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Modeling reconfigurability in supply chains using total interpretive structural modeling

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Abstract

Purpose – The purpose of this paper is to identify, analyze, and categorize the major enablers of reconfigurability that can facilitate structural changes within a supply chain in a global scenario. The paper also addresses five reconfigurability dimensions in the perspective of supply chains and the major enablers to attain them. The paper further aims to understand the mutual interactions among these enablers through the identification of hierarchical relationships among them.

Design/methodology/approach – A framework that holistically considers all the major enablers of reconfigurability has been developed. The hierarchical interrelationships between major enablers have been presented and interpreted using a novel qualitative modeling technique, i.e., total interpretive structural modeling (TISM), which is an extension of ISM. SPSS 22.0 is employed to carry out a one-tailed one-sample *t*-test further to test the hypotheses for validating the results of TISM. Impact matrix cross-reference multiplication applied to a classification (MICMAC) analysis has been employed to identify the driving and dependence powers of these reconfigurability enablers.

Findings – In this paper, 15 enablers for reconfigurability paradigm have been identified through literature review and expert opinions. The authors established interrelationships and interdependencies among these enablers and categorized them as enablers of each dimension. New product development and customer satisfaction come at the highest level of priority. The levels of these enablers were obtained using TISM. The authors compared the results with the clusters derived from MICMAC analysis, and the results are found to be well within the acceptable range.

Research limitations/implications – The study has implications for both practitioners and academia. The work provides a comprehensive list of enablers that are relevant to reconfigure supply chains in today's volatile global market. This research will also help decision makers to strategically focus on the top-level enablers and their concerned dimensions. The research is based on an automobile company case study and can be extended to products with volatile and changing demands.

Originality/value – The proposed model for reconfigurability enablers using TISM is a new effort altogether in the area of supply chain management. The novelty of this research lies in its identification of specific enablers to reconfigure a supply chain through different dimensions.

Keywords Reconfigurability, Supply chain network,
Impact matrix cross-reference multiplication applied to a classification (MICMAC) analysis, SPSS 22.0,
Total interpretive structural modeling (TISM)

Paper type Research paper

1. Introduction

In today's uncertain business environment, change is imperative, and a significant competitive advantage can be gained by incorporating reconfigurability into the design of supply chain network. This process would also enable companies to cope with change in demand and technology. Global companies are therefore considering relocation and new facility decisions for their production sites and to include new potential supplier worldwide (Hammami and Frein, 2014). Companies were forced to utilize supply chain reconfiguration decisions through relocation of facilities to countries with favorable economic policies. Many such situations were identified by researchers (Chandra and Grabis, 2007; Hammami *et al.*, 2008; Melo *et al.*, 2009). Factors that include expansion opportunities to new markets, off-shoring, mergers, acquisitions, and strategic alliances are the driving force for supply chain reconfigurability processes.

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Reconfigurable supply chains (RSC) will be beneficial if the supply chain undergoes strategic or operational changes in either planned or unplanned manner. Supply network entities in RSC are designed with the capability of being easily rearranged or modified (added/removed) timely and cost effectively (Kelepouris *et al.*, 2006). Rapid is the keyword of RSC and aims to achieve strategic and operational objectives with a quick adjustment of supply chain processes. These modifications include rapid response to changes in customer requirements, rapid outsourcing/in-sourcing activities, rapid addition or removal of supply network partners, and achieving a responsive manufacturing system (Kelepouris *et al.*, 2006). The concept allows rapid reconfiguration to combine creative product-driven supply chain and manufacturing, enabling new technologies and intelligent software agents.

Reconfigurability is the capability of a system to be designed, modeled, upgraded, and reconfigured for changing demand requirements. The RSC is a network of independent enterprises possessing the flexibility of altering their structures with relatively minor resource requirements and without losing out on operational efficiency in response to changing customer demands and operating environments (Chandra and Grabis, 2007). In today's scenario, retaining of supply chain structures over an extended period may result in a risk of losing competitiveness or internal collapse. Reinforcement with reconfigurability can be a viable solution that meets these requirements (Chandra and Grabis, 2007).

Kelepouris *et al.* (2006) has identified five dimensions which can play a vital role in the quick rearrangement of supply chain entities and will result in a supply chain that is "truly reconfigurable." These five dimensions are listed below:

(1) modularity;

(2) integrability;

(3) convertibility;

(4) diagnosability; and

(5) customization.

We discussed the definitions of these dimensions in detail in later sections. Kelepouris *et al.* (2006) also stated that with the dimensions described above, the strategic and operational objectives that can be achieved through rapid adjustment of supply chain processes are as follows:

- accommodate changing customer requirements rapidly;
- carry out activities related to outsourcing and in-sourcing rapidly;
- addition or removal of supply network partners rapidly; and
- achieving a manufacturing system that is responsive.

The RSC can be beneficial to all those supply chains which are subjected to any form of changes that can be both planned and unplanned (Kelepouris *et al.*, 2006). The necessary redesign decisions that remain the focus of the reconfigurability dimensions are as follows: relocation of manufacturing facilities from existing facilities to new installations and subsequent closing and the opening of facilities. Reconfigurability works with the assumption that the supply chain already exists and structural change is required to incorporate the adjustments. The supply chain redesign decisions being a part of reconfigurability are significantly affected by two factors: first, the structural aspects of the initial supply chain network entities along with their capacities, and second, the tentative cost that will be incurred in closing facilities and relocating capacities (Hammami and Frein, 2014).

