Chapter 13
Modeling Hierarchical Relationships Among Enablers of Supply Chain Coordination in Flexible Environment

Dhanya Jothimani, Ravi Shankar and Surendra S. Yadav

13.1 Introduction

Recently, the number of supply chain (SC) partners has risen, thus, increasing the complexity of the SC. Growing competition is one of the contributing factors for increased complexity of the SC. With increasing competition, these SC members try to maximize their individual profits which ultimately increases the overall SC costs. Presently, it is not the individual firms that are competing with each other but their SCs are certainly doing so. SC coordination is the process of tackling the interdependencies among the SC members which improves the overall SC performance (Arshinder et al. 2008). Hence, the firms should coordinate with each other to increase the overall profitability and reduce the overall cost of the SC.

The ability of the organization to meet the demands arising within and outside the organization is known as flexibility. The role, SC coordination plays in SC flexibility, is important (Kumar et al. 2013). Like product and process flexibilities, coordination flexibility is one of the dimensions of SC flexibility (Singh and Acharya 2013). Hence, it is necessary for the firms to understand the importance of coordination.

There are various mechanisms that aid coordination among the SC members. Few of them include SC contracts, information sharing, and collaborative efforts. These mechanisms are known as enablers of SC coordination. Henceforth, from this point onwards, the terms mechanism and enablers of SC coordination are used interchangeably. There are studies that deal with the implementation of

D. Jothimani (✉) · R. Shankar · S. S. Yadav
Department of Management Studies, Indian Institute of Technology Delhi, New Delhi, India
e-mail: dhanya.jothimani@dms.iitd.ac.in; dhanyajothimani@gmail.com

R. Shankar
e-mail: ravi1@dms.iitd.ac.in

S. S. Yadav
e-mail: ssyadav@dms.iitd.ac.in

Sushil et al. (eds.), *Managing Flexibility*, Flexible Systems Management,
DOI 10.1007/978-81-322-2380-1_13

these mechanisms individually (Stank et al. 1999; Hahn et al. 2000). The overall SC performance can be improved by focusing and executing various combinations of these mechanisms. To achieve this, the interrelationship among the enablers of SC coordination should be understood. This understanding would enable the top management to focus on specific enablers to move towards coordination. Hence, this chapter aims to determine the enablers of SC coordination and to understand the relationship among them.

The next section discusses various enablers of SC coordination. Sections 13.3 and 13.4 deal with interpretive structural modeling (ISM) and MICMAC analysis, respectively. Managerial implications are presented in Sect. 13.5. Limitations of the study and the scope for future work are presented in Sect. 13.6.

13.2 Enablers for SC Coordination

13.2.1 Channel Coordination

Channel coordination is an important factor that would lead to better SC coordination. Information sharing leads to channel coordination, which further increases the operational efficiency of the SC (Lee et al. 1997a).

13.2.2 Collaborative Planning Forecasting and Replenishment

A number of promotional activities can be planned as a joint measure between two or more members in a SC. This initiative is called collaborative planning, forecasting, and replenishment (CPFR). SC members try to synchronize their forecasts which help them to determine the production and replenishment processes. Few benefits that are achieved through CPFR are lower product inventories, increased service levels, lower capacity requirements, shorter response time, improvement in forecast accuracy, reduced system requirements, and lesser number of stocking points (Larsen 2000).

13.2.3 Implementation of Information Systems

SC performance can be improved through implementation of information systems (ISs) since it enables easy and faster information sharing among the SC members (Stank et al. 1999). Implementation of IS aids to reduce the information mismatch among them and it eliminates the consequences of the demand forecasts in bullwhip effect.

13.2.4 Information Sharing

Supply coordination can be successful with effective and proper communication among the SC members (Hahn et al. 2000). Hence, it is considered to be an important enabler. Information sharing is needed to increase trust among the SC members (Henriott 1999). Information sharing helps the organizations in the SC to reduce the distortion in the demand information, thus, reducing the bullwhip effect (Lee et al. 1997a, b; Lee and Whang 2000).

13.2.5 Incentive Alignment Policies

Various SC contracts can help promote incentive policies among the members. This reduces the cost and increases the profit in the SC. This further increases the SC efficiency (Tsay and Lovejoy 1999).

13.2.6 Joint Decision-Making

Joint working and joint promotions encourage the SC members to make their decision together. Joint decision-making influences the members to share information and increases trust among them (Hill and Omar 2006). This would minimize the operating cost of all the members.

