Chapter 20
TISM-Based Model to Evaluate the Flexibility Index of a Supply Chain

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20.1 Introduction

A supply chain (SC) is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. SCs exist in both service and manufacturing organizations. Figure. 20.1 shows a simple SC for a single product, where raw material is procured from suppliers, transformed into finished goods in a single step, and then transported to distribution centers, and then to retailers and ultimately, to customers. Realistic SCs have multiple end products with shared components, facilities, and capacities. Various modes of transportation may be considered, and the bill of materials for the end items may be both deep and large. The complexity of the chain may vary greatly from industry to industry and firm to firm (Chopra and Meindl 2003). In the globalized economy, the market has become highly uncertain. Requirements of customers are fast changing in terms of cost, quality, and delivery. Therefore, to sustain in such an environment, organizations need to have a flexible SC.

Flexibility is the ability of a system to perform proactive and reactive adaptations of its configuration in order to cope with internal and external uncertainties. Under an uncertain environment, flexible strategies help in sustaining competitiveness (Singh et al. 2005). Upton (1995) defines flexibility as 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. Singh et al. (2013) have considered flexibility as a major competitive weapon for manufacturing organizations operating in increasingly uncertain environments and turbulent markets that

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Fig. 20.1 A supply chain network

provide organizations with the ability to change levels of production rapidly. The increasing complexity of the value-added processes and the shortening of response times to demand changes are the main causes for having flexibility in SCs (Wilding 1998). A fast response to changing demands is necessary for a competitive advantage in today's markets. Customers expect their needs to be satisfied at the time of their expression. Companies therefore must have quick response times to changing needs, in order to gain or hold market shares (Talluri et al. 2004). Thus, flexibility is necessary to stay in this competitive environment. According to Shimizu and Hitt (2004), organizations need to develop flexibility at the strategic level in order to cope with the external pressure posed by frequent changes in the customer's expectations, changing market trends, and competitor action. The complexity of business processes is increasing as companies attempt to respond to their customers' needs with an increasing number of highly customized products. At the same time, the offered products themselves are becoming increasingly complex. This complexity results from the different embedded technologies. A single company can no longer produce or handle these technologies alone. The general trend of outsourcing and decreasing the vertical range of manufacturers intensifies the need of flexibility.

The objective of this chapter is to identify different attributes of flexibility and develop a structural relationship between them. This chapter is organized as follows. Section 20.2 discusses the literature review. Section 20.3 discusses the research methodology. It is followed by results and discussions and finally, concluding remarks.

20.2 Literature Review

In today's scenario, the survival and growth of the organization depend on the competitiveness of the SC. Consumers are highly sophisticated. They demand customized quality products, timely delivery, and low cost. Therefore, in order to compete in this scenario, organizations and their respective SC need to be more flexible. Flexibility reflects the ability of a system to respond rapidly to changes that occur inside and outside the system. Vickery et al. (1999) defined five SC flexibilities, which include product, launch, volume, access, and responsiveness flexibility. They considered flexibility dimensions that directly impact firms' customers and share responsibilities of two or more functions along the SC. Information plays a key role in decision making regarding changes in customers' needs, delivery dates, storage, and transportation (D'Souza and Williams 2000, Duclos et al. 2003, Martinez and

Perez (2005). The promptness and the degree to which the SC changes its speed, destinations, and volumes in response to changes in customer demands gives the benefits of mass customization and positive relationship between each node of the SC (Das and Abdel-Malek 2003, Garavelli 2003, Lummus et al. 2003). Motivation and growth of employees (Efstathiades et al. 2002) and adoption of the total quality management (TQM) culture in the organization leads to better understanding among the workers in the organization thereby developing a sound relationship with the suppliers and distribution personnel. A combination of the entire flexibilities gives rise to SC flexibility. It should be seen as a tool for competitive advantage to the company and gaining success in all areas as well as satisfying customers.

The present study tries to develop a framework for managing the flexibility in the SC. For this, 29 enablers of flexibility in the SC have been identified. For developing the framework, interpretive structural modeling (ISM) has been used. These enablers have been categorized into seven groups. These groups are:

20.2.1 Information Flow Flexibility

According to Closs et al. (2005), the flow of information (information connectivity) and flexible logistics programs can positively impact the performance of the SC. They have also observed that the overall competitiveness of the SC depends on reducing time to market with the right products. To achieve this, speeding up of the flow of information and expediting logistics activities through the entire SC is extremely important and hence logistics is a key factor in organizational competitiveness (Bhatnagar et al. 1999). Lau and Lee (2000) have described the role of information systems in attaining enhanced responsiveness. Crum et al. (1998) have stated that information exchange between channel members is important for successful supply chain management (SCM) as timely and accurate information is essential for flexibility, responsiveness, and dependability. Parthasarthy and Sethi (1993) have felt that structures that emphasize a high differentiation of task and vertical information flows are incongruent with a commitment to flexibility.