Chandra and Grabis (2007) pointed out key benefits and difficulties of RSCs. The advantages are robustness, flexibility, and agility. The challenges to attain reconfigurability as stated by them are organizational problems in achieving new business processes, technological constraints, and trust. Achieving reconfigurability in supply chains requires sufficient time and most importantly needs a collective effort of all the network partners. The network should be redesigned to meet the benefits in stages which were decided strategically and previously prioritized (Kelepouris *et al.*, 2006).

Literature available on RSCs discusses only the definitions of reconfigurability dimensions. The reconfigurability enablers and their interrelationships are yet to be analyzed by researchers. Therefore, there is a need to identify the enablers/variables that influence reconfigurability dimensions in supply chains along with a graphical framework that can explain the interrelationships among these enablers.

1.1 Need for modeling supply chain reconfigurability

Chandra and Grabis (2007) stated that supply chains risk losing competitiveness or face internal collapse if they expect to work out a longer horizon with the original supply chain structure. Responding to changing customer demands and operating environments must be the aim of all supply chain configurations. Reconfigurability is one of the most viable ways to attain these requirements. Supply chain configuration decisions must incorporate an appropriate mechanism to cater reconfigurability. Wang *et al.* (2004) point out that product characteristics and product life cycles should be the driving force behind global supply chain design decisions.

Modeling of supply chain reconfigurability will enable top managers and researchers to understand the importance of each dimension and the enablers associated with them. The driving power and dependencies of these enablers would establish their position in the supply chain priority structure. This research will facilitate supply chain design decisions based on reconfigurability.

1.2 Objectives of research

In global enterprises, RSC is an emerging paradigm and needs to be studied to enable its long-term benefits as stated in the literature. Research about reconfigurability in supply chains is available at either the conceptual level or reviews. However, few studies address issues related to structural flexibility in supply chains. It is therefore attempted to holistically consider the dimensions and enablers of reconfigurability and develop a framework and explore the interrelationships between them.

This research is carried out with the primary objectives as summarized in the following points:

- to perform the identification of enablers and then define these enablers pertaining to each reconfigurability dimension using a standard procedure;
- to study the interaction among these enablers with the help of total interpretive structural modeling (TISM);
- to rank the enablers using impact matrix cross-reference multiplication applied to a classification (MICMAC) analysis and position them as per their driving and dependence powers toward the reconfigurability paradigm in supply chains; and
- to understand the interrelationships between the five dimensions on the basis of their major enablers.

2. Reconfigurability variables identification in supply chain

The research was carried out with an automobile company and its supply chain partners. These include a network that accommodates 652 dealers and 1,845 service centers. The service centers were strategically placed in 1,098 cities and towns. The company handles 16 joint ventures; most of them are production facilities with computer integrated systems. The management believes in the philosophy of reducing the supply chain cost and is committed to establishing an efficient supply chain. The dealers in downstream and suppliers in the upstream were connected through mailing systems and a centralized server. The production planning is executed after the real demand is received from the dealers. The dealers plan their market demand after comparing the forecasted data with the point of sale information and emanate the same upstream.

Reconfigurability variables in the supply chain are identified, and a mutual relationship is developed through brainstorming sessions. The TISM methodology is proposed for the research work. We discussed in details the TISM methodology in the later section. The work is divided into two parts: the first part deals with the identification of the variables followed by the second part that deals with modeling and developing the interrelationships among these variables. An initial meeting was planned with the management of the automobile company selected for research, and five experts in the area of supply chain management with more than ten years of experience were identified. They were provided with the literature pertaining to reconfigurability and were invited for a brainstorming session for the identification of the variables after 15 days. The brainstorming session was held, and a group of research scholars working in supply chain management also participated along with the five experts to establish the variables. The final number of variables selected after this session was 15, and few other variables were rejected in the process to avoid duplicity in the final list. The literature pertaining to these identified variables were then circulated among all the participants and given a timeframe of one week to reassemble to establish the interrelationships. These variables were categorized under the reconfigurability dimensions after a discussion with a team of research scholars. Later on, during the brainstorming session, the interrelationships were finalized in the meeting, and a reachability matrix is developed.