13.2.7 Joint Promotion

Joint promotional activities among the SC members motivate them to share benefits as well as the risks (Hill and Omar 2006).

13.2.8 Joint Working

Joint working is one of the mechanisms to improve the coordination among the SC members and hence improving the overall SC performance (Hill and Omar 2006). The joint working influences both joint promotion and joint decision-making.

13.2.9 Performance Monitoring

The SC members should measure their performance to understand the overall view of their position. This will encourage them to improve their performance and realize the importance of coordination among them. Various performance models like supply chain operations reference (SCOR) model and balanced scorecard (BSC) can be used to measure performance of the SC members (Huan et al. 2004).

13.2.10 Resource Sharing

Resource sharing is nothing but collaboration among the independent but related members of SC to share resources to fulfill the requirements of customers on time (Narus and Anderson 1996). SC performance can be improved with resource sharing among the SC members. This also influences the information sharing among the members.

13.2.11 Risk Sharing

Like resource sharing, both reward and risk sharing among different SC members are necessary. Focus of a company should be not only on its risk but also at other points in the SC. The direct risks and their potential causes at each point should be identified (Souter 2000; Mentzer et al. 2001; Christopher et al. 2002).

13.2.12 SC Contracts

The risk-related issues and conflicts among the members can be resolved using SC contracts. There are various types of contracts which include revenue sharing contracts, buy back contract, wholesale price contract, and quantity flexibility contract. The aim of SC contracts is to reduce the underage and overage costs and to increase the SC profit (Arshinder et al. 2008). The problem of double marginalization can be reduced.

13.3 Interpretive Structural Modeling

A system consists of various elements and these elements interact with each other. The terms elements, factors, and variables are used interchangeably. The direction and order of the relationships among the system elements can be established using interpretive structural modeling (ISM). It handles a large number of relationships among the system elements and establishes a hierarchical arrangement (Warfield 1974). The system can be well explained with the help of indirect and direct relationships among the variables than the individual elements. ISM is comprehendible

Table 13.1 Contributions of researchers in ISM in various fields

S. no.	Field of study	Researchers
1	Information security management	Chander et al. (2013)
2	Supply chain collaboration	Ramesh et al. (2010)
3	Cold SC	Joshi et al. (2009)
4	SC performance measurement system	Charan et al. (2008)
5	Flexible manufacturing systems	Raj et al. (2008)
6	Technology transfer for rural housing	Singh and Kant (2007)
7	IT-enabled SC	Jharkharia and Shankar (2005)
8	Reverse logistics	Ravi and Shankar (2005)
9	Knowledge management	Singh and Agarwal (2003)
10	Vendor selection	Mandal and Deshmukh (1994)

since the relationships can be presented in the form of graph. A group of experts are consulted to decide whether and how the elements are related; hence, it is classified under group decision-making technique. A systemic model is constructed on the basis of these relationships. In this chapter, the relationships among the enablers influencing the SC coordination are corroborated using ISM methodology. ISM has been adopted by various researchers for various fields of study (Table 13.1).

The ISM methodology consists of following steps:

i. The system under consideration is defined first. Elements affecting the system are identified through survey or group decision-making process. The elements can be individuals, actions, or outcomes.
ii. Each element is examined with respect to other elements for establishing a contextual relationship among them.
iii. Based on the established relationships, structural self-interaction matrix (SSIM), which is a upper triangular matrix, is conceptualized for the identified elements.
iv. SSIM is transformed into initial reachability matrix. Final reachability matrix is derived from the same on the basis of transitivity. Transitivity states that if an element P influences Q and Q influences R, then P necessarily influences R.
v. Using the concepts of set theory, the final reachability matrix, obtained in the previous step, is partitioned into different levels.
vi. A digraph (which refers to a directed graph) is drawn with the final reachability matrix and the levels obtained, as inputs. At this stage, the transitive links are discarded.
vii. The element nodes in the digraph are replaced with statements to obtain the final model of ISM.
viii. The final model is checked for conceptual consistency. Requisite changes are made in case of inconsistency.

13.3.1 Structural Self-Interaction Matrix

Consensus methodologies, such as nominal group technique and brainstorming, can be used to obtain the contextual relationship among the elements. In this chapter, enablers were identified and shortlisted with the help of domain experts and from existing literature. The contextual relationships among the enablers of SC coordination were obtained with the help of four SC experts, having experience of 8–15 years.