20.2.2 Suppliers' Flexibility

Mason-Jones et al. (2000) argued that lean manufacturing has triggered organizations to reengineer their supply mechanism to be flexible through the value chain. According to Soon and Udin (2011), the flexibility value can be achieved through extending the manufacturing practices (just-in-time (JIT), efficient and real-time material requirement planning (MRP)) with management support and coordinating collaborative forecast with a network of suppliers. They have also indicated that supplier selection is not based solely on cost but equal consideration needs to be given to the responsiveness of the suppliers to reconfigure supply response without additional cost. By engaging suppliers early in the SC process or product design, manufacturers can gain cost reduction in material cost, improved material quality, and reduced development time (Paulraj et al. 2008). Gunasekaran et al. (2008) stated that the information technology that connects the suppliers, customers, and organizations provides a platform where all the parties mutually understand and are responsive to each other's needs.

20.2.3 Organizational Flexibility

Koste and Malhotra (1999) and Lummus et al. (2003) have found that organizational flexibility is mainly associated with the flexibility of the top management. If the organization has a higher logistics flexibility, it will have an opportunity to be more customer-responsive with respect to product delivery (Kumar et al. 2008). Efstathiades et al. (2002) have suggested that motivation and growth of employees with proper training and empowerment are necessary for developing organizational flexibility within the firm. D'Souza and Williams (2000) have also emphasized the development of multiple skills and multiple capabilities of the workforce. Kumar et al. (2008) have observed that a workforce with higher levels of cross-training facilitates more possible job assignment combinations can be made in order to adapt the changing production schedules. Integrated sourcing flexibility in the SCM improves the organization's ability to deliver products and services in a timely and effective manner (Tan et al. 1996). Sourcing flexibility refers to the ability to change sourcing decisions such as the number of suppliers per part and delivery schedule (Kumar et al. 2008).

20.2.4 Production System Flexibility

The availability of methods such as building smaller production units, cellular manufacturing systems, multipurpose machines, material handling, and workforce agility have been cited as manufacturing flexibility approaches being integrated from the shop floor to the plant level (Koste and Malhotra 1999). If the end products are very sophisticated in terms of technology content and are experiencing a high growth in the market, the intermediate product manufacturers need to design their system with a higher level of flexibility (Kumar et al. 2006).

Seamless coordination between the operation and supply network provides the flexibility to response to different product life cycle, ramp different production ramp-rate and the ability to mix match supplier selection in anticipation of demand changes (Perez and Sanchez 2001). Production system scheduling with enterprise resource planning (ERP) system has been given primary reference with a customized MRP system configured around it to provide flexibility in analyzing the demand–supply and execution strategies. The organizations also need to adopt lean manufacturing techniques in order to reduce cycle time and align their SC by establishing a common goal and reward system (Soon and Udin 2011).

20.2.5 Transportation and Warehousing Flexibility

Koste and Malhotra (1999) have defined transportation flexibility as the ability of a firm to serve distinct customers' shipping requirements with an acceptable level of quality and at the right time. Kumar et al. (2008) have considered the mode of transportation as the first measure of logistics flexibility. They have observed that the product that can be delivered through multiple modes (i.e., ship, train, plane, etc.) provides more logistics flexibility than the product transported via a single delivery mode. Flexibility in warehousing and storage facilities also seeks importance in SCM . Martinez and Perez (2005) and Garavelli (2003) have considered warehousing flexibility as the ability of a firm to vary its warehouse space according to the changing customer demands and product variety. Changes in overall warehouse locations, distribution of products among the warehouses, transportation network, and mode of transportation impact the SC performance significantly (Kopczak 1997). Baumol and Vinod (1970) have determined a shipper choice of transportation option in a single market and it may be viewed as a cost model that provides the total transportation and inventory cost associated with each transportation option. Buffa and Reynolds (1977) have also developed a transportation model which includes number of transport-related variables.

20.2.6 Product Development and Design Flexibility

Kumar et al. (2006) have defined product flexibility as the ability of the SC partners to produce a customized product or upgrade existing ones economically and with no additional time to meet customer's specifications. Carter (1986) and Gerwin (1993) suggest that product flexibility allows the company to be responsive to the market by enabling it to bring newly designed products quickly to the market. Schneider and Bowen (1995) have observed that in order to achieve long-term relationships, firms are seeking direct customer contact, collecting customer information, and using this information to design and deliver enhanced products and services.