Supply chain reconfigurability variables were identified and were categorized under each dimension. These five dimensions along with the 15 variables were utilized to understand the reconfigurability preparedness in the researched supply chain. The variables are also termed as enablers by few authors as they enable the supply chains to attain the dimensions of the paradigm. The variables/enablers identified and categorized by the experts and research scholars are presented in Table I. These enablers and

Supply chain network reconfigurability Dimensions	Variables/Enablers		Abbrs.	Literature source
Modularity	E_1	Network structure design	NSD	Tang (2006) and Simchi-Levi and Muriel (2003)
	E_2	Responsiveness	RPN	Gunasekaran *et al.* (2008)
	E_3	Total cycle time	TCT	Tersine and Himmingbird (1995) and Agarwal *et al.* (2007)
Integrability	E_4	Real-time integration	RTI	Christopher (2005) and Agarwal *et al.* (2007)
	E_5	Collaboration	CBR	Agarwal and Shankar (2002a), Christopher and Jittner (2000) and Lee *et al.* (1997a, b)
	E_6	Transfer pricing	TRP	Perron *et al.* (2010), Shunko and Gavirneni (2007) and Lakhal (2006)
Convertibility	E_7	Adaptability	ADP	Sheffi and Rice (2005)
	E_8	Leagility	LGY	Naylor *et al.* (1999) and Agarwal *et al.* (2007)
	E_9	Trust	TST	Heide and John (1990) and Agarwal *et al.* (2007)
Diagnosability	E_{10}	Visibility	VBT	Barratt and Oke (2007)
	E_{11}	Data reliability	DRT	Lee *et al.* (1997b)
	E_{12}	Resilience	RES	Starr (2003), Robert (1997), Brian *et al.* (2009) and Smith (2004)
Customization	E_{13}	New product development	NPD	Jayaram *et al.* (1999)
	E_{14}	Customer satisfaction	CSF	Oliver (1980)
	E_{15}	Sustainability	SNB	Seuring and Müller (2008)

Table I. Final list of variables/enablers of reconfigurability dimensions are discussed in details in the following sections. We start with each dimension and discuss the enablers associated to attain them with suitable inputs from the literature reviewed.

2.1 Modularity

Modularity in supply chain reconfigurability relates to all levels of enterprises, and it refers to the degree to which all products, processes, and resource entities are modular (Kelepouris *et al.*, 2006).

2.1.1 Network structure design (NSD). NSD is one of the enablers selected for modularity. This enabler involves strategic decisions regarding the structural factors such as its number of echelons, nodes, and distribution links. These decisions have long-term impact as they are selected to last for several years. The design decisions must include sufficient options in case of demand changes, disruptions, and uncertainties. The network may be designed in modules to have structural flexibility in supply chains that will be less vulnerable to disruptions. Vulnerability toward disruption increases if the supply chain is complex (Tang, 2006). Network design in supply chains is the primary and the most important step for increasing the profit and decreasing the cost of the whole chain (Simchi-Levi and Muriel, 2003).

2.1.2 Responsiveness (RPN). Responsiveness in the view of the supply chain can be defined as "A network of firms that is capable of creating wealth for its stakeholders in a competitive environment by reacting quickly and cost-effectively to changing market requirements" (Gunasekaran *et al.*, 2008). Responsiveness can be attained with collaborative partners, information systems, and knowledge management. Responsiveness results in speed and flexibility in supply networks. With reduced production lead times, lesser setup costs, and small batch sizes so as to capture the market demands, responsiveness is attained. Responsiveness enabler is selected for modularity dimension as we can achieve quick changes with responsiveness.

2.1.3 Total cycle time (TCT). TCT is a managerial philosophy that aims to reduce the total time required to perform all the activities that occur in the entire supply chain. TCT reduction without compromising quality, cost, innovation, and productivity is an indicator of an efficient supply chain. Performance is enhanced automatically by reducing the waste time (Tersine and Himmingbird, 1995). The other hidden time components also play a major role in increasing the cost. In today's time-based competition in supply chains, delivery times are the ones that decide the customer satisfaction. The bottlenecks of the system must be attacked while making strategies to reduce lead times (Agarwal *et al.*, 2007).

2.2 Integrability

Integrability is the ability to integrate existing processes and resources within the supply network and also to establish a mechanism to integrate new processes and resources introduced in the supply chain (Kelepouris *et al.*, 2006).

2.2.1 Real-time integration (RTI). RTI is based on strategies focused on how operations in supply chains should be performed and on providing a collaborative environment, and last but not the least, it is dependent on real-time information. Collaborative technologies are based on a unified supply chain philosophy such as efficient consumer response (ECR), quick response (QR), and vendor managed inventory (VMI). They also include collaborative planning forecasting and replenishment and automated replenishment program, where the fundamental rule is exchange of real-time demand information (Christopher, 2005). Estimation of future market order is done to prevent stock out situation and reduce excessive inventory. In the "extended enterprise," there can be no boundaries, and an ethos of trust and commitment must prevail (Agarwal *et al.*, 2007).

2.2.2 Collaboration (CBR). Collaboration among supply chain members leads to improved efficiency and effectiveness to attain customer demands, grow markets, and increase competitive market share. Trust among trading partners is established by collaborative strategies, which results in sharing business information and working in a unified supply chain philosophy (Agarwal and Shankar, 2002a). Collaboration among supply chain partners can reduce the information imbalances that result in the dreaded "bullwhip effect" (Lee *et al.*, 1997b). Organizations, to progress beyond mere operational-level information exchange and optimization and make business partners more competitive, must promote collaborative strategies (Christopher and Jittner, 2000).