On the basis of the contextual relationship for each element, following four symbols indicate the direction of the relation between any two elements (*x* and *y*):

V Enabler *x* will alleviate enabler *y*;
A Enabler *y* will alleviate enabler *x*;
X Enablers *x* and *y* are related to each other;
O Enablers *x* and *y* are not related to each other.

The context of the above mentioned symbols in SSIM is explained using following examples:

i. Enabler 5 helps alleviate enabler 9. Information sharing (enabler 5) leads to increase in performance of SC (enabler 9). Thus, "V" denotes the relationship between enablers 5 and 9 in the SSIM.
ii. Enabler 12 helps alleviate enabler 1. SC contracts help in achieving channel coordination. Thus, "A" represents the relationship between enablers 12 and 1 in the SSIM.
iii. Enablers 6 and 7 help alleviate each other. The enabler 6, viz, joint decision-making and enabler 7, viz, joint promotions help alleviate each other. Thus, "X" denotes the relationship between enablers 6 and 7 in the SSIM.
iv. There is no relation between enabler 6 (joint decision-making) and enabler 9 (performance monitoring). Thus, "O" represents the relationship between these enablers in the SSIM.

The SSIM developed for all 12 enablers identified for implementation of SC coordination is presented in Table 13.2.

Table 13.2 Structural self-interaction matrix

	Enablers	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**
1	Channel Coordination	A	A	A	A	O	O	O	A	A	A	A
2	CRPF	X	O	V	O	A	O	O	V	X	X	
3	Implementation of IS	O	O	O	V	O	O	A	V	O		
4	Incentive Alignment	X	O	V	O	A	A	A	O			
5	Information Sharing	A	X	X	V	O	O	O				
6	Joint Decision-making	V	O	O	O	X	X					
7	Joint Promotions	V	O	O	O	X						
8	Joint Working	O	O	O	O							
9	Perf. Monitoring	A	O	O								
10	Resource Sharing	A	O									
11	Risk Sharing	A										
12	SC Contracts											

13.3.2 Reachability Matrix

Symbols in SSIM, viz, A, V, O, and X are substituted by 1 and 0 based on a set of rules (as shown in Table 13.3) to form a binary matrix called the initial reachability matrix.

Initial reachability matrix, derived in accordance to the rules, for SC coordination enablers is shown in Table 13.4.

Final reachability matrix is obtained after checking the initial reachability matrix for a property of set theory called transitivity (Table 13.5). The dependence power (DP) and the driving power (Dr.P) of each enabler are shown in Table 13.5. The dependence of an element P is the sum of all those elements that may help in achieving it. This includes the element itself. The driving power of an element P is defined as the sum of all those enablers (including itself) that may be achieved with the help of element P. Their role in MICMAC analysis is explained in Sect. 13.4.

Table 13.3 Rules for transformation of SSIM

Entry in SSIM	Entry in reachability matrix	
(*x*, *y*)	(*x*, *y*)	(*y*, *x*)
V	1	0
A	0	1
X	1	1
O	0	0

Table 13.4 Initial reachability matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	0	0	0	0	0	0	0	0	0	0	0
2	1	1	1	1	1	0	0	0	0	1	0	1
3	1	1	1	0	1	0	0	0	1	0	0	0
4	1	1	0	1	0	0	0	0	0	1	0	1
5	1	0	0	0	1	0	0	0	1	1	1	0
6	0	0	1	1	0	1	1	1	0	0	0	1
7	0	0	0	1	0	1	1	1	0	0	0	1
8	0	1	0	1	0	1	1	1	0	0	0	0
9	1	0	0	0	0	0	0	0	1	0	0	0
10	1	0	0	0	1	0	0	0	0	1	1	0
11	1	0	0	0	1	0	0	0	1	1	1	0
12	1	1	0	1	1	0	0	0	1	1	1	1

Table 13.5 Final reachability matrix

	1	2	3	4	5	6	7	8	9	10	11	12	Dr.P
1	1	0	0	0	0	0	0	0	0	0	0	0	*1*
2	1	1	1	1	1	0	0	0	1	1	1	1	*9*
3	1	1	1	1	1	0	0	0	1	1	1	1	*9*
4	1	1	1	1	1	0	0	0	1	1	1	1	*9*
5	1	0	0	0	1	0	0	0	1	1	1	0	*5*
6	1	1	1	1	1	1	1	1	1	1	1	1	*12*
7	1	1	1	1	1	1	1	1	1	1	1	1	*12*
8	1	1	1	1	1	1	1	1	1	1	1	1	*12*
9	1	0	0	0	0	0	0	0	1	0	0	0	*2*
10	1	0	0	0	1	0	0	0	1	1	1	0	*5*
11	1	0	0	0	1	0	0	0	1	1	1	0	*5*
12	1	1	1	1	1	0	0	0	1	1	1	1	*9*
DP	*12*	*7*	*7*	*7*	*10*	*3*	*3*	*3*	*11*	*10*	*10*	*7*	