20.2.7 Flexible SC

Flexibility has been proved to be a crucial weapon to increase the competitiveness in a volatile market (Upton 1994). Adrian et al. (2007) have described the SC flexibility as operation systems flexibility, market flexibility, logistics flexibility, supply flexibility, organizational flexibility, and information systems flexibility. According to Kumar et al. (2008), flexibility in the SC means to maintain the customer service levels adapting disturbances in supply and sudden changes in demand. Stevension and Spring (2007) categorized the flexibility on various levels of operations in the SC: operational flexibility (resource and shop floor level), tactical flexibility (plant level), strategic flexibility (firm level), and SC flexibility (network level). Kumar et al. (2007) reviewed the flexibility perspectives in the global SC and categorized the entire SC into five flexibility perspectives such as product development flexibility, manufacturing flexibility, sourcing flexibility, logistics flexibility, and information systems flexibility. Gupta and Gautam (2002) used the analytic hierarchy process (AHP) to calculate the global weights for the variables of flexibility in the SC.

These groups along with the sub-factors are shown in Table 20.1.

20.3 Research Methodology

To develop a structural relationship between different groups of flexibility in the SC, ISM is used, which is upgraded as TISM.

20.3.1 Interpretive Structural Modeling

ISM is an interactive learning process, which systemizes the different and directly related elements into a structured system (Warfield 1974; Sage 1977). It transforms a complex problem into visible, well-defined models serving the purposes (Sage 1977). It helps in identifying the interrelationships among variables and to impose order and direction on the complexity of the relationships among elements of a system. It is very difficult to handle all the enablers of a complex problem if the number of enablers is large. ISM develops a collective understanding of relationships among the enablers. ISM is a modeling technique in which the specific relationships of the variables and the overall structure of the system under consideration are presented in a digraph model. It is primarily intended as a group learning process, but it can also be used individually. Jharkharia and Shankar (2005) applied ISM for understanding the barriers in IT-enablement of SCs. Singh et al. (2007a, b) applied ISM for improving the competitiveness of small and medium enterprises (SMEs) and for the implementation of advanced manufacturing technologies (AMTs) in firms. The various steps involved in the ISM technique are:

1. Identification of elements, which are relevant to the problem or issues, could be done by any group problem-solving technique.
2. Establishing a contextual relationship between elements with respect to which pairs of elements will be examined.
3. Developing a structural self-interaction matrix (SSIM) of elements indicates pair-wise relationship between elements of the system.
4. Developing a reachability matrix from the SSIM, and then checking the matrix for transitivity. Transitivity of the contextual relation is a basic assumption in ISM which states that if element A is related to B and B is related to C, then A will be necessarily related to C.
5. Partitioning of the reachability matrix into different levels.

Table 20.1 Enablers of flexibility in supply chain

Suppliers' flexibility	*References*
Ability to meet changes in volume requirement on short notice	Kumar et al. (2008), Singh et al. (2012), Gunasekaran et al. (2008), Mason-Jones et al. (2000)
Ability to alter the supply of products in line with customers' demand	Duclos et al. (2003), Singh (2011), Soon and Udin (2011)
Ability to change delivery dates of raw materials to the suppliers	Duclos et al. (2003), Paulraj et al. 2008), Kumar et al.(2008), Sumita and Yoshii (2013)
Transportation and warehousing flexibility	*References*
Ability to serve distinct customers' shipping requirements	Koste and Malhotra (1999), Kumar et al. (2008)
Ability to vary warehouse space	Martinez and Perez (2005), Garavelli (2003), Kopczak, (1997); Baumol and Vinod (1970)
Ability to vary transportation carriers	Garavelli (2003), Buffa and Reynolds (1977)
Production system flexibility	*References*
Ability to reconfigure assets (equipments) in line with customer needs	D'Souza and Williams (2000), Koste and Malhotra (1999), Kumar et al. (2006), Perez and Sanchez (2001)
Ability to change processes as demand changes	Das and Abdel-Malek (2003)
Ability to adjust capacity	Das and Abdel-Malek (2003)
Ability to produce parts in different ways	Vickery et al.;(1999)
Ability to produce a part by alternate routes through the system	Duclos et al. (2003), Soon and Udin (2011), Martinez and Perez (2005)
Ability to reduce the machine downtime	Lummus et al. (2003)
Organizational flexibility	*References*
Flexibility of top management	Koste and Malhotra (1999) Lummus et al. (2003)
Motivation and growth of employees	Efstathiades et al. (2002)
Training and empowerment of employees	Efstathiades et al. (2002)
Development of multiple skills and capabilities of workforce	D'Souza and Williams (2000), Tan et al. (1996), Kumar et al. (2008)
Ability to form personal links with other nodes	Duclos et al. (2003)
Cultural flexibility	D'Souza and Williams (2000)
Information flow flexibility	*References*
Ability to get point-of-sales data	D'Souza and Williams (2000); Closs et al. (2005)
Ability to synchronize information systems with supply chain partners	Duclos et al. (2003), Crum et al. (1998), D'Souza and Williams (2000)
Ability to share information across internal departments	Duclos et al (2003), Parthasarthy and Sethi (1993), D'Souza and Williams (2000), Kumar et al. 2013

