RAIRO-Oper. Res. 56 (2022) 2139–2158
https://doi.org/10.1051/ro/2022075

RAIRO Operations Research
www.rairo-ro.org

CAUSAL MODELLING OF THE ENABLERS OF CPFR FOR BUILDING RESILIENCE IN MANUFACTURING SUPPLY CHAINS

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Abstract. Supply chain resilience is widely receiving attention during the past decade. Collaboration and visibility enhancement in supply chains is a key to achieve resilience and robustness in supply chains. Collaborative Planning, Forecasting and Replenishment (CPFR) is always been one of the difficult, yet powerful tool for collaboration in supply chains. Companies, in general attempt to address the technological side of changes, but avoid addressing the non-technological side of it, while implementing CPFR. This paper aims to explore the technological and non-technological enablers of CPFR, separately considering the Indian manufacturing industries and study their causal relations, using the Interpretive Structural Modeling (ISM). The results are beneficial, as managers can concentrate on causal enablers, while implementing CPFR. The success factors for implementation can slightly vary across different industries, but the applicability of the result is wider due to several common issues that arise during its implementation. Thus, the paper aims to provide directions for considering the most influencing enablers that can act as critical factors in the successful implementation of the CPFR. These influential enablers can be given much focus to reduce the vulnerabilities and to enhance the resilience capabilities of firms and their supply chains.

Mathematics Subject Classification. 62D20, 68U01, 90B90, 90B50.

Received July 5, 2021. Accepted May 14, 2022.

1. Introduction

Many global supply chains (SCs) face situation of crisis in the present COVID-19 era. Resilience and robustness in SCs can help them to mitigate and cope with such crises or disruptions [2]. Resilience in supply chains is the property and capability by which supply chains can manage, mitigate and prevent any adverse effects of disruptions. But to achieving resilience, collaboration and visibility need to be enhanced for their supply chains [25, 30]. It is apparent that due to competitive pressures and rapid changes in economic conditions, corporate executives are forced to re-evaluate the functionality and composition of their supply chains. Seeing the literature, we observe that supply chain management activities have already taken decisions for continuous restoration, local content development, relationship management and asset restoration, so that it reduces costs and reduces several risk related to sustainability [7, 42]. Christopher and Jüttner [11] described supply chain

Keywords. Supply chain resilience; Collaborative Planning, Forecasting and Replenishment (CPFR); information sharing; interpretive structural modeling (ISM).

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management (SCM) as "*the management of upstream and downstream relations with suppliers and customers in order to deliver better customer value at lower cost considering the supply chain as a whole*". Hence, any strategies for collaboration should be in effect to all supply chain tiers that can increase the value of products that are delivered to customers, ranging from product development to delivery.

Resilience and risk management concepts are always a part of the discussion in the literature of supply chains, as proactive practices for reducing risks can enhance the resilience of supply chains. Many scholars pointed that collaboration is an effective strategy to alleviate risks in supply chains. Say for instance, Tang [50] described supply chain risk management (SCRM) as "*the management of supply chain risks through coordination, collaboration or both among the supply chain partners, so as to ensure the participating firm's profitability and continuity*" and he suggested four ways to mitigate the risk impacts as, supply management, demand management, product management, and information management. Provisioning management of some non-core operations, the organization can deal with issues of network formation, supplier selection process, supplier order distribution, etc. [8, 46]. Management of demand uncertainty across time, market and delivery of products, requires flexibility in supply chains [26]. Increasing brand organizations and product portfolio organizations can help to treat products using several product management strategies; such as streamlining, process and product successions, etc.

Similarly, due to the large variability in the life cycle of different products, various strategies for collaboration are used by organizations to deal with potential risks and to achieving sustainable competitiveness [1, 29, 45]. CPFR are one attempt in this direction to reducing the risks and improving the flexibility in supply chains [3, 33]. Also we can see that, there are various researches that discuss the information flow and link the same to the effectiveness in implementing CPFR. Still, a critical study and causal analysis of the technological and non-technological enablers of CPFR is not found in the literature till date. We attempt in this paper to understand and assort various technological and non-technological enablers of CPFR for finding their causal relations, considering the context of Indian manufacturing firms. The paper elaborates the enablers of CPFR that the firms can focus on and discusses in detail about causal relations among them. As collaboration is a major component of risk management and resilience of firms and their supply chains, effective implementation of CPFR can help achieving this. The causal enablers of CPFR can be focused on to reduce the vulnerability and enhance capabilities of CPFR. This also helps in effectively managing firms' risks and help to improve the resilience of their supply chains. The paper is further arranged as follows. Section 2 elaborates a literature survey on CPFR and related practices. The model development and the descriptions about major enablers of CPFR, which are classified into four categories, are elaborated in Section 3. The results from the study and the related discussions are presented in Section 4, which is followed by conclusions of the study, limitations and scope of future works as in Section 5.

2. Literature survey

Resilience is defined as the property of a system to regain back to its original conditions or to achieve a better state, after when an adverse event or a disruption occurs [41, 44]. Supply chain resilience is defined as the property of supply chains to resist, restructure, recover, and renew from the impacts of any potential disruptions [2,43]. We study the role of collaboration and enhanced information sharing mechanisms in bringing resilience for supply chains. As mentioned earlier, supply chain resilience can be enhanced by improving the visibility through information sharing. Many companies have recognized the importance of information flow and are taking actions that can allow information to be shared across blocks of distribution channels [49]. The supply chain has two main objectives: to match the demand and supply of a particular product or service and to improve the efficiency and responsiveness of their suppliers and customers; hence, these are the primary purposes of sharing information [39]. As pointed out by Lee and Whang [28], manufacturers are more benefited by data sharing in comparison to the retailer. In addition to price discount offered by the manufacturers, Waller *et al.* [51] introduced a program called Vendor Managed Inventory (VMI). VMI acts as a two-way communication between manufacturer and vendor. The retailer provides specific information about the product demand in the market and its inventory. VMI has not only reduced the uncertainty about demand due to the sharing of precise data between manufacturer and vendor, but also provided a proper re-inventory system for all retailers and have reduced logistics and travel costs [16]. The prime limitation of VMI is the lack of vendor engagement in the final forecast. The addition of CPFR enhances the information sharing practices of many firms. This is detailed in the subsequent section.

2.1. CPFR: A tool of information sharing

The promising tool was designed by the Vol Volustustry Commerce Standards (VICS) that includes vendor interactions and predictions on product demand. This tool was named Collaborative Planning, Forecasting and Replenishment (CPFR). CPFR can act as a substitute for electronic data exchange (EDI), as CPFR responds faster and is cheaper than EDI [24]. The theme behind introducing CPFR was to remove the obstructions that are upsetting the supply chains [13]. These issues arise owing to lack of transparency in demand from markets, which are magnified by poor choices resulting from inaccurate information [6]. The aim of CPFR is to coordinate various procurement planning activities, forecasting and replenishment of assets among commercial parties in supply chain management. Skjoett-Larsen *et al.* [48] define CPFR as "*collaboration, where two or more parties in the supply chain can jointly plan a number of promotional activities and implement this in synchronized forecasts, based on which the production and replenishment processes can be executed*".

