vendors and logistics management capability. Vendors development and logistics management capability will improve suppliers' flexibility, distribution flexibility and manufacturing flexibility, which will ultimately lead to flexibility in supply chains. These findings imply that top management should be proactive in improving information flow and in developing trust among supply chain members to make their supply chain opertaions flexible. As ISM is based on inputs given by team of experts, chances of bisaing may be there. To overcome biasedness, fuzzy ISM can be also applied as future scope of study. Apart from this, the ISM framework for flexible supply chain management can be further validated with some case studies and survey-based empirical findings.

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