Table 20.1 (continued)

Ability to pass information along the supply chain	Duclos et al (2003), Bhatnagar et al. (1999), Lau and Lee (2000), Martinez and Perez (2005)
Product design and development flexibility	*References*
Ability to introduce and design new product	Vickery et al. (1999), Carter (1986), Gerwin (1993), Martinez and Perez (2005)
Ability to mass customize	Lummus et al. (2003), Kumar et al. (2006)
Postponement of final product	Martinez and Perez (2005), Schneider and Bowen (1995)
Flexible supply chain	*References*
Ability to change the volume	Duclos et al. (2003), Upton (1994), Adrian et al. (2007), Martinez and Perez (2005)
Ability to change delivery time	Duclos et al. (2003), Kumar et al. (2008), Stevension and Spring (2007), D'Souza and Williams (2000)
Ability to change design of product	Martinez and Perez (2005), Kumar et al. (2007), Gupta and Gautam (2002)
Ability to adapt processes to specific products	Duclos et al. (2003)

6. Drawing a digraph based on the relationships given above in the reachability matrix and removing transitive links.
7. Converting the resultant digraph into ISM, by replacing element nodes with statements.
8. Reviewing the ISM model to check for conceptual inconsistency and making the necessary modifications.

The above-described steps, which lead to the development of the ISM model, are discussed below.

Structural Self-Interaction Matrix

For analyzing the criteria, a relationship of "leads to" is chosen here. For developing contextual relationships among variables, expert opinions based on various management techniques such as brainstorming, nominal group technique, idea engineering, etc. were considered. For expressing the relationship between different critical factors, four symbols have been used to denote the direction of the relationship between the parameters i and j (here i, j):

1. V: parameter i will lead to parameter j.
2. A: parameter j will lead to parameter i.
3. X: parameter i and j will lead to each other.
4. O: parameters i and j are unrelated.

Considering the above notations, SSIM is developed in Table 20.2.

Table 20.2 Structural self-interaction matrix

S. No.	Factors	1	2	3	4	5	6	7
1	Information flow flexibility		V	V	V	V	V	V
2	Suppliers' flexibility			X	X	V	V	V
3	Organizational flexibility				X	V	V	V
4	Production system flexibility					V	V	V
5	Transportation and warehousing flexibility						O	V
6	Product design and development flexibility							V
7	Flexible supply chain							

Initial Reachability Matrix

The SSIM has been converted into a binary matrix, called the initial reachability matrix by substituting V, A, X, and O by 1 and 0 as per the case. The substitution of 1s and 0s are as per the following rules:

1. If the (i, j) entry in the SSIM is V, the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
2. If the (i, j) entry in the SSIM is A, the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
4. If the (i, j) entry in the SSIM is O, the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following the above rules, the initial reachability matrix for the critical success factors is shown in Table 20.3.

Final Reachability Matrix

The final reachability matrix is obtained by incorporating the transitivity as enumerated in Step (4) of the ISM methodology. This is shown in Table 20.4. In this, the driving power and dependence of each factor are also shown. The driving power (DP) of a particular factor is the total number of factors (including itself), which it may help achieve, while the dependence is the total number of factors, which may help achieving it. On the basis of driving power and dependencies, these factors will be classified into four groups of autonomous, dependent, linkage, and independent (driver) factors.