13.3.3 Level Partitioning

From the final reachability matrix, two sets, viz, the antecedent and reachability set (Warfield 1974) for each enabler are deduced. Reachability set for an element constitutes of an element itself and other elements that may be reached with its help. It is obtained by examining the rows of the final reachability matrix. The antecedent set constitutes of those elements that help in reaching this element. It is obtained by analyzing the columns in the final reachability matrix. Finally, the intersection set consists of the elements that are common in both antecedent and reachability sets. In the ISM hierarchy, level 1 would consist of those element(s) with same intersection and reachability sets. These elements do not affect any other elements above their own level. These elements are discarded from further iteration process. Enabler 1 occupies level 1, as shown in Table 13.10. Hence, the top level of the ISM model consists of enabler 1. It can be seen that enabler 1 is removed for second iteration process (Table 13.11). This iteration process is carried out till the level of each element is found out. Tables 13.10, 13.11, 13.12, 13.13, 13.14 show the iteration processes (refer Appendix). The digraph and final ISM are constructed based on the identified elements along with their levels.

13.3.4 Conical Matrix

The elements in the same level are clubbed across the columns and the rows to develop conical matrix. The resultant matrix is shown in Table 13.6.

Table 13.6 Conical form

	1	9	5	10	11	2	3	4	12	6	7	8
1	1	0	0	0	0	0	0	0	0	0	0	0
9	1	1	0	0	0	0	0	0	0	0	0	0
5	1	1	1	1	1	0	0	0	0	0	0	0
10	1	1	1	1	1	0	0	0	0	0	0	0
11	1	1	1	1	1	0	0	0	0	0	0	0
2	1	1	1	1	1	1	1	1	1	0	0	0
3	1	1	1	1	1	1	1	1	1	0	0	0
4	1	1	1	1	1	1	1	1	1	0	0	0
12	1	1	1	1	1	1	1	1	1	0	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1

13.3.5 Construction of ISM-Based Model

A digraph is obtained from the conical model and final reachability matrix. An arrow pointing from y to x is drawn to show the relationship between the enablers y and x. The transitive links are removed at this stage and the model is checked for conceptual consistency. From digraph, the nodes are substituted with the statements to obtain a systemic and structural model. The ISM model for the enablers of implementation of SC coordination is shown in Fig. 13.1.

The factors, namely, joint promotion (enabler 7), joint decision-making (enabler 6), and joint working (enabler 8) play a major role in SC coordination, as shown in Fig. 13.1. These variables form the base of the ISM hierarchy. Channel coordination (enabler 1) is the dependent variable which helps SC coordination. This enabler has occupied the top most position in the hierarchical structure.

13.4 MICMAC Analysis

There are two ways to analyze the system elements: direct relationship analysis and indirect relationship analysis using MICMAC. In direct relationship analysis, the direct relationships among the variables in the final model of ISM are examined to obtain a direct relationship matrix M (Table 13.7). In this matrix, the diagonal elements are considered to be zero. The transitive relationships are ignored. The driving power is calculated by sum of the interactions along the row. In the similar way, the dependence power is calculated by adding the interactions along the column. Ranks of the driving power and the dependence power are estimated. The direct relationship matrix signifies the maximum direct impact, but it is unable to