There are five steps to implementing CPFR such as; creation of a pre-termination agreement, joint venture planning and forecasting, scenario development, and forecasting and restructuring [20]. An agreement outlining the needs of both manufacturers and vendors with an appropriate understanding and documentation of the purpose, requirement and results of information are required in the initial phase of collaborative planning [36]. In the second phase of collaborative planning, both partners formulate a strategy and plan activities by taking into account the differences they expect during a given forecast period. The sales information provider is instrumental in developing a demand forecast. Both groups will receive their respective predictions separately. In the next section, both agencies will share their position and explore the differences between the predictions. If the differences between the prediction exceeds the safety level, which has already been determined by both parties, then they can work together to reach an agreement. In the end, after reaching agreement for the demand forecast, the actual order is placed and then the inventory is renewed.

2.2. Benefits of implementing CPFR

Various researchers have developed CPFR measures and mentioned potential benefits for organizations that use CPFR practices. Crum and Palmatier [12] argued about the reduction in inventory by 30–50 percent, reduction in transaction costs, and also they mention about improvement of customer service experiences. Firms that use CPFR tend to have better production and flow planning, reduced forecast errors and better product availability than when compared to firms that do not use CPFR. Mohammaddust *et al.* [34] argued about the reduction in inventory, increase in sales and better financial performance measured by the cost of goods sold, while implementing CPFR. Also, it is observed that CPFR helps to build strong partnerships with your supplier or customer. Sari [47] concluded that CPFR has greater stability than VMI under market conditions with higher demand uncertainty and considering lead times in operation.

2.3. Enablers of CPFR

Along with those driving forces that recognize the need for the implementation of the CPFR, power has also become an important focus of discussion in research papers. Empowering has many similar meanings to allow someone to do something. According to a study by Daugherty *et al.* [14], some progress has been made in the adoption of partnerships as a viable option for managing supply chain relationships, and many firms currently are studying or planning to use the collaborative system for future. Panahifar *et al.* [37] analyzed the CPFR implementation capability using a hybrid approach that combines a comprehensive analytical process and model ordering, and found that seven of the top ten providers are not technologically advanced, including competitiveness, high pressure management support and commitment, and also not a having a clear communication plan. Their study also identified data accuracy, uniformly agreed objectives, and high level of reliability as CPFR enhancers; hence, suggested that careful selection of collaborative partners is essential to the success of any startups.

Fu [21] used an analytical network process approach to analyze the factors influencing the adoption of CPFR by vendors and suppliers, and found that CPFR adoption is more management, rather than a technological issue. And with the help of top management, trusting relationships, and careful selection of strategic partners, CPFR can be successfully adopted. Panahifar *et al.* [38] examined 24 factors that influence the selection of retail partners through the implementation of CPFR, and observed that retailer familiarity has the greatest impact among the factors studied. Several studies have proposed frameworks that will facilitate the implementation of CPFR. For example, Demiray *et al.* [15] proposed a systematic CPFR road mapping with a case study of an automotive supply company. Lin and Ho [31] developed a CPFR implementation model for integrating purchasing, operations, and installation considering medical supply chains. Panahifar *et al.* [37] reviewed the CPFR literature and developed a plan to perform CPFR related activities effectively. We consider for this study, several enablers that are documented in literature for the implementation of CPFR and the same are discussed in detail in Table 1. These enablers can help in the successful implementation of CPFR practices for firms and hence, can reduce the vulnerabilities and enhance the resilience capabilities.

3. Model development

We aim to find the most influencing enablers from all the listed enablers in Table 1. These most influencing enablers can be focused more to aid successful implementation of CPFR, reduce vulnerabilities, and to improve resilience. In order to enhance the focus of the study, we have classified the enablers into categories of intra and inter organization related enablers and sub-classify them into technological and non-technological factors, separately for both the categories. This exercise can identify the enablers falling in all the four categories and the same is shown in Table 2. We conduct further causal analysis of these clusters using the Interpretive Structural Modelling (ISM) methodology [18, 35], which helps in establishing the interrelationship between the enablers and it also help us to find which among them has the highest driving power and which has highest dependence power. The steps of ISM are briefly mentioned as follows:

(i) Formation of Structural Self Interaction Matrix (SSIM).
(ii) Generate reachability matrix using the SSIM.
(iii) Divide the factors into various levels.
(iv) Use the reachability matrix to generate the conical matrix.
(v) Develop the ISM-based model by including transitivity.

Panahifar *et al.* [38] discussed on these enablers in two dimensions, as the inter organization and the intra organization and divided it into two categories, namely technical and non-technical. We adapt and modify this categorization as shown in Table 2.

3.1. Implementation of the ISM for a case

For finding the most influential enablers considering the case of manufacturing industries in India, we collect expert opinion from ten experts from different manufacturing organizations. Out of those, eight were working in multi-national companies and remaining two was from the leading imminent national companies. The two expert opinions were taken separately from national firms to understand and study the probable bias, if any exist in the influential ratings, when compared to that of multi-national companies. And we observe that the effects of bias in the influence ratings are nullified. The opinion represents the influence ratings of one enabler over the other. The rating scales are discussed in the next sub-section. The selected experts were having a working experience of over 5 years in manufacturing and supply chains and their firms have successfully implemented the CPFR practices in one form or other. The average of these obtained ratings was used to build the ISM model for the study.

TABLE 1. List of the enablers considered for the study with brief descriptions.