Table 20.3 Initial reachability matrix

S. No.	Factors	1	2	3	4	5	6	7
1	Information flow flexibility	1	1	1	1	1	1	1
2	Suppliers' flexibility	0	1	1	1	1	1	1
3	Organizational flexibility	0	1	1	1	1	1	1
4	Production system flexibility	0	1	1	1	1	1	1
5	Transportation and warehousing flexibility	0	0	0	0	1	0	1
6	Product design and development flexibility	0	0	0	0	0	1	1
7	Flexible supply chain	0	0	0	0	0	0	1

Table 20.4 Final reachability matrix

S. No.	Factors	1	2	3	4	5	6	7	D. P.
1	Information flow flexibility	1	1	1	1	1	1	1	7
2	Suppliers' flexibility	0	1	1	1	1	1	1	6
3	Organizational flexibility	0	1	1	1	1	1	1	6
4	Production system flexibility	0	1	1	1	1	1	1	6
5	Transportation and warehousing flexibility	0	0	0	0	1	0	1	2
6	Product design and development flexibility	0	0	0	0	0	1	1	2
7	Flexible supply chain	0	0	0	0	0	0	1	1
	Dependence	1	4	4	4	5	5	7	

Level Partitions

From the final reachability matrix, the reachability and antecedent sets for each factor are found. The reachability set consists of the element itself and other elements to which it may help achieve, whereas the antecedent set consists of the element itself and the other elements which may help 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. Once the top-level element is identified, it is separated out from the other elements. Then by the same process, the next level of elements is found. These identified levels help in building the digraph and final model. From Table 20.5, it is seen that the performance improvement is found at level I. Thus, it would be positioned at the top of the ISM hierarchy. This iteration is repeated till the levels of each factor are found out (Tables 20.5–20.8).

Table 20.5 Iteration 1

Factors	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 7	1	1	
2	2, 3, 4, 5, 6, 7	1, 2, 3, 4	2, 3, 4	
3	2, 3, 4, 5, 6, 7	1, 2, 3, 4	2, 3, 4	
4	2, 3, 4, 5, 6, 7	1, 2, 3, 4	2, 3, 4	
5	5, 7	1, 2, 3, 4, 5	5	
6	6, 7	1, 2, 3, 4, 6	6	
7	*7*	1, 2, 3, 4, 5, 6, 7	*7*	*I*

Table 20.6 Iteration 2

Factors	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6	1	1	
2	2, 3, 4, 5, 6	1, 2, 3, 4	2, 3, 4	
3	2, 3, 4, 5, 6	1, 2, 3, 4	2, 3, 4	
4	2, 3, 4, 5, 6	1, 2, 3, 4	2, 3, 4	
5	*5*	1, 2, 3, 4, 5	*5*	*II*
6	*6*	1, 2, 3, 4, 6	*6*	*II*

Classification of Factors

In this section, the critical success factors described earlier are classified into four clusters (Fig. 20.2). This classification is similar to that made by Mandal and Deshmukh (1994). The first cluster consists of the "autonomous factors" that have a weak driving power and weak dependence. These factors are relatively disconnected from the system, with which they have only few links, which may not be strong. The "dependent factors" constitute the second cluster which has a weak driving power but strong dependence. The third cluster has the "linkage factors" that have strong driving power and strong dependence. These factors are unstable due to the fact that any change occurring to them will have an effect on others and also a feedback on themselves. The fourth cluster includes the "independent factors" which have a strong driving power but weak dependence. The driving power and dependence of each of these factors are shown in Table 20.4. In this table, an entry of "1" added along the columns and rows indicates the dependence and driving power, respectively. Subsequently, the driver power-dependence diagram is constructed as shown in Fig. 20.2. For illustration, the factor five having a driving power of 2 and dependence 5 is positioned at a place corresponding to driving power of 2 and dependency of 5 in Fig. 20.2. Similarly, all other factors considered in this study are positioned on different quadrants depending on their driving power and dependency.

Table 20.7 Iteration 3

Factors	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4	1	1	
2	*2, 3, 4*	1, 2, 3, 4	*2, 3, 4*	*III*
3	*2, 3, 4*	1, 2, 3, 4	*2, 3, 4*	*III*
4	*2, 3, 4*	1, 2, 3, 4	*2, 3, 4*	*III*