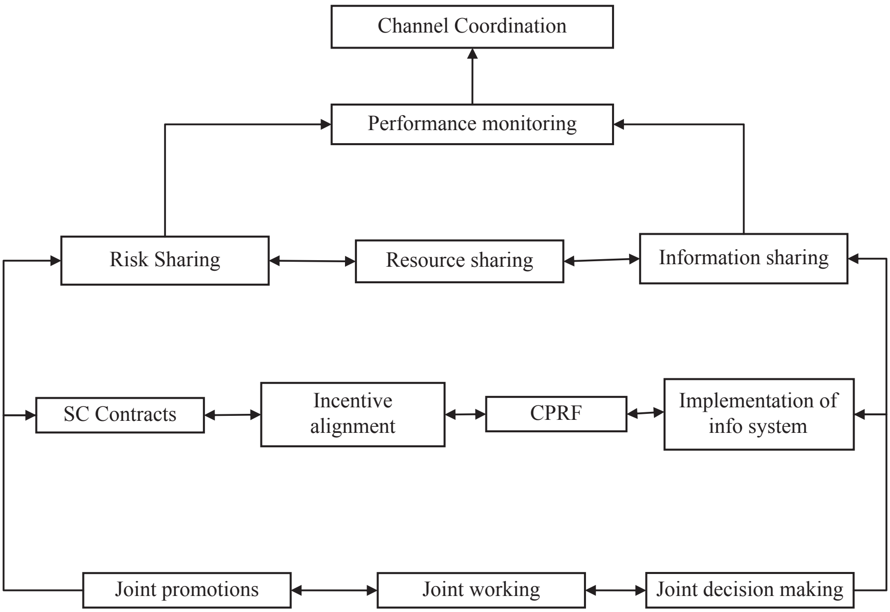

Fig. 13.1 ISM model for enablers of SC coordination

Table 13.7 Direct relationship matrix (M)

	1	2	3	4	5	6	7	8	9	10	11	12	Dr.P	Rank
1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2	0	0	1	1	0	0	0	0	0	0	0	0	2	1
3	0	1	0	0	1	0	0	0	0	0	0	0	2	1
4	0	1	0	0	0	0	0	0	0	0	0	1	2	1
5	0	0	0	0	0	0	0	0	1	1	0	0	2	1
6	0	0	1	0	0	0	0	1	0	0	0	0	2	1
7	0	0	0	0	0	0	0	1	0	0	0	1	2	1
8	0	0	0	0	0	1	1	0	0	0	0	0	2	1
9	1	0	0	0	0	0	0	0	0	0	0	0	1	2
10	0	0	0	0	1	0	0	0	0	0	1	0	2	1
11	0	0	0	0	0	0	0	0	1	1	0	0	2	1
12	0	0	0	1	0	0	0	0	0	0	1	0	2	1
DP	1	2	2	2	2	1	1	2	2	2	2	2		
Rank	2	1	1	1	1	2	2	1	1	1	1	1		

Table 13.8 Matrix stabilization using MICMAC

Factors	M^2		M^4		M^6		M^8	
	Dr.P.R[a]	DPR[a]	Dr.P.R	DPR	Dr.P.R	DPR	Dr.P.R	DPR
1	3	3	6	4	7	4	7	4
2	1	1	2	2	3	3	3	3
3	1	2	3	3	4	5	4	5
4	1	1	2	2	3	3	3	3
5	2	1	5	1	6	2	6	2
6	1	3	2	5	2	6	2	6
7	1	3	2	5	2	6	2	6
8	1	3	1	5	1	6	1	6
9	3	1	6	1	7	1	7	1
10	1	1	4	1	5	1	5	1
11	2	1	5	1	6	2	6	2
12	1	2	3	3	4	5	4	5

[a] *Dr.P.R* driving power rank, *DPR* dependence power rank

identify the hidden impact of the elements. Hence, the importance of the variables is analyzed by its indirect relationship using MICMAC. The dependence power and the driving power of the system elements can be analyzed using MICMAC analysis (Mandal and Deshmukh 1994).

MICMAC analysis works on the principle of matrix multiplication. If an element *x* affects an element *y* and element *y* affects third element *z*, then any change in element *x* would influence element *z*. Now, elements *x* and *z* are known to have indirect connections. Direct relationship approach provides no information related to numerous indirect relations that exist in the system. When the matrix is squared, then the second order relationship is obtained. In the similar manner, the matrix is multiplied *n* times to obtain the interconnecting elements. The process is continued till the hierarchy of driving power and dependence reaches a stable stage. This completes the process of MICMAC analysis.

Direct matrix, M is taken as the input for MICMAC analysis. Multiply the matrix *n* times till the ranks of dependence and driving power stabilized. The power by which the matrices is raised indicates the length of the circuit (Saxena et al. 2006). It is seen in Table 13.8 that the hierarchy of both the dependence and the driving power is stabilized at both M^6 and M^8. But the matrix gets stabilized at M^6 and the sequence of the ranks gets repeated at M^8. Thus, in this case, 6 represents the length of the circuit. In Table 13.9, the e_{21} (third row and second column) represents a path length of 4 influencing the enablers 2 and 1. Similar to the direct relationship matrix, the dependence power and the driving power are calculated by taking the sum of entries along the columns and rows, respectively. The elements are categorized based on MICMAC analysis (Fig. 13.2) into four different categories: dependent, independent, autonomous, and linkage variables.