2.2.3 Transfer pricing (TRP). Transfer pricing as the enabler of integrability for attaining reconfigurability focuses on pricing strategies linked with exchanging intermediate and final products between subsidiaries of global firms. Transfer price is defined as the price a buying subsidiary has to pay to a selling subsidiary of the same company to obtain an intermediate or final product (Perron *et al.*, 2010). Transfer pricing is viewed as a powerful tool if subsidiaries are in different countries. Transfer pricing strategies can help increase the after-tax profit of the supply chain by shifting income to subsidiaries in lower tax countries (Shunko and Gavirneni, 2007). The reconfigurability involves redesign strategies, and transfer pricing can be strategically determined to move revenues from high-tax to low-tax countries and to maximize the global after-tax profit. Shunko *et al.* (2014), Shunko and Gavirneni (2007), and Lakhal (2006) explain the technical know-hows of transfer pricing with relevant examples.

2.3 Convertibility

Convertibility in reconfigurability refers to the ability of supply chain partner firms to adapt to future products from the existing ones quickly. Convertibility involves the flexibility of process and resource entities within each firm (Kelepouris *et al.*, 2006).

2.3.1 Adaptability (ADP). Adaptability in supply chains depends on visibility to understand changing needs for market demands and focuses on quick changeovers. Adaptability requires the implementation of an enterprise integration strategy that drives RTI across the supply chain partners. Adaptability is an enabler which promotes horizontal convertibility dimension and is structured along three distinct phases in the supply chain, which are a readiness, responsiveness, and recovery (Sheffi and Rice, 2005). The dynamic nature of adaptability allows the supply chain to recover after being disrupted, returning to its original state or achieving a more desirable state of supply chain operations.

2.3.2 Leagility (LGY). Leagility focuses on reducing wastages and increasing quick changeovers. The leagility is aimed to leverage synergies in both leanness and agility through their de-coupling via strategic use of stock in the product delivery process specifically in a manufacturing context (Agarwal *et al.*, 2007). Agility and leanness can be attained by structuring the entire supply chain strategy, particularly considering market knowledge via information enrichment and positioning of the de-coupling point. Combining agility and leanness in one SC via the strategic use of a de-coupling point has been termed "leagility" (Naylor *et al.*, 1999).

2.3.3 Trust (TST). Trust is defined as the binding force in most buyer-supplier transaction and is especially critical when two situational forces are present in a transaction: uncertainty and asymmetric product information. Convertibility is about quickly changing to new products and processes and involves buyer-supplier transactions. Trust among trading partners in inter-organizational relationships improves communication and dialogue and creates common strategic visions to cater changing market demands (Heide and John, 1990). Many researchers have proposed that trust is essential for understanding interpersonal behavior and economic exchanges (Agarwal *et al.*, 2007). Trust is also perceived as a state of readiness for unguarded interaction with someone or something (Ba, 2001).

2.4 Diagnosability

Diagnosability refers to the quick identification of problems and the sources of their origin that reduce supply network effectiveness and efficiency. Diagnosability initiates the process of structural redesign and helps restore the effectiveness and efficiency of the supply chain (Kelepouris *et al.*, 2006).

2.4.1 Visibility (VBT). Visibility is defined as keeping track of raw materials, intermediate parts, or final products in transit from the start (suppliers) to their final destination (customers) within a supply chain network. The shared information must be of high quality, accurate, timely, complete, and in a usable format to attain visibility in a supply chain network (Barratt and Oke, 2007). The aim of visibility is to achieve the prime goal of improving and strengthening the supply chain information network by making accurate and reliable data readily available to all stakeholders, including the end customer by collaboration and using IT tools. Supply chain visibility promotes QR to change by allowing users to take action and reshape demand or redirect supply.

2.4.2 Data reliability (DRT). Data reliability influences the performance of a supply chain and focuses on the fact that the data received or transmitted are complete and accurate. In a supply chain, most of the distributors do not have the actual point of sale demand data, and they make their inventory decisions based on market forecasts. With inaccurate forecasts, materials ordered do not match the demand and the distorted orders are passed to the upstream giving rise to the well-known "bullwhip effect." The data accuracy must be maintained along the supply chain so that the demand variability can be checked in supply chains reliably (Lee *et al.*, 1997b).

2.4.3 Resilience (RES). Resilience involves both the ability to withstand systematic discontinuities, as well as, the capability to adapt to new risk environments (Starr, 2003). Supply chain resilience aims to strengthen the ability of a system to return to a stable state after a disruption and thereby develop the adaptability to prepare for unexpected events and finally recover from them (Robert, 1997). Supply chain resilience focuses on the system's flexibility to deal with temporary disruptive events (Brian *et al.*, 2009; Smith, 2004).

2.5 Customization

Customization refers to the capability and flexibility of the supporting infrastructure for supply network to match the supply chain activities (Kelepouris *et al.*, 2006).

2.5.1 New product development (NPD). NPD is a vital functionality for supply chains to have a competitive superiority in the market. NPD has emerged as the winning strategy recently over quality, which was the model to follow regarding competitive strategy previously. Significant benefits, including greater market share and higher price premiums, consequently resulting in higher profitability, are the long-term benefits of NPD (Jayaram *et al.*, 1999). Companies in global market may face negative consequences such as lower market share and lower margins and may most critically face the loss of customers' goodwill by delaying the introduction of new products into the market.