Table 20.8 Iteration 4

Factors	Reachability set	Antecedent set	Intersection set	Level
1	*1*	1	*1*	*IV*

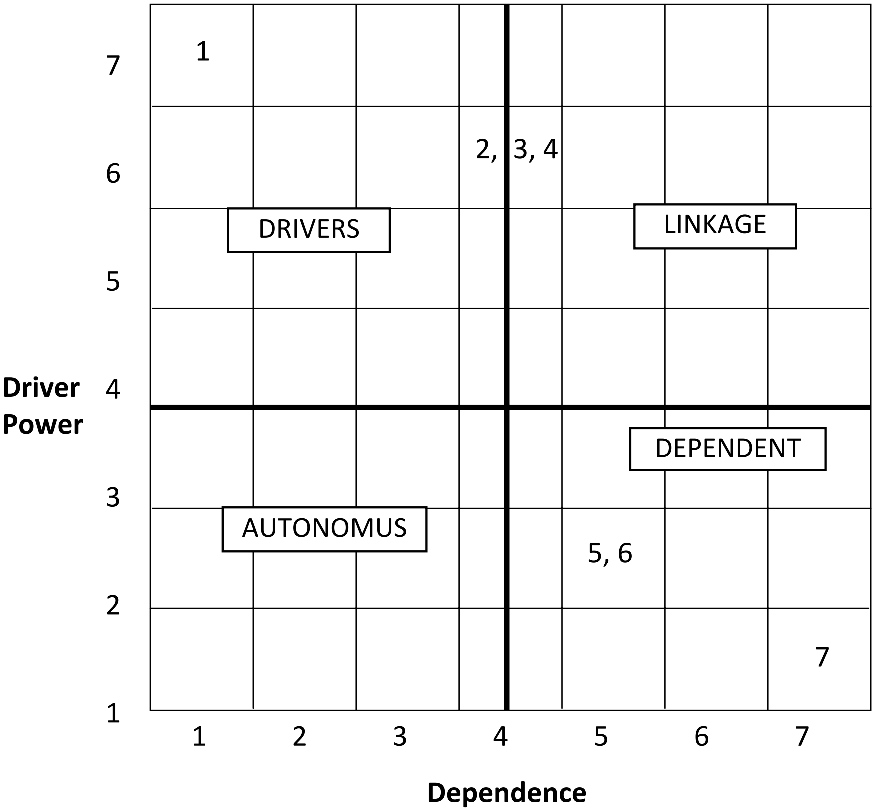

Fig. 20.2 Driving power and dependence diagram

20.3.2 Formation of a Total Interpretive Structural Model

From the final reachability matrix (Table 20.4), the structural model is generated by means of vertices or nodes and lines of edges. If there is a relationship between the flexibility factors i and j, 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 the ISM methodology, the digraph is finally converted into a total interpretive structural model (TISM). The connective and interpretive information contained in the interpretive direct interaction matrix and digraph is used to derive TISM (Sushil 2012). The nodes in the digraph are replaced by the interpretation of elements placed in boxes. The interpretation in the cells of interpretive direct interaction matrix is depicted by the side of respective links in the structural model. This leads to a total interpretation of the structural model in terms of the interpretation of its nodes as well as links as shown in Fig. 20.3.

Some of the observations based on this analysis are:

1. The driver power-dependence matrix shows that there is no autonomous factor for flexibility in the SC.
2. Information flow flexibility has a strong driving power and is capable of leading the organization to achieve the desired objective independently.
3. Suppliers' flexibility, organizational flexibility, and production system flexibility have a strong driving power and medium dependence. Thus, they also act as drivers next to information flow flexibility. They are categorized as linkage variables.
4. Dependence increases as we move from transportation and warehousing flexibility to product design and development flexibility till flexible SC. A flexible SC has the highest dependence and represents the ultimate goal to be achieved in the SC.

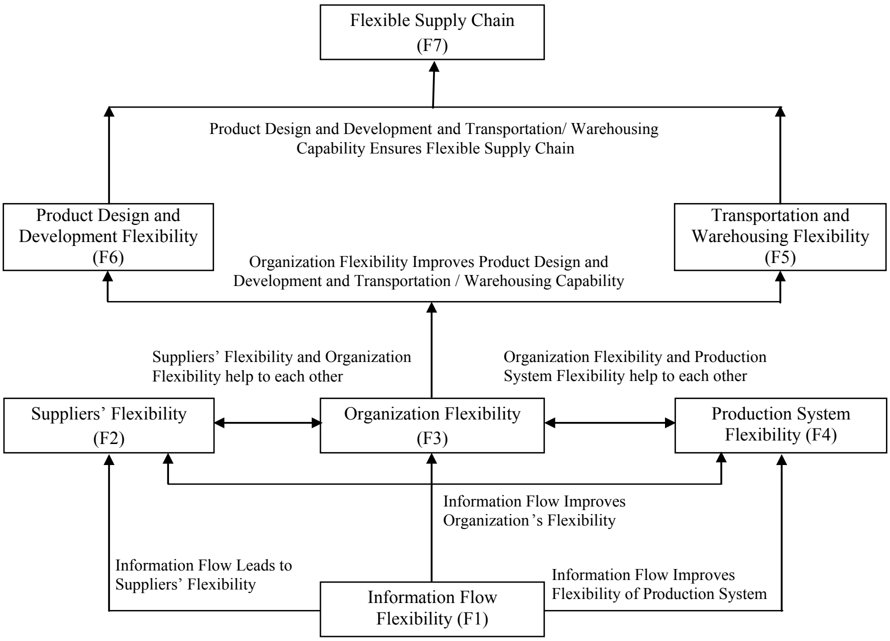

Fig. 20.3 Total interpretive structural model (TISM) for enablers of supply chain flexibility