Table 13.9 Indirect relationship matrix (M^6)

	1	2	3	4	5	6	7	8	9	10	11	12	Dr.P	Rank
1	0	0	0	0	0	0	0	0	0	0	0	0	0	7
2	4	13	0	0	9	0	0	0	5	5	4	8	48	3
3	1	0	5	8	1	0	0	0	8	8	4	0	35	4
4	4	0	8	13	4	0	0	0	5	5	9	0	48	3
5	4	0	0	0	4	0	0	0	0	0	4	0	12	6
6	5	9	1	4	10	4	4	0	1	1	8	4	51	2
7	5	4	4	9	8	4	4	0	1	1	10	1	51	2
8	0	5	8	5	1	0	0	8	10	10	1	8	56	1
9	0	0	0	0	0	0	0	0	0	0	0	0	0	7
10	0	0	0	0	0	0	0	0	8	8	0	0	16	5
11	4	0	0	0	4	0	0	0	0	0	4	0	12	6
12	1	8	0	0	4	0	0	0	8	8	1	5	35	4
DP	28	39	26	39	45	8	8	8	46	46	45	26		
Rank	4	3	5	3	2	6	6	6	1	1	2	5		

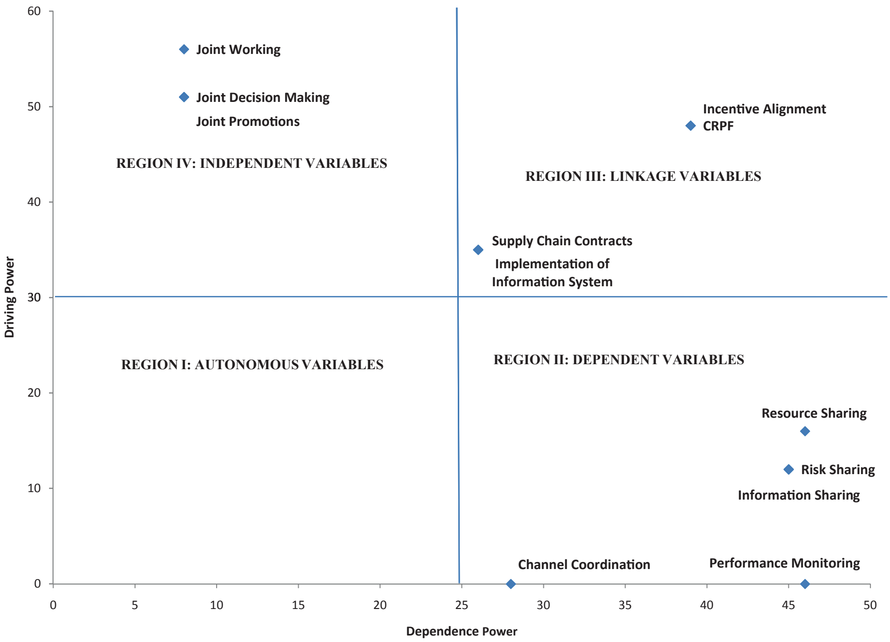

Fig. 13.2 MICMAC analysis of the SC coordination enablers

13.5 Managerial Implications

In this chapter, a hierarchy of elements which would lead to better SC coordination is developed using ISM. Analyzing these variables is important because it is the SC that is competing and not the individual organizations competing anymore; hence, coordination among these members is important. SC can be well coordinated if all the SC members work and make decisions together and also encourage joint promotions. This would improve SC performance since it would encourage all SC members to share their information.

Various enablers of SC coordination are classified with the help of MICMAC analysis. The autonomous cluster (Region I in Fig. 13.2) does not contain any variables, which indicates that all the variables are well connected in the whole system and the management has to focus on all the enablers influencing the SC coordination.

Next cluster (Region IV in Fig. 13.2) consists of independent variables like joint promotion, joint working, and joint decision-making, which have low dependence and high driving power. These enablers play an important role to coordinate all the SC members. Joint decision-making encourages them to share information and which further reduces the need for forecasting at different levels and finally help mitigate the consequences of the bullwhip effect. Joint making, joint promotions, and joint working are all dependent on each other. These variables help in dealing with the operational issues in the SC. These factors should be considered by the management for immediate action, which would influence the factors above their own level.