Sl. no	Enablers	Author(s)	Description(s)
1	Technological capability	Figueiredo and Eiras [19]	Technological capability can be explained as integrating the requirements needed to generate and manage changes in technology, which can play an important part in the successful implementation of CPFR.
2	Information visibility	Kim *et al.* [27]	Information visibility can be defined as the level to which supply chain partners receive available information related to the availability of the material and their need in market.
3	System capability	Fu [21]	System compatibility and capability is considered as one of the important ingredient for enablement of CPFR.
4	Amalgamation capability of technology	Fu [21]	Amalgamation is a way to define the process of bringing two units together and work together. Authors pointed that amalgamation capability of technology and culture has important effects on the CPFR enablement on retailer.
5	High internal service rate	Aviv [5]	For the successful enablement of CPFR and to generate benefits out of it, internal service rate needs to be at a higher level.
6	Information system management	Wang *et al.* [52]	An information system can generate a platform for organizations to communicate with its supply chain partners effectively and timey, while collaboration.
7	Internal alignment	Chen *et al.* [10]	Internal alignment is the determination of internal sub- systems working in close collaboration for a common goal achievement through the exchange of information and resources.
8	Information accuracy	Whipple *et al.* [54]	Lack of accuracy of data can cause delays in providing information to suppliers and partner distributers.
9	Willingness to collaborate	Panahifar *et al.* [37]	A mutual interest among business partners is required for enablement of CPFR. Thus, to work with business partners can be considered as a culture that may help to decide whether to provide sensitive information.
10	Information readiness	Panahifar *et al.* [38]	People concerned with enablement must ensure that all the concerned parties should follow the particular pattern suggested to them.
11	Senior management support and commitment	Ireland and Bruce [24]	Senior management support and commitment is one of the important ingredients in the successful enablement of collaborations strategy.
12	Culture fits and collaborative culture	Wu *et al.* [55]	Partners' cultural capability and collaboration culture can be defined as the challenge of coordinated energy transfer strategy. Organizational culture or related cultures between organizations have a positive impact on sharing data.
13	Organization innovation capability	Yao *et al.* [56]	Innovation capability is a key ingredient that allows organizations to make use external data to learn new knowledge.
14	Flexible organization structure	Attaran and Attaran [4]	Organizational flexibility is defined as 'the capacity to respond to environmental change'. Flexible organizational structure is one of the key ingredients, which can enable the influence of collaboration in organizations.
15	Data compatibility across users	Whipple and Russell [53]	Matching information according to the system configurations can be problematic, if the mean of data is not compatible according to the needs of organizations.
16	Electronic Data Interchange	Fliedner [20]	Electronic Data Interchange (EDI) is defined as the transmission of standard business documents in a standard format between industrial trading partners from one computer application to other computer application. EDI is one of the key determinants of enablement of CPFR adoption.

Table 1. continued.

Sl. no	Enablers	Author(s)	Description(s)
17	Developing IT infrastructure	Panahifar *et al.* [37]	IT availability and technological infrastructure advancement can improve supply chain collaboration by improving its flexibility.
18	System function integrity	Fu *et al.* [22]	System function integrity can be a key to introduce CPFR with commercial partners in an effective manner.
19	High level of trust	Eksoz *et al.* [17]	High level of trust can be one of the key ingredients in the enablement of CPFR, which has been suggested in many literatures.
20	Mutual agreed objectives	Büyüközkan and Vardaloğlu [9]	It is important to define common objectives at the start of collaboration.
21	Clear communication plans	Fu *et al.* [22]	A clear communication plan creates an effective platform for communication between organizations that is essential for effective performance.
22	Information sharing security	Panahifar *et al.* [37]	In CPFR enablement process, the concern of the stakeholders in sharing sensitive data related to financial, production and inventory and its levels and values is essential.
23	Competition pressure	Panahifar *et al.* [38]	Competition pressure is a key ingredient in the enablement of collaboration. Competition pressure can affect the strategy of the organizations and its effects on a company's incentives for collaboration with other organizations related to their innovations.
24	Upfront planning	Panahifar *et al.* [38]	Ability of the organization to visualize the extent of the implementation can help the organization to choose a strategy that will work during the implementation of the CPFR.
25	Information technology services	Panahifar *et al.* [37]	The growing popularity of Information Technology (IT) in Supply Chain Management (SCM) can be a key factor in increasing the flow of decision-making networks for organization's competitiveness, improving service quality, reducing inventory, cost of supply and for reducing energy risk.
26	Major change to operational process	Panahifar *et al.* [37]	High CPFR acceptance rate is related to modification in the operating process, which is not an easy process as it requires both time and money.
27	Organization size	Panahifar *et al.* [38]	A large corporation with a large product mix is forcing collaboration between supply chain partners to avoid duplication.
28	Compatibility of partners ability	Panahifar *et al.* [38]	The same strength of partners can help to raise the level of understanding among partners of the materials provided.
29	Joint training	Ireland and Bruce [24]	Joint training can helps to build cohesion between the two sides and understands the problems in field. The joint training of both groups may be related to planning or the execution of partnerships or may be technical aspects of the delivery.
30	Customer implants	Panahifar *et al.* [38]	Customer implants or the customer service coordinator can act as informal channels of information. These implants are hired by the manufacturer, who spends time in the vendor organization and is given unlimited access to information.
31	Board to board dialogue	Panahifar *et al.* [37]	In order to maintain strategic alignment, the senior management team is requested to meet in a timely manner. Timeliness of these interactions needs to be increased.

Table 2. Categorization of enablers for the study.

	Group	Enablers
Intra organization	Technological factors	– Technological capability – Information visibility – System capability – Amalgamation capability of technology – High internal service rate – Information technology services – Information system management
	Non technological factors	– Willingness to collaborate – Information readiness – Senior management support and commitment – Cultural fits and collaborative culture – Organization innovation capability – Flexible organization structure – Major changes to operational process – Organization size
Inter organization	Technological factors	– Information sharing security – Electronic data interchange – Developing IT infrastructure – Compatibility of partners ability – Joint training – Data compatibility across users – System function integrity
	Non technological factors	– High level of trust – Mutual agreed objectives – Clear communication plan – Competitive pressure – Upfront planning – Customer implants – Board to board dialogue

3.2. Structural Self-Interaction Matrix (SSIM)

For the development of SSIM, relations "*lead to*" or "*influences*" are selected. The following relations are used; "O" when both the factors do not influence each other, "X" when both factor influence each other, "V" when only horizontal factor influence vertical factor and "A" when only vertical factor influences the horizontal [23, 32, 40]. The vertical factors are same as the horizontal factors and are represented by their serial number. SSIM matrices are as shown in Table 3 and the structural matrices are shown in Table 4.

3.3. Reachability matrix

The next step in ISM is to generate reachability matrix using the SSIM. This is done by substituting the symbols (*e.g.*, V, X, A, or O) by the 1 and 0. The rules of the replacement are; V and X is replaced by the 1 and the A and O are replaced by 0. After replacement, the first reachability matrix is generated. To fill the inconsistencies or the gaps, transitivity is included, which are usually indicated by *1. These entries are based on the indirect influence of a factor and are generally filled by using the expert opinion. We have collected expert responses for the transitive relations, also during the initial process of data collection. The reachability matrices of all the SSIM are given below with their final matrices, showing driving and dependence power. Driving power is the sum of the elements in a row of the factor matrix or the total number of factor it influences, while the

TABLE 3. SSIM matrices constructed.