20.4 Model for Evaluating the Flexibility Index of SC

Based on interaction from experts and the literature review, different factors have been identified for evaluating the flexibility index of the SC. These factors have been grouped into seven areas/issues (Table 20.9). These are suppliers' flexibility, transportation and warehousing flexibility, production system flexibility, organizational flexibility, information flow flexibility, product design and development flexibility, and measures for flexible SC. The framework of Cleveland et al. (1989) for production competence is extended to compute the SC flexibility index. Singh (2011) has used this framework to evaluate the competitiveness/coordination index of a medium-scale organization. On the basis of the Cleveland et al. (1989) model and competitiveness index model, the SC flexibility index can be given as:

$$S_{\text{Flexibility}} = \sum \{W_i \log K_i\},$$

where $S_{\text{flexibility}}$ is the SC flexibility index for a the given SC, i is the SCM issue ($i=1$ to 7), R is the rank of the SCM issue, K_i is the inverse rank (if $R=1$, $K=7$, when $i=7$, if $R=2$, $K=6$), and W_i is the weight assigned to a particular SCM issue.

For assigning the weight to different issues of flexible SC, the highest and lowest values of a five-point Likert scale, i.e., 5 and 1 are mapped 100 and 0%, respectively. For each of the seven issues of flexible SC, a weight is assigned. The criteria for weight (W_i) is as under:

$W_i=+1$ (strength), when percentage score >60% (mean value >3); $W_i=0$ (neutral), when percentage score is between 40 and 60% (mean value between 2 and 3); and $W_i=-1$ (weakness), when percentage score <40% (mean value <2).

For illustration, an example of computation of weight is given below. Say, the mean score for a flexible SCM issue = 4.2 on a scale of 1 to 5. Using a two-point equation, the percentage may be calculated, i.e., 4.2/5 = 84%; therefore, it is assigned a weight of +1.

The computation of the SC flexibility index of Alpha Ltd. is illustrated with the help of a worksheet as shown in Table 20.10. First of all, key items of different issues of the flexible SC framework are graded in the Likert scale of 1–5 (1, very low; 5, very high). The mean for a particular issue is calculated after taking the average of scores for all its key items. After this rank, the inverse rank and weight for each issue is decided. The sum of the entries of the last column (W_i log K_i) will give the SC flexibility index of Alpha Ltd. On the basis of the score, the organization can visualize its position in the industry/sector and identify gaps with respect to market leaders. It can also help in strengths, weaknesses, opportunities, and threats (SWOT) analysis of organization.

Table 20.9 Score on flexibility measures for Alpha Ltd.

Flexibility attributes	Rating in scale of 1–5	Mean value
Suppliers' flexibility		3.67
Ability to meet changes in volume requirement on short notice	4	
Ability to alter the supply of products in line with customers' demand	4	
Ability to change delivery dates of raw materials to the suppliers	3	
Transportation and warehousing flexibility		
Ability to serve distinct customers' shipping requirements	3	2.33
Ability to vary warehouse space	2	
Ability to vary transportation carriers	2	
Production system flexibility		
Ability to reconfigure assets (equipments) in line with customer needs	5	4.00
Ability to change processes as demand changes	4	
Ability to adjust capacity	3	
Ability to produce parts in different ways	4	
Ability to produce a part by alternate routes through the system	4	
Ability to reduce the machine downtime	4	
Organizational flexibility		
Flexibility of top management	5	4.67
Motivation and growth of employees	5	
Training and empowerment of employees	5	
Development of multiple skills and capabilities of workforce	5	
Ability to form personal links with other nodes	4	
Cultural flexibility	4	
Information flow flexibility		
Ability to get point of sales data	4	4.5
Ability to synchronize information systems with supply chain partners	4	
Ability to share information across internal departments	5	
Ability to pass information along the supply chain	5	
Product design and development flexibility		
Ability to introduce and design new product	4	3.33
Ability to mass customize	3	
Postponement of final product	3	
Measures for flexible supply chain		
Ability to change the volume	4	3.50
Ability to change delivery time	3	
Ability to change design of product	3	
Ability to adapt processes to specific products	4	

Table 20.10 Illustration for SC flexibility index of AB Ltd.