The next cluster (Region III in Fig. 13.2) consists of linkage variables, which include factors like implementation of ISs, CPFR, incentive alignment, and SC contract. Lower level variables affect linkage variables, which in turn, affect other elements in the system. Any disturbances in this cluster would affect the whole SC since it acts as a connecting link between other variables in the system.

Implementation of the IS is possible if the SC members work jointly and take decisions together. This implementation encourages SC members to have incentive mechanisms amongst themselves, which in turn, helps the organizations to improve the forecast accuracy in the SC. Joint working promotes the usage of supply contracts among various members in the SC. These factors can be also of tactical focus to the management.

The last cluster (Region II in Fig. 13.2) includes variables like information sharing, resource sharing, risk sharing, performance monitoring, and channel coordination. Channel coordination forms the top variable in the hierarchy. This element in the top represents that it is resultant of other actions of SC coordination. Resource sharing, risk sharing, information sharing, and performance monitoring have high dependence and these variables also tend to drive the topmost variable. The strong dependence of the elements indicates that all other enablers should be taken care to enable better coordination. The elements at the top level are also important since they are finally needed by the SC to coordinate its members to increase the profitability of the SC. These factors can be considered as the strategic issues. They are not of immediate concern to the management since any action at the lower level variable would influence these variables.

13.6 Conclusion

Only 12 variables have been considered for understanding the relationship among the enablers of SC coordination. Few more variables can be considered. Since the relationships among the variables are obtained using expert opinion, they may be subject to bias. As a part of future work, structural equation modeling (SEM) can be used to validate the proposed model.

Appendix

Table 13.10 Iteration 1

Barrier	Reachability set	Antecedent set	Intersection set	Level
1	{1}	{1,2,3,4,5,6,7,8,9,10,11,12}	{1}	I
2	{1,2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
3	{1,2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
4	{1,2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
5	{1,5,9,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	
6	{1,2,3,4,5,6,7,8,9,10,11,12}	{6,7,8}	{6,7,8}	
7	{1,2,3,4,5,6,7,8,9,10,11,12}	{6,7,8}	{6,7,8}	
8	{1,2,3,4,5,6,7,8,9,10,11,12}	{6,7,8}	{6,7,8}	
9	{1,9}	{2,3,4,5,6,7,8,9,10,11,12}	{9}	
10	{1,5,9,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	
11	{1,5,9,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	
12	{1,2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	

Table 13.11 Iteration 2

Barrier	Reachability set	Antecedent set	Intersection set	Level
2	{2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
3	{2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
4	{2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
5	{5,9,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	
6	{2,3,4,5,6,7,8,9,10,11,12}	{6,7,8}	{6,7,8}	
7	{2,3,4,5,6,7,8,9,10,11,12}	{6,7,8}	{6,7,8}	
8	{2,3,4,5,6,7,8,9,10,11,12}	{6,7,8}	{6,7,8}	
9	{9}	{2,3,4,5,6,7,8,9,10,11,12}	{9}	II
10	{5,9,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	
11	{5,9,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	
12	{2,3,4,5,9,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	

Table 13.12 Iteration 3

Barrier	Reachability set	Antecedent set	Intersection set	Level
2	{2,3,4,5,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
3	{2,3,4,5,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
4	{2,3,4,5,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	
5	{5,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	III
6	{2,3,4,5,6,7,8,10,11,12}	{6,7,8}	{6,7,8}	
7	{2,3,4,5,6,7,8,10,11,12}	{6,7,8}	{6,7,8}	
8	{2,3,4,5,6,7,8,10,11,12}	{6,7,8}	{6,7,8}	
10	{5,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	III
11	{5,10,11}	{2,3,4,5,6,7,8,10,11,12}	{5,10,11}	III
12	{2,3,4,5,10,11,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	

Table 13.13 Iteration 4

Barrier	Reachability set	Antecedent set	Intersection set	Level
2	{2,3,4,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	IV
3	{2,3,4,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	IV
4	{2,3,4,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	IV
6	{2,3,4,6,7,8,12}	{6,7,8}	{6,7,8}	
7	{2,3,4,6,7,8,12}	{6,7,8}	{6,7,8}	
8	{2,3,4,6,7,8,12}	{6,7,8}	{6,7,8}	
12	{2,3,4,12}	{2,3,4,6,7,8,12}	{2,3,4,12}	IV

Table 13.14 Iteration 5

Barrier	Reachability set	Antecedent set	Intersection set	Level
6	{6,7,8}	{6,7,8}	{6,7,8}	V
7	{6,7,8}	{6,7,8}	{6,7,8}	V
8	{6,7,8}	{6,7,8}	{6,7,8}	V