2.5.2 Customer satisfaction (CSF). Customer satisfaction in supply chains is achieved when the customer's expectation regarding the product/service delivered from the concerned firm is met (Oliver, 1980). The positive reaction to the perception of the value received as a result of using a particular product or service is termed as customer satisfaction. This response is influenced by the desired value as well as by the perceived value of competitive offerings. Today, in the global supply chains, the strategies need to be focused toward satisfying customers as customers can be from any corner of the world.

2.5.3 Sustainability (SNB). Sustainability in supply chains is a holistic perspective of supply chain processes and technologies. It is based on the principle that socially responsible products and practices are not only good for the environment but are also critical for long-term profitability. Seuring and Müller (2008) define sustainable SCM as the management of material, information, and capital flows as well as cooperation among companies along the SC while taking goals from all three dimensions of sustainable development, namely, economic, environmental, and social, into account, which are derived from customer and stakeholder requirements. Collaborative strategies among internal and external supply chain partners should involve reexamining delivery methods, products, and packaging and measurement systems.

3. Methodology

The methodology adopted in the research is TISM as there is a need to establish the relationships logically among reconfigurability enablers using a standard qualitative modeling technique. TISM is a novel qualitative modeling technique which is an extension of the ISM (Yadav, 2014). An ISM works with contextual relationship, whereas TISM methodology uses the approach of interpretation on causal thinking. TISM can be used to establish relationships with their definitions from literature logically. This process helps answer "why" the relationship exists between the two elements. Structural models can be developed using TISM to identify the relationship between the variables of interest which assist in understanding the structure of the system better.

TISM has been applied in this research to develop a framework and achieve the few broad objectives for the case supply chain. The general objectives intended to achieve are as follows:

- to analyze and derive the interrelationships among supply chain reconfigurability enablers;
- to generate interpretive logic of pair-wise comparison; and
- to classify these enablers based on the driving and dependence power.

In this research work, our aim was to obtain correlation matrix pertaining to reconfigurability enablers in supply chains. This survey is carried out by sending 500 questionnaires to original equipment manufacturers (OEM) and their suppliers. The response rate of 23.80 percent is achieved with 119 (41 percent OEM and 59 percent suppliers) usable responses. These attained percentages of usable responses are considered adequate for such surveys (Malhotra and Grover, 1998). Cronbach's coefficient (α), meant to test the reliability and internal consistency of the responses is found to be 0.85. Experts' opinion along with correlation matrix is used together in defining the mutual relationships.

3.1 TISM methodology

TISM is used to develop the hierarchical relationship among the identified enablers. The TISM methodology is a nine-step process; the details of which are briefly presented below (Yadav, 2014). These steps and the activities performed in TISM are sequentially stated as follows.

Step I: identify and define elements. The elements for modeling in the study are reconfigurability enablers related to the RSCs and are identified through brainstorming sessions that were conducted with experts from the trading partners of the supply chain.

Step II: define contextual relationship. To develop the structure, it is imperative to determine the contextual relationship between the variables/factors of interest. Here, the contextual relationships identified between the reconfigurability enablers are "Enabler E_1 will influence or enhance Enabler E_2."

Step III: interpretation of relationship. This step gives TISM an edge over traditional ISM, as the former seeks an interpretation of the relationships. In the context of this study, the interpretation will be "In what way Enabler E_1 will influence or enhance Enabler E_2?" It will help in achieving in-depth knowledge explicitly.

Step IV: interpretive logic of pair-wise comparison. An "Interpretive Logic-Knowledge Base" is to be created for pair-wise comparison of the elements; the answer for each comparison may be yes (Y) or no (N). If the answer is Y, further interpretation is necessary. The (Y) rows of the interpretive logic-knowledge base are illustrated in Table AI. The total number of pair-wise comparisons is $15 \times 14/2 = 105$, and the total number of entries is $15 \times 14 = 210$ for the knowledge base of reconfigurability enabler. Only 53 entries were Y out of 105, and their pair-wise comparisons were illustrated in Table AI.

Step V: reachability matrix and transitivity check. The reachability matrix for the reconfigurability enablers is prepared with entries 1 for Y and 0 for N from the interpretive logic-knowledge base and shown in Table AII. The matrix is checked for the transitivity rule (if E_1-E_2 and E_2-E_3, then E_1-E_3). For each transitive link, the knowledge base is updated as Y, and in the interpretation column, "transitive" is entered. The final reachability matrix with transitive links is presented in Table AIII.

Step VI: level partition on reachability matrix. Level partitioning is carried out similar to the ISM methodology. This step provides levels to all the elements. The level partition matrices and level matrix are developed in six iterations. A comprehensive table showing levels of reconfigurability enablers in the supply chain is presented in Table AIV.

Step VII: developing digraph. The elements are portrayed in the form of a directed graph, where the elements are arranged according to the levels and relationships are portrayed from the reachability matrix. The digraph for the reconfigurability enablers is developed.

Step VIII: interaction matrix. A binary matrix is developed by translating the final digraph using "1" to indicate direct and significant transitive links. It is further developed as an interpretive matrix by providing the relevant interpretation from the knowledge base. The interaction matrices are in relation to the TISM for the reconfigurability enablers and are prepared to understand the interaction in details. The detailed interaction matrix is shown in Table AVII.