Sr. No.	Factors of coordination	Mean	Rank	Inverse rank (K_i)	Log Ki	Weight (W_i)	W_i log K_i
1	Suppliers' flexibility	3.67	4	4	0.60	+1	0.60
2	Transportation and warehousing flexibility	2.33	7	1	00	00	00
3	Production system flexibility	4.00	3	5	0.70	+1	0.70
4	Organizational flexibility	4.67	1	7	0.85	+1	0.85
5	Information flow flexibility	4.50	2	6	0.78	+1	0.78
6	Product design and development flexibility	3.33	6	2	0.30	+1	0.30
7	Measures for flexible SC	3.50	5	3	0.48	+1	0.48

SC flexibility index = $S_{\textbf{Flexibility}} = \sum\{Wi \log Ki\} = 3.71$

SC supply chain

20.4.1 Case Illustration of the Model

For Illustrating the Use of this Model a Two-Wheeler-Manufacturing Company Has Been Considered

Background of the Case Company

Alpha Ltd. (name changed) is the world's largest manufacturer of two-wheelers, based in India. In 2001, the company achieved the coveted position of being the largest two-wheeler-manufacturing company in India and the "World No.1" two-wheeler company in terms of unit volume sales in a calendar year by a single company. Alpha Ltd. has retained that coveted position till date. Alpha Ltd. has sold more than 15 million motorcycles and has consistently shown a double-digit growth since its inception.

Alpha Ltd. bikes are manufactured across three globally benchmarked manufacturing facilities. Two of these are based at Gurgaon and Dharuhera, which are located in the state of Haryana in northern India. The third and the latest manufacturing plant is based at Haridwar, in the hill state of Uttarakhand.

In 2010–2011, the total unit sales were 4,600,130 two-wheelers with a growth of 23.6 %, the total net operating income was 158,600 million INR with a growth of 28.1 %, and the net profit after tax was 22,310 million INR with a growth of 74.1 %.

The key strategy of Alpha Ltd. has been driven by innovation in every sphere of activity, i.e., building a robust product portfolio across categories, exploring new markets, aggressively expanding the network, and continuing to invest in brand-building activities. In the 1980s, Alpha Ltd. pioneered the introduction of fuel-efficient, environment-friendly, four-stroke motorcycles in the country. Today, it continues to be a technology pioneer. It became the first company to launch the fuel injection (FI) technology in Indian motorcycles, with the launch of the Glamour FI in June 2006. The Alpha Ltd. product range includes a variety of motorcycles that have set the industry standards across all the market segments. The company also started manufacturing scooters in 2006.

The company's growth in the two-wheeler market in India is the result of an intrinsic ability to increase reach in new geographies and growth markets. The extensive sales and service network of Alpha Ltd. now spans close to 4500 customer touch points. These comprise a mix of authorized dealerships, service and spare part outlets, and dealer-appointed outlets across the country. The company has been continuously investing in brand building not only utilizing the new product launch and new campaign launch opportunities but also through innovative marketing initiatives revolving around cricket, entertainment, and ground-level activation. The quality policy of the company is "We are committed at all levels to achieve high quality in whatever we do, particularly in our products and services which will meet and exceed customer's growing aspirations through, innovation in products processes and services, continuous improvement in our TQM systems, teamwork, and responsibility."

SC Flexibility Index for Alpha Ltd.

Alpha Ltd. is aggressively trying to make its SC flexible. In this regard, this organization has taken multiple initiatives. To evaluate the flexibility index of its SC, different attributes of SC flexibility were rated in a Likert scale of 5. These are shown in Table 20.9. The above-discussed model was applied to evaluate the flexibility index as shown in Table 20.10. The overall SC flexibility index for Alpha Ltd. was found equal to 3.71. Based on these results, it is observed that Alpha Ltd. needs to improve its performance in terms of transportation and warehousing flexibility as well as in terms of product design and development flexibility. This model can also be used to compare the flexibility index of two SCs. It can also be useful to do SWOT analysis of a given SC for taking different initiatives to improve its flexibility.

20.5 Conclusion

In today's scenario, the demand of the customer changes very rapidly, and there are lots of complexities in the products. Also, the competition is very high. So, in order to survive, flexibility is necessary in the SCs, which allows them to adapt to market uncertainties. This chapter has identified important enablers of flexibility in the SC. These enablers are categorized into seven flexibility subgroups and the ISM approach has been applied to develop a structural relationship between these groups for managing flexibility in the SC. Information flow flexibility has emerged as major driving force for flexibility in the SC. It implies that an organization should focus on generating accurate information and its availability at the right time. Based on this model, further a framework is suggested to evaluate the flexibility index of the SC. Based on this framework, any organization can evaluate its SC flexibility index. It can be also used for SWOT analysis and strategy development. ISM has some limitations such as the interpretation of links being partial, thereby exposing the mode of multiple interpretations by the user. To overcome such limitations, TISM has been used.

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