SSIM matrix for intra organizational technological enablers							
Factors	7	6	5	4	3	2	1
1. Technological capability	V	V	A	A	O	A	
2. Information visibility	O	O	V	V	O		
3. System capability	O	O	V	V			
4. Amalgamation capability of technology	V	V	X				
5. High internal service rate	V	V					
6. Information accuracy	A						
7. Information system management							

SSIM matrix for intra organizational non-technological enablers									
Factors	9	8	7	6	5	4	3	2	1
1. Willingness to collaborate	V	A	O	O	V	V	A	A	
2. Information readiness	O	A	V	V	V	O	O		
3. Senior management support and commitment	O	A	V	V	V	O			
4. Cultural fits and collaborative culture	A	A	V	A	O				
5. Organization innovation capability	V	O	V	O					
6. Flexible organization structure	V	A	V						
7. Major changes to operational process	A	O							
8. Organization size	O								
9. Internal alignment									

SSIM matrix for inter organizational technological enablers							
Factors	7	6	5	4	3	2	1
1. Information sharing security	X	V	V	A	X	O	
2. Electronic data interchange	O	A	O	A	O		
3. Developing IT infrastructure	O	V	O	O			
4. Compatibility of partner's ability	O	V	O				
5. Joint training	O	V					
6. Data compatibility across users	A						
7. System function integrity							

SSIM matrix for inter organizational non technological enablers							
Factors	7	6	5	4	3	2	1
1. High level of trust	X	O	O	O	V	A	
2. Mutual agreed objectives	A	A	V	O	O		
3. Clear communication plan	A	A	A	A			
4. Competitive pressure	V	A	V				
5. Upfront planning	A	A					
6. Customer implants	O						
7. Board to board dialogue							

dependence power is the sum of all elements in the column of the factor matrix or the number of the factor it get influenced by. Rank is decided by the highest power. Factor with the highest power gets the highest rank. The final reachability matrices are indicated in Table 4.

3.4. Level partition

Using the reachability matrix, the reachability and antecedent sets are generated. Reachability sets consist of the factor itself and all the factors it is influencing, while the antecedent set consists of the factor and all the factors it is influenced by. Common factors from both the sets are included in the intersection set. If the factors that appears in the intersection and the reachability set are same, then it is kept at the top level. These set of factors are influenced by all the other factors and it does not influence any of them. These factors are removed

Table 4. Initial and final reachability matrices.

Reachability matrix for intra organizational technological enablers

Factor	1	2	3	4	5	6	7
1. Technological capability	1	0	0	0	0	1	1
2. Information visibility	1	1	0	1	1	0	0
3. System capability	0	0	1	1	1	0	0
4. Amalgamation capability of technology	1	0	0	1	1	1	1
5. High internal service rate	1	0	0	1	1	1	1
6. Information accuracy	0	0	0	0	0	1	0
7. Information system management	0	0	0	0	0	1	1

Final reachability matrix for intra organizational technological enablers

Factor	1	2	3	4	5	6	7	Driving power	Rank
1. Technological capability	1	0	0	*1	*1	1	1	5	ii
2. Information visibility	1	1	0	1	1	*1	*1	6	i
3. System capability	1*	0	1	1	1	*1	*1	6	i
4. Amalgamation capability of technology	1	0	0	1	1	1	1	5	ii
5. High internal service rate	1	0	0	1	1	1	1	5	ii
6. Information accuracy	*1	0	0	0	0	1	0	2	iv
7. Information system management	0	0	*1	0	0	1	1	3	iii
Dependence power	6	1	2	5	5	7	6		
Rank	ii	v	iv	iii	iii	i	ii		

Reachability matrix for intra organizational non technological enablers

Factors	1	2	3	4	5	6	7	8	9
1. Willingness to collaborate	1	0	0	1	1	0	0	0	1
2. Information readiness	1	1	0	0	1	1	1	0	0
3. Senior management support	1	0	1	0	1	1	1	0	0
4. Cultural fits and collaborative culture	0	0	0	1	0	0	1	0	0
5. Organization innovation capability	0	0	0	0	1	0	1	0	1
6. Flexible organization structure	0	0	0	1	0	1	1	0	1
7. Major changes to operational process	0	0	0	0	0	0	1	0	0
8. Organization size	1	1	1	1	0	1	0	1	0
9. Internal alignment	0	0	0	1	0	0	1	0	1

Final reachability matrix for intra organizational non technological enablers

Factors	1	2	3	4	5	6	7	8	9	Driving power	Rank
1. Willingness to collaborate	1	0	0	1	1	*1	*1	0	1	6	iii
2. Information readiness	1	1	0	*1	1	1	1	0	*1	7	ii
3. Senior management support	1	0	1	*1	1	1	1	0	*1	7	ii
4. Cultural fits and collaborative culture	0	0	0	1	0	0	1	0	0	2	vi
5. Organization innovation capability	0	0	0	*1	1	0	1	0	1	4	iv
6. Flexible organization structure	0	0	0	1	0	1	1	0	1	4	iv
7. Major changes to operational process	0	0	0	0	0	0	1	0	0	1	vii
8. Organization size	1	1	1	1	*1	1	*1	1	*1	9	i
9. Internal alignment	0	0	0	1	0	0	1	0	1	3	v
Dependence power	4	2	2	8	5	5	9	1	7		
Rank	v	vi	vi	ii	iv	iv	i	vii	iii		

TABLE 4. continued.

Reachability matrix for inter organizational technological enablers

Factors	1	2	3	4	5	6	7
1. Information sharing security	1	0	1	0	1	1	1
2. Electronic data interchange	0	1	0	0	0	0	0
3. Developing IT infrastructure	1	0	1	0	0	1	0
4. Compatibility of partner's ability	1	1	0	1	0	1	0
5. Joint training	0	0	0	0	1	1	0
6. Data compatibility across users	0	1	0	0	0	1	0
7. System function	1	0	0	0	0	1	1

Final reachability matrix for inter organizational technological enablers

Factors	1	2	3	4	5	6	7	Driving power	Rank
1. Information sharing security	1	*1	1	0	1	1	1	6	ii
2. Electronic data interchange	0	1	0	0	0	0	0	1	v
3. Developing IT infrastructure	1	*1	1	0	*1	1	*1	6	ii
4. Compatibility of partner's ability	1	1	*1	1	*1	1	*1	7	i
5. Joint training	0	*1	0	0	1	1	0	3	iii
6. Data compatibility across users	0	1	0	0	0	1	0	2	iv
7. System function	1	*1	*1	0	*1	1	1	6	ii
Dependence power	4	7	4	1	5	6	4		
Rank	iv	i	iv	v	iii	ii	iv		

Reachability matrices for inter organizational non technological enablers

Factors	1	2	3	4	5	6	7
1. High level of trust	1	0	1	0	0	0	1
2. Mutual agreed objectives	1	1	0	0	1	0	0
3. Clear communication plan	0	0	1	0	0	0	0
4. Competitive pressure	0	0	1	1	1	0	1
5. Upfront planning	0	0	1	0	1	0	0
6. Customer implants	0	1	1	1	1	1	0
7. Board to board dialogue	1	1	1	0	1	0	1

Final reachability matrix for inter organizational non technological enablers

Factors	1	2	3	4	5	6	7	Driving power	Rank
1. High level of trust	1	*1	1	0	1*	0	1	5	iii
2. Mutual agreed objectives	1	1	*1	0	1	0	*1	5	iii
3. Clear communication plan	0	0	1	0	0	0	0	1	v
4. Competitive pressure	*1	*1	1	1	1	0	1	6	ii
5. Upfront planning	0	0	1	0	1	0	0	2	iv
6. Customer implants	*1	1	1	1	1	1	*1	7	i
7. Board to board dialogue	1	1	1	0	1	0	1	5	iii
Dependence power	5	5	7	2	6	1	5		
Rank	iii	iii	i	iv	i	v	iii		

and the same procedure is further repeated. Table 5 shows the reachability set, the antecedent set and the intersection set of the final reachability matrix of the intra organizational technological enablers. The iterative procedure is also shown. Final level partition of all the other three matrices indicating intra organizational non technological enablers, inter organizational technological enablers, and inter organizational non technological enablers are shown in Table 6, respectively. Conical matrix is generated by taking the dependency and the driving power on the axis and placing the factors in them according to their powers. Conical matrices of all the categories are shown in the Figure 1.

TABLE 5. Iterations for level partition of the intra organizational technological enablers.

Enabler	Reachability set	Antecedent set	Intersection	Level
		Iteration 1		
1	1, 4, 5, 6, 7	1, 2, 3, 4, 5, 6	1, 4, 5, 6	
2	1, 2, 4, 5, 6, 7	2	2	
3	1, 3, 4, 5, 6, 7	3, 7	3, 7	
4	1, 4, 5, 6, 7	1, 2, 3, 4, 5	1, 4, 5	
5	1, 4, 5, 6, 7	1, 2, 3, 4, 5	1, 4, 5	
6	6	1, 2, 3, 4, 5, 6, 7	6	1
7	6, 7	1, 2, 3, 4, 5, 7	7	
		Iteration 2		
1	1, 4, 5, 7	1, 2, 3, 4, 5	1, 4, 5	
2	1, 2, 4, 5, 7	2	2	
3	1, 3, 4, 5, 7	3, 7	3, 7	
4	1, 4, 5, 7	1, 2, 3, 4, 5	1, 4, 5	
5	1, 4, 5, 7	1, 2, 3, 4, 5	1, 4, 5	
7	7	1, 2, 3, 4, 5, 7	7	2
		Iteration 3		
1	1, 4, 5	1, 2, 3, 4, 5	1, 4, 5	3
2	1, 2, 4, 5	2	2	
3	1, 3, 4, 5	3	3	
4	1, 4, 5	1, 2, 3, 4, 5	1, 4, 5	3
5	1, 4, 5	1, 2, 3, 4, 5	1, 4, 5	3
		Iteration 4		
2	2	2	4	4
3	3	3	4	4

3.5. MICMAC analysis

In this study, MICMAC analysis is also conducted to find the critical enablers in the manufacturing industry, using their dependence and driving power. Enablers can be classified in four groups; "autonomous", which have low dependence and driving power, "dependent", which have high dependence power, but low driving power, "linkage" having high driving and dependence power and "driving or independent" having low dependence but high driving power.

4. Results and discussion

Resilience and risk management are discussed at widely at the time of the global pandemic arising due to COVID-19. We observe from the literature that collaboration and information sharing can reduce associated vulnerabilities and can enhance the resilience capabilities of supply chains. Hence, we construct our study with the focus that in order to building resilience, the collaboration capabilities of the supply chain need to be enhanced. Also, for the successful implementation of any collaboration tool, the focus on the enablers of its implementation is a must. For this, we study the enables of the collaboration tool, CPFR. An interpretive structural modeling approach was engaged to study the major enablers of CPFR and the enablers were grouped into various categories of intra organizational technological enablers, intra organizational non technological enablers, inter organizational technological enablers, and inter organizational non technological enablers. The ISM models of all these four categories of enablers are shown below. Enablers like information visibility and *system capability* emerges as the top influencer for the intra organization technological enablers, as shown in Figures 2 and 3, and *organization size*, *senior management support and commitment*, and *information readiness*

Table 6. Level partition of the other three categories of enablers.

Level partition of the intra organizational non technological enablers				
Enabler	Reachability set	Antecedent set	Intersection	Level
1	1, 4, 5, 6, 7, 9	1, 2, 3, 8	1	5
2	1, 2, 4, 5, 6, 7, 9	2, 8	2	6
3	1, 3, 4, 5, 6, 7, 9	3, 8	3	6
4	4, 7	1, 2, 3, 4, 5, 6, 8	4	2
5	4, 5, 7, 9	1, 2, 3, 5, 8	5	4
6	4, 6, 7, 9	2, 3, 6, 8	6	4
7	7	1, 2, 3, 4, 5, 6, 7, 8, 9	7	1
8	1, 2, 3, 4, 5, 6, 7, 8, 9	8	8	7
9	4, 7, 9	1, 2, 3, 5, 6, 8, 9	9	3
Level partition of the inter organizational technological enablers				
1	1, 2, 3, 56, 7	1, 3, 4, 7	1, 3, 7	4
2	2	1, 2, 3, 4, 5, 6, 7	2	1
3	1, 2, 3, 5, 6, 7	1, 3, 4, 7	1, 3, 7	4
4	1, 2, 3, 4, 5, 6, 7	4	4	5
5	2, 5, 6	1, 3, 4, 5, 7	5	3
6	2, 6	1, 3, 4, 5, 6, 7	6	2
7	1, 2, 3, 5, 6, 7	1, 3, 4, 7	1, 3, 7	4
Level partition of the intra organizational non technological enablers				
1	1, 2, 3, 5, 7	1, 2, 4, 6, 7	1, 2, 7	3
2	1, 2, 3, 5, 7	1, 2, 4, 6, 7	1, 2, 7	3
3	3	1, 2, 3, 4, 5, 6, 7	3	1
4	1, 2, 3, 4, 5, 7	4,6	4	4
5	3, 5	1, 2, 4, 5, 6, 7	5	2
6	1, 2, 3, 4, 5, 6, 7	6	6	5
7	1, 2, 3, 5, 7	1, 2, 4, 6, 7	1, 2, 7	3

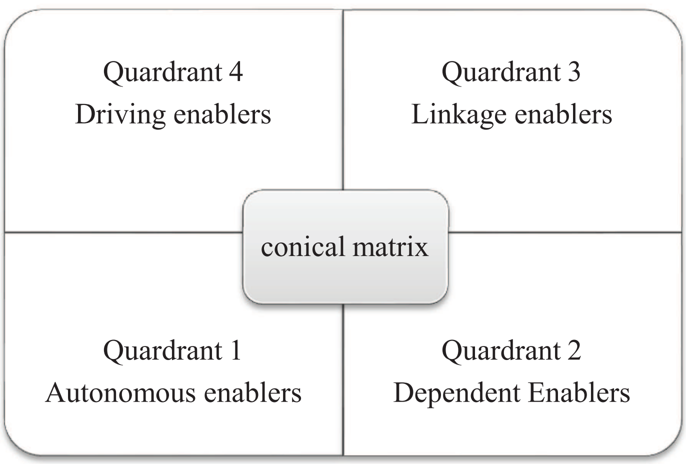

Figure 1. Power matrix.

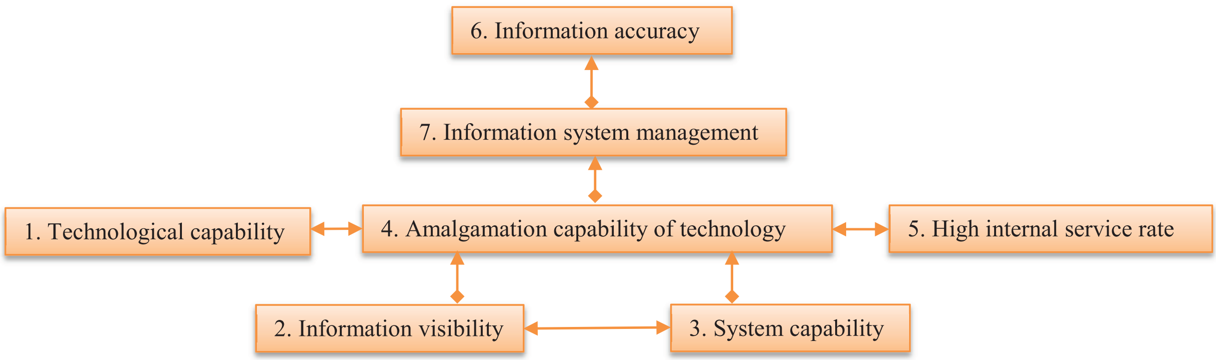

FIGURE 2. ISM model for intra organizational technological enablers.

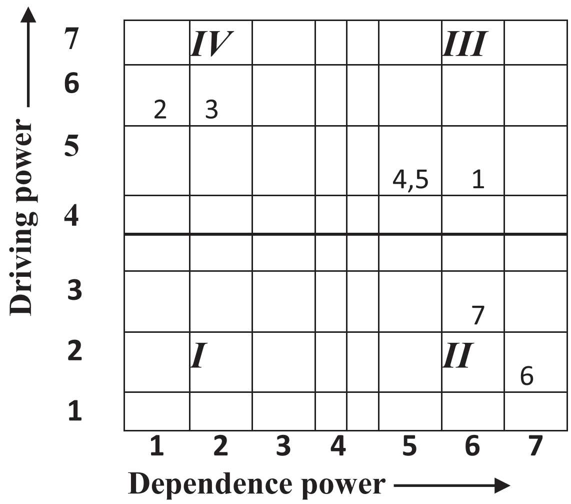

FIGURE 3. Conical and power matrix for intra organizational technological enablers.

came out to be most influential enablers for the intra organization non technological enablers, as shown in Figures 4 and 5. However, surprisingly *information accuracy* came out to be least influential intra organizational technological enabler and *major changes to operational process* were the least influential enabler among intra organizational non technological enablers.

From MICMAC analysis, as shown in Figure 5, we can say that *information visibility* and *system capability* can act as the driving variables, while *technological capability*, *amalgamation capability of technology*, and *high internal service rate* acts as the linkages. And, *information system management* and *information accuracy* can act as dependent variables. Similarly from Figure 3, we can say that *organization size*, *information readiness*, *senior management support and commitment*, and *willingness to collaborate* are the driving enablers, while *major changes to operational process* and *cultural fits & collaborative culture* can act as the dependent enablers.

In case of the inter organizational factors, *compatibility of partner' ability* came out as the most influencing technological enablers as shown in Figures 6 and 7, and *customer implants* was the most influencing non technological enabler as shown in Figures 8 and 9. *Electronic data interchange* was the least influential for inter organizational technological enablers as shown in Figure 6. *Clear communication plan* came out to be least influential enabler for inter organization non technological enablers as shown in Figure 8. From Figure 7, we

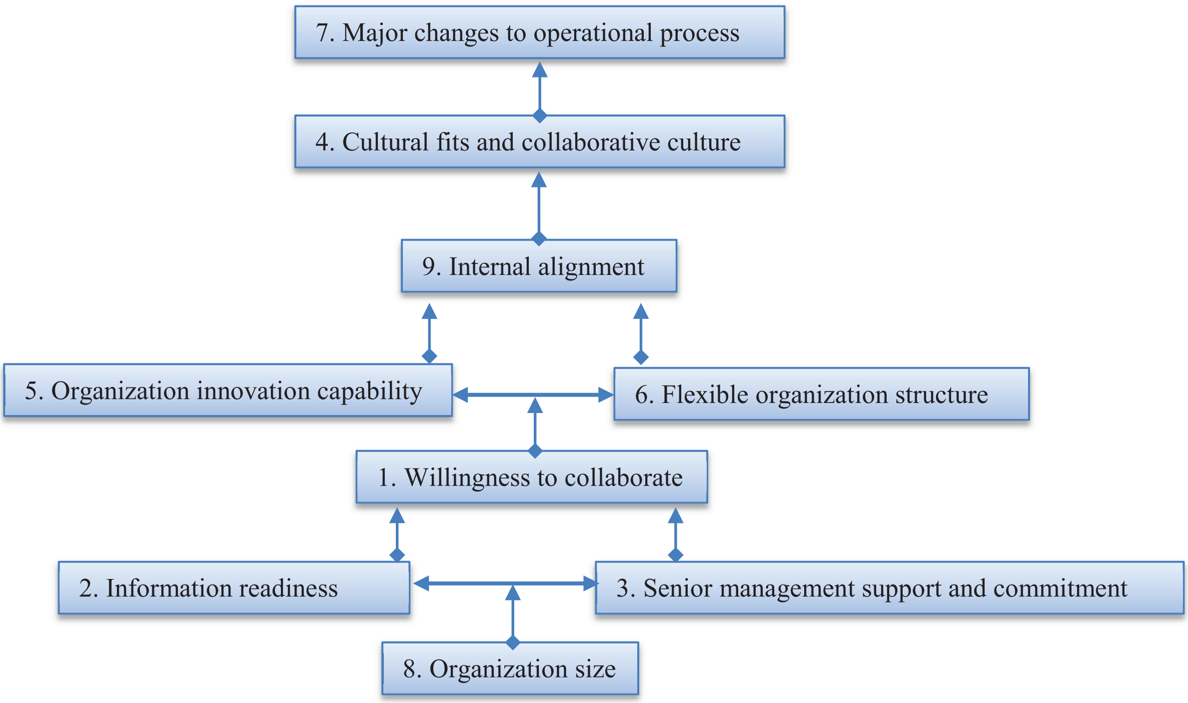

FIGURE 4. ISM model for intra organizational technological enablers.

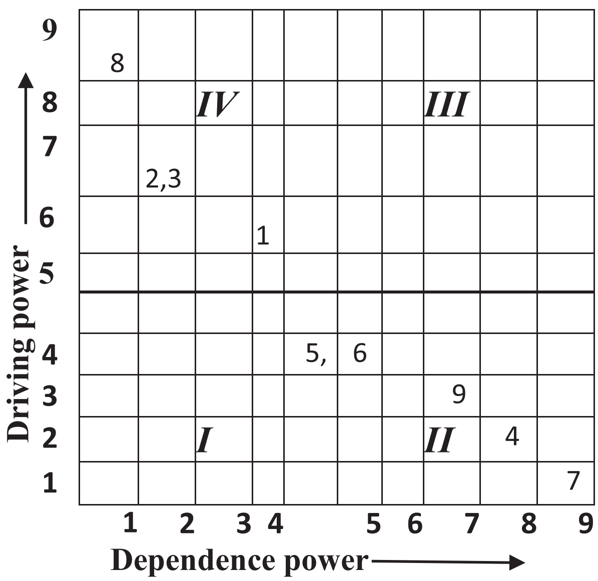

FIGURE 5. Conical and power matrix for intra organizational technological enablers.

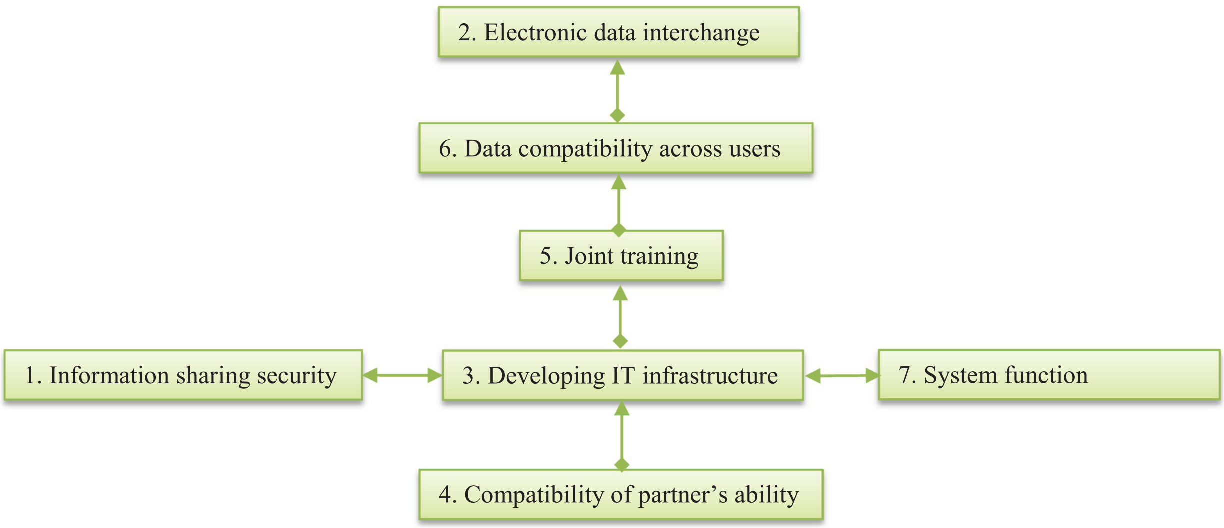

FIGURE 6. ISM model for inter organizational technological enablers.

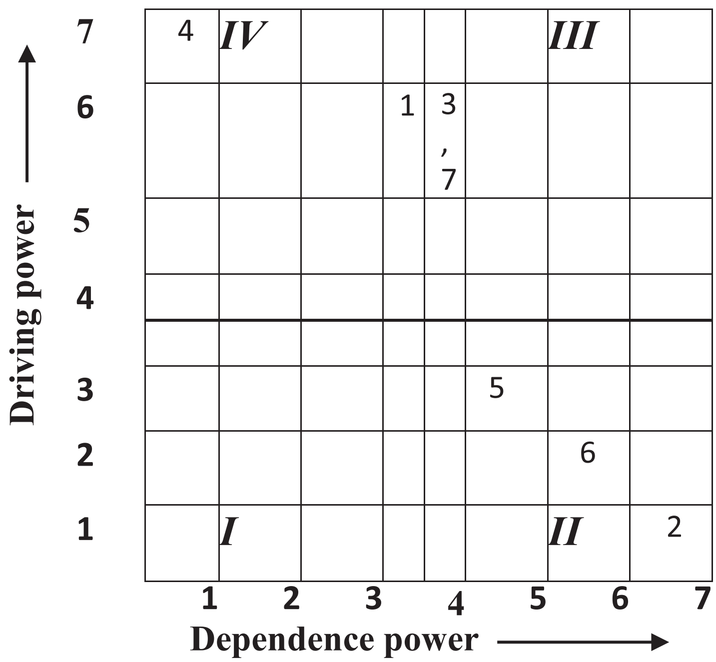

FIGURE 7. Conical and power matrix for inter organizational technological enablers.

can say that *compatibility of partners ability* can act as the driving enabler for CPFR implementation, while *information sharing security*, *developing IT infrastructure* and *system function* can act as the linkage drivers, while remaining *joint training*, *electronic data interchange*, and *data compatibility across users* are observed as the dependent enablers.

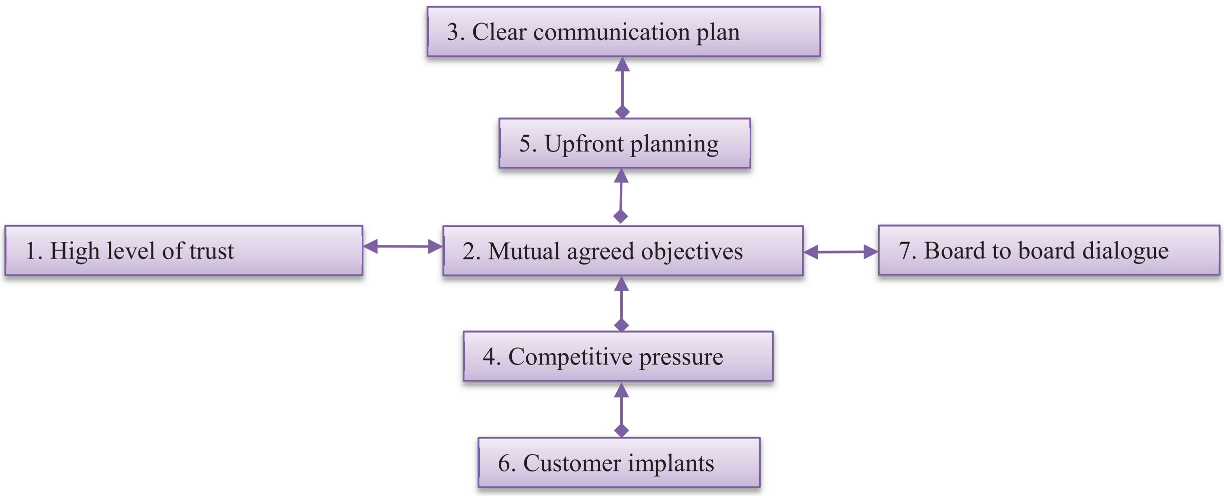

FIGURE 8. ISM model for Inter organizational non technological enablers.

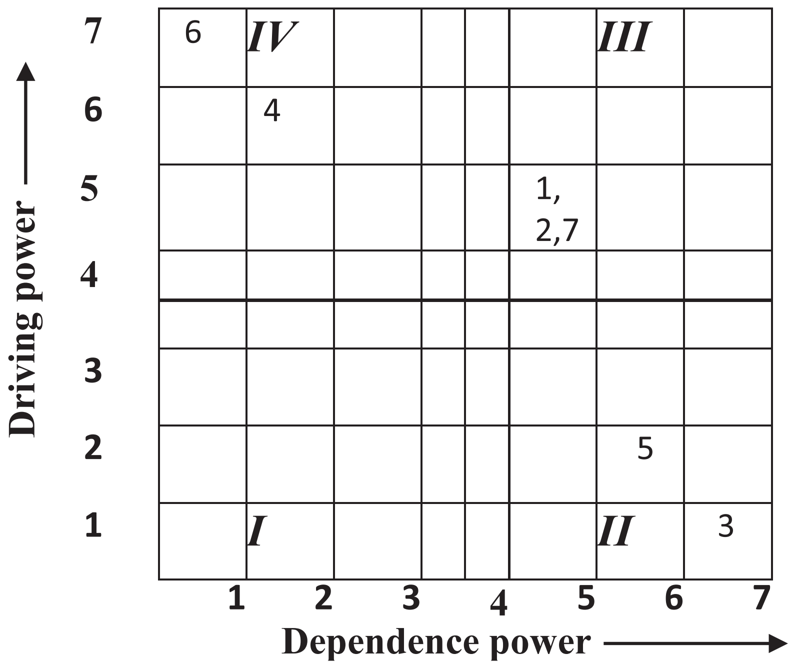

FIGURE 9. Conical and power matrices for inter organizational non technological enablers.

From Figure 9, we can say that *customer implants* and *competitive pressure* can act as the driving enabler for CPFR implementation, while *upfront planning* and *clear communication plan* emerges as the dependent enablers. *High level of trust*, *mutual agreed objective* and *board to board dialogue* acts as the linkage enablers. The enablers that are at the bottom need to be given specific attention for the proper implementation of the CPFR. However, this study concludes with the relation or influence between enablers of different categories.

5. Conclusions and scope of future works

The study is motivated by the fact that resilience, the property of organizations to manage disruptions is an essential feature of modern firms or their supply chains. We observe from the literature that collaborative working of organizations can enhance the resilience capabilities of firms and their supply chains. This also helps them to manage and mitigate particular crises situations, say for example; the spread of a pandemic, such as COVID-19. Supply chains have become more vulnerable and resilience needs to be enhanced to handle impending vulnerabilities. Collaboration in the supply chain is an effective tool for managing the uncertainty with the supply and demand. Collaborative Planning, Forecasting and Replenishment (CPFR) is always been treated as the one of the most difficult, yet useful strategy for collaboration in supply chains. Even having a large number of benefits of CPFR that are well documented in past research, CPFR is one of the least favorite strategies, because of the large number of difficulties in its implementation. In this paper, we tried to list out the most influencing enablers of the CPFR. It may be noted that; not much of the literature are available in the area focusing on analysing the enablers for the successful implementation of CPFR.

Interpretive structural modeling technique enabled us to find out the most influencing enablers in the implementation of CPFR. The success factors can slightly vary across different industries, but the applicability of the result is wider due to the common issues that arise during its implementation. In each industry, a good information system will lead to information accuracy in the organization. High *system capability* can provide us with a high internal service rate, so does uniting the technology of the supply chain partners will help to access and manage the information easily. Companies are directing their people to understand the working of their partner companies and teach them their way of working. No doubt, we can say that, it the one of the most influencing enabler, which is followed by *competitive pressure*, which urges the need of collaboration in any industry. Without *competitive pressure*, none of the industry will be willing to invest money to implementing these practices. Other enablers like *mutual agreed objective* and *board to board dialogue* also influences the successful enablement of the CPFR.

Discussing on the other efforts by the supply chain partners, *compatibility of partners' ability* has the most influence. None of the company can survive in collaboration, if it cannot match the standards of its partners. Many technological aspects like information sharing security, developing its infrastructure, and system function also can influence the successful implementation of the CPFR. Big organization can afford to give time to such practices, due to high product mix and supply chain complexity. *Information readiness* and *senior management support*, along with commitment and *willingness to collaborate* emerges as among the few non technological enablers of CPFR, which can influence its' successful implementation.

Since this paper is based on the study of the manufacturing industry, other industry segments like service industry and the retail industry are not considered. Since all these sectors are very much different from each other, the requirement of these enablers would also be different. Hence, a blind generalization of the results is out of the box, considering feasibility. The levels of influence shown in this paper for the manufacturing sector may vary with other industry segments also. A comparative study in this area can bring more insights and can be considered as a direction for future work. Similarly, a study related to the supporting factors and the driving forces of CPFR, considering the Indian manufacturing environment is still lacking in the literature. This can be another possible direction for future work.

The study has several implications for managers and practitioners. *Firstly*, the study is motivated by the need of supply chain resilience for organizations in the present situations of COVID-19 crisis. Hence, the study argues the need of collaborative working practices for organizations to manage several vulnerabilities and for achieving resilience. Managers and practitioners can think on this direction to managing and mitigating from crisis situations. *Secondly*, the study familiarizes the use of CPFR as a tool for collaboration in supply chains and suggests firms with directions and observes several enablers for the successful implementation of CPFR. These enablers were categorized into four categories for the understanding of managers and the classification can help practitioners to observe each group separately for the successful implementation of CPFR. *Thirdly*, managers can identify the primary causal enablers and the primary effect enablers in each of the four categories, namely intra organizational technological enablers, intra organizational non technological enablers, inter organizational technological enablers, and inter organizational non technological enablers. This can help firms in understanding the primary causal and effect enablers in each of these categories, thereby implementing steps to manage the causal enablers, so as to have a successful implementation of CPFR for the firms or their supply chains.

Acknowledgements. The authors sincerely thank the editor in Chief, Prof. Ridha Mahjoub, and the unknown reviewers for their insightful comments to improve the quality of content to a greater extent.

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