Step IX: total interpretive structural model. The connective information from the digraph and interpretations from the interaction matrix are used to develop the TISM. The nodes in the digraph are replaced by interpretations provided in the interaction matrix. The digraph previously developed is updated from TISM models after validating the 28 identified links by experts for reconfigurability enablers. The digraph is shown in Figure A1.

3.2 Development of the total interpretive structural model for reconfigurability enablers

To develop the TISM, the variables of interest were identified through brainstorming sessions conducted with experts from the trading partners of the case supply chain. The contextual relationship was identified between the reconfigurability enablers like "Enabler E_1 will influence or enhance Enabler E_2." The interpretive logic-knowledge base was developed. As there were 15 strategic enablers, the total number of rows in the knowledge base was 105. The 119 responses received out of 500 questionnaires were further used to develop the reachability matrix. For any pair-wise comparison, if 60 percent of the responses were Y, it was taken as Y otherwise as N. All the responses for Y were analyzed in terms of the interpretations given by the experts and a consolidated statement integrating all responses was developed. The total interpretive structural model was developed which is exhibited in Figure A1; the interpretation would make the model cumbersome, and thus the readers can refer the interpretive matrix (Table AVII) for interpretations. The working details used to develop TISM are elaborated in the Appendix. The hierarchical structure portrayed in Figure A1 shows the driving forces related to attainment of reconfigurability in supply chains. This TISM structure clearly depicts a hierarchy, where the lagging indicators of performance are at the top. It is very clear that to obtain competitive advantages and to cope with variability in markets, the case supply chain needs to develop strategies and action plans related to reconfigurability dimensions.

4. Validation of TISM

It is challenging for a researcher to collect responses from the top management of companies due to the paucity of time of managers (Yadav, 2014). TISM for reconfigurability enablers needed further validation, as it was developed from a survey of general questionnaires. Specific questionnaires and their responses were obtained from 25 other experts on the 28 identified links. It is suggested that multiple methods combining both qualitative and quantitative tools help in building accurate, generalizable, and practically useful theory (Shah and Corley, 2006). Following this, the TISM was further validated by validating the relationships identified by previous experts using quantitative methods. There were 28 links identified by the previous experts, which were further validated by obtaining responses from 25 other experts. In all, 25 responses were collected on a five-point scale ranging from "strongly agree" to "strongly disagree" in relation to the linkages and reason(s) given by previous experts. Research hypotheses for all these links were developed. The sample hypotheses are enumerated as follows:

H_O (i). There is no significant difference between the observed mean and the specified mean in relation to the opinion of the current experts.

H_A (i). There is a positive significant difference between the observed mean and the specified mean in relation to the opinion of the current experts:

$$\text{i.e. } H_0(i) : \text{mean(observed)–mean(specified)} = 0.$$

$$H_A(i) : \text{mean(observed)–mean(specified)} > 0.$$

here $i = 28$.

A one-tailed one-sample t-test was found to be appropriate to test these hypotheses as we are interested in finding out whether the mean is significantly higher than the test value. The "test value" was set as 3.5. SPSS 22.0 was used to run the t-test. On the basis of the sample statistics and t-values, the results of hypotheses testing are shown in Table AV. At the 5 percent significance level, all links, except four links E_1-E_{15}, E_3-E_{14}, E_9-E_{13}, and E_{12}-E_{13}, were accepted, as the null hypothesis could not be rejected for these four links. The rejected links are dropped from TISM, and the validated TISM developed is shown in Figure A1.

5. MICMAC analysis

In this study, the objective is to identify and analyze the variables according to their driving power and dependence power toward supply chain reconfigurability with the help of MICMAC analysis (Mandal and Deshmukh, 1994; Saxena *et al.*, 1990; Sharma, 1995). In the Table AVI, an entry of "1" along the columns indicates the dependence, and an entry of "1" along the rows indicates the driving power. The variables are categorized into ranks by adding each column or rows for dependence and driving power, respectively. As an example, enabler 1 (NSD) has the 6th rank in dependence and ninth in driving power, while enabler 2 (responsiveness) has the 11th rank in dependence and 4th rank in driving power. The ranks of the enablers on the basis of dependence and driving power are stated in Table II. The variables are plotted according to their driving and dependence power, and these variables are then grouped into four clusters. Four clusters are presented in Figure 1.

The autonomous variables in the first cluster include customer satisfaction, sustainability, data reliability, and resilience. These variables have few links which may be strong and are therefore called autonomous variables. They are relatively disconnected from the system as they have weak dependence and weak driver power. The dependent variables in the second cluster include NPD, transfer pricing, responsiveness, visibility, and TCT. They have strong

Table II.
Ranking of enablers on the basis of dependence and driving power

Sl. no.	Reconfigurability enablers	Abbrs.	Dependence	Driving power
1	Network structure design	NSD	6	9
2	Responsiveness	RPN	11	4
3	Total cycle time	TCT	8	6
4	Real-time integration	RTI	5	12
5	Collaboration	CBR	3	12
6	Transfer pricing	TRP	8	5
7	Adaptability	ADP	8	11
8	Leagility	LGY	5	11
9	Trust	TST	7	9
10	Visibility	VBT	11	6
11	Data reliability	DRT	5	6
12	Resilience	RES	7	7
13	New product development	NPD	8	2
14	Customer satisfaction	CSF	7	2
15	Sustainability	SNB	6	3

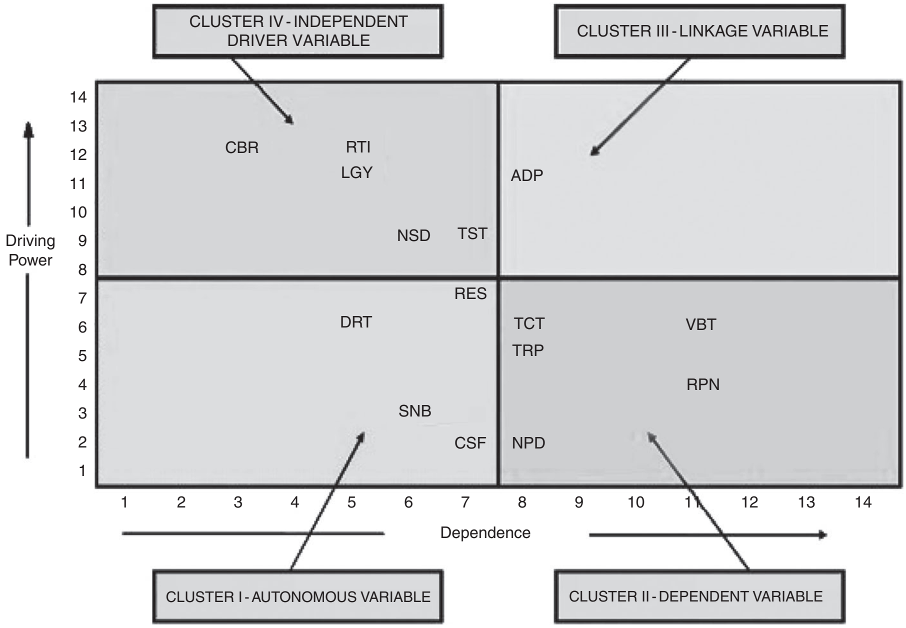

Figure 1.
Enablers in cluster of variables

dependence but weak driver power. The linkage variable in the third cluster is adaptability which has strong dependence and strong driver power but is unstable. These variables will affect other variables and will have an influence on other variables. The fourth cluster of independent driver variable includes collaboration, RTI, leagility, NSD, and trust. They have strong driver power but weak dependence. The research indicates that supply chain practitioners must concentrate on fourth and second clusters. The first and third cluster variables can be automatically attained if variables in the fourth and second clusters are strategically implemented. The detailed list of enablers and the clusters they are placed according to the dependence and driving power is shown in Table III.

Cluster I – autonomous variable		
E_{11}	Data reliability	DRT
E_{12}	Resilience	RES
E_{14}	Customer satisfaction	CSF
E_{15}	Sustainability	SNB
Cluster II – dependent variable		
E_2	Responsiveness	RPN
E_3	Total cycle time	TCT
E_6	Transfer pricing	TRP
E_{10}	Visibility	VBT
E_{13}	New product development	NPD
Cluster III – linkage variable		
E_7	Adaptability	ADP
Cluster IV – independent driver variable		
E_1	Network structure design	NSD
E_4	Real-time integration	RTI
E_5	Collaboration	CBR
E_8	Leagility	LGY
E_9	Trust	TST

Table III.
Reconfigurability enablers in clusters

An attempt is also made to group the dimensions of reconfigurability as per the ranks of enablers associated with them. The results show that diagnosability and customization are autonomous in nature; modularity is dependent in nature; integrability and convertibility are independent in nature, and there is no dimension fall in the cluster III as reconfigurability focuses toward stability. The MICMAC analysis is shown in Figure A2.

6. Discussion

TISM-based conceptual framework for supply chain reconfigurability is presented in Figure A1. The direction of relationship has been established on the basis of driving as well as dependence power of factors. MICMAC analysis uses the multiplication properties of matrices. The primary purpose of this analysis is to classify enablers into four clusters, namely, autonomous, dependent, linkage, and driving. NSD (enabler 1), RTI (enabler 4), collaboration (enabler 5), leagility (enabler 8), and trust (enabler 9) are at the bottom level in the TISM model and form the core building block of the case supply chain. These enablers have strong driver power and will play a significant role in establishing the first block of reconfigurability. The variables in the dependent variable cluster will be the second block in reconfigurability and include responsiveness (enabler 2), TCT (enabler 3), transfer pricing (enabler 6), visibility (enabler 10), and NPD (enabler 13). These variables have weak driving power but have strong dependence on other variables. They are dependent on the independent driver variables for their functioning. Supply chain reconfigurability is also influenced by autonomous variables such as sustainability (enabler 15), customer satisfaction (enabler 14), data reliability (enabler 11), and resilience (enabler 12), which are generally market driven and do not depend on either independent or dependent variables. The adaptability (enabler 7) variable in the third cluster is occasionally required and can be used as a linkage variable. Therefore, it is considered as an unstable variable. Adaptability needs particular attention as it may de-stabilize the supply chain if adequate planning is not done before initiating this capability.

The management of the case supply chain should focus on the bottom- and middle-level variables for performance improvement as indicated in the digraph. Improvement in bottom-level variables can only initiate the achievement of improved performance of other variables (Katayama and Bennett, 1999; Power *et al.*, 2001; Yusuf *et al.*, 2004). The process of improvement in performance should start from bottom level as per the digraph to enhance supply chain reconfigurability. Therefore, management of the case supply chain should focus its attention on building up a strong network of trading partners focusing on RTI, collaboration, leagility, and trust among partners. They should be driven by focused strategies toward customer satisfaction, NPD, and sustainability.

The reconfigurability dimensions are also categorized in clusters and will play a substantial role in understanding them technically. The reconfigurability in supply chains should be started with strategies pertaining to integrability dimension and convertibility dimension as they are categorized under independent variables with strong driver power. The enablers linked with them are the ones that should be on priority. The second dimension to be strategically implemented is modularity as it is the dependent variable. The last two dimension which needs particular attention as they have weak dependency and driver power are customization and convertibility.

7. Limitations and scope for future work

The study has implications for both practitioners and academia. The work provides a comprehensive list of enablers that are relevant to reconfigure supply chains in today's volatile global market. A panel of supply chain experts helped with their valuable inputs to analyze driving power and dependence of the variables of supply chains reconfigurability. The framework developed depends upon the opinion of a group of supply chain experts from automobile sector and may have some element of bias. This research will also help decision makers to strategically focus on the top-level enablers and their subsequent dimensions. The research is based on an automobile company case study and can be extended to products with volatile and changing demands. This work may be extended to different supply chains pertaining to food items and construction materials, and the result may be compared to understand the behavior of the same enablers on other chains.

8. Conclusions

The proposed model for reconfigurability enablers using TISM is a new effort altogether in the area of supply chain management. The novelty of this research lies in its identification of specific enablers, to reconfigure a supply chain through different dimensions.

The reconfigurability paradigm is driven by functionalities such as collaboration, RTI, trust, and leagility. The functionalities such as responsiveness, transfer pricing, visibility, and TCT are to be implemented as dependent variables. Customer satisfaction and sustainability are the variables that keep the process of reconfiguration active as autonomous variables.

In this paper, 15 enablers for reconfigurability paradigm have been identified through literature review and expert opinions. The interrelationships and interdependencies were established among these enablers and are categorized as enablers of each dimension. NPD and customer satisfaction come at the highest level of priority. The levels of these enablers were obtained using TISM. These results were compared with the clusters derived from MICMAC analysis and found to be well within the acceptable range.

The results also show that reconfigurability should be initiated with independent dimensions such as integrability and convertibility. Modularity being a dependent dimension should be implemented once the independent variables are established strategically. Autonomous dimensions such as diagnosability and customization can be used as inputs to reconfigure the chain. Reconfigurability in supply chains can only be attained and reattained if and only if a detailed implementation procedure is followed.

TISM is developed for reconfigurability paradigm, and the results obtained are quite generic and may be helpful for supply chain practitioners and entrepreneurs to establish a chain that never gets obsolete and can change with time. Reconfigurability in supply chains is just a philosophy as of now but can give profits if implemented with thorough and potential strategies.

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Appendix

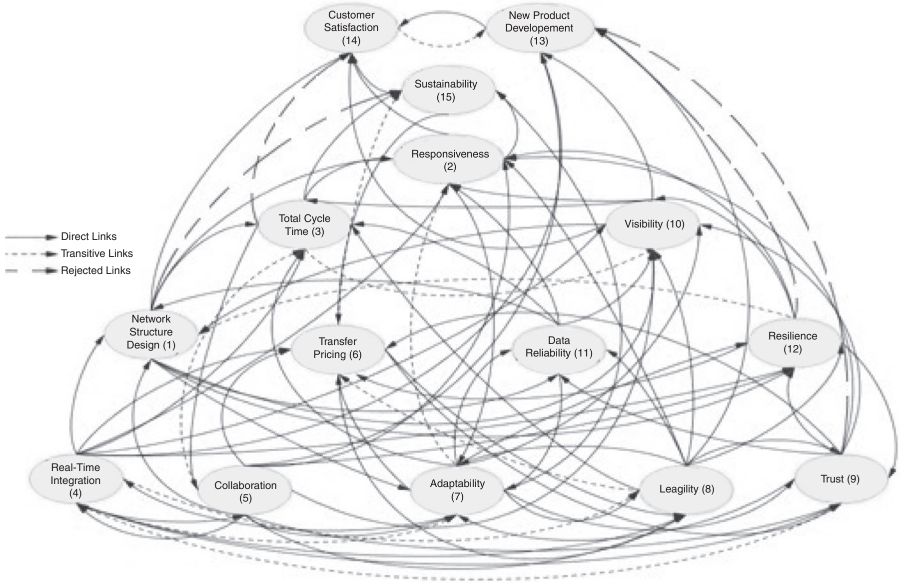

Figure A1.
Final digraph for the reconfigurability enablers