References

Arshinder, Kanda A, Deshmukh SG (2008) Supply chain coordination: perspectives, empirical studies and research directions. Int J Prod Econ 115(2):316–335

Chander M, Jain SK, Shankar R (2013) Modeling of information security management parameters in Indian Organizations using ISM and MICMAC approach. J Model Manage 8(2):171–189

Charan P, Shankar R, Baisya RK (2008) Analysis of interactions among the variables of supply chain performance measurement system implementation. Bus Process Manage J 14(4):512–529

Christopher M, McKinnon A, Sharp J, Wilding R, Peck H, Chapman P, Juttner U, Bolumole Y (2002) Supply chain vulnerability. Report for Department of Transport, Local Government and the Regions, Cranfield University, Cranfield

Hahn CK, Duplaga EA, Hartley JL (2000) Supply chain synchronization: lessons from Hyundai Motor Company. Interfaces 30(4):32–45
Henriott L (1999) Transforming supply chains into e-chains. Supply Chain Manage Rev (Global Supplement), Spring:15–18
Hill RM, Omar M (2006) Another look at the single-vendor single-buyer integrated production inventory problem. Int J Prod Res 44(4):791–800
Huan SH, Sheoran SK, Wang G (2004) A review and analysis of supply chain operations reference (SCOR) model. Supply Chain Manage Int J 9(1):23–29
Jharkharia S, Shankar R (2005) IT-enablement of supply chains: understanding the barriers. J Enterp Inf Manage 18(1):11–27
Joshi R, Banwet DK, Shankar R (2009) Indian cold chain: modeling the inhibitors. Br Food J 111(11):1260–1283
Kumar R, Singh RK, Shankar R (2013) Study on coordination issues for flexibility in supply chain of SMEs: a case study. Glob J Flex Syst Manage 14(2):81–92
Larsen TS (2000) European logistics beyond 2000. Int J Phys Distrib Logist Manage 30(5):377–387
Lee HL, Whang S (2000) Information sharing in a supply chain. Int J Manuf Technol Manage 1(1):79–93
Lee HL, Padmanabham V, Whang S (1997a) The bullwhip effect in supply chains. Sloan Manage Rev 38(3):93–102
Lee HL, Padmanabhan P, Whang S (1997b) Information distortion in a supply chain: the bullwhip effect. Manage Sci 43(4):546–558
Mandal A, Deshmukh SG (1994) Vendor selection using interpretive structural modeling (ISM). Int J Oper Prod Manage 14(6):52–59
Mentzer JT, DeWitt W, Keebler JS, Min S, Nix NW, Smith CD, Zacharia ZG (2001) Defining supply chain management. J Bus Logist 22(2):1–25
Narus JA, Anderson JC (1996) Rethinking distribution: adaptive channels. Harv Bus Rev 74(4):112–120
Raj T, Shankar R, Suhaib M (2008) An ISM approach for modelling the enablers of flexible manufacturing system: the case for India. Int J Prod Res 46(24):6883–6912
Ramesh A, Banwet DK, Shankar R (2010) Modeling the barriers of supply chain collaboration. J Model Manage 5(2):176–193
Ravi V, Shankar R (2005) Analysis of interactions among the barriers of reverse logistics. Technol Forecast Soc Change 72(8):1011–1029
Saxena JP, Sushil, Vrat, P (2006) Policy and strategy formulation—an application of flexible systems methodology. GIFT Publishing, New Delhi
Singh D, Agrawal DP (2003) CRM practices in Indian industries. Int J CRM 5(3):241–257
Singh MD, Kant R (2007) Knowledge management barriers: an interpretive structural modeling approach. In proceedings of the international conference on industrial engineering and engineering management (IEEM) 2007 in Singapore, IEEE, 2091–2095
Singh RK, Acharya P (2013) Supply chain flexibility: a frame work of research dimensions. Glob J Flex Syst Manage 14(3):157–166
Souter G (2000) Risks from supply chain also demand attention. Bus Insur 34(20):26–28
Stank TP, Crum MR, Arango M (1999) Benefits of inter-firm coordination in food industry in supply chains. J Bus Logist 20(2):21–41
Tsay AA, Lovejoy WS (1999) Quantity flexibility contracts and supply chain performance. Manuf Serv Oper Manage 1(2):89–111
Warfield JW (1974) Developing interconnected matrices in structural modeling. IEEE Trans Syst Man Cybern 4(1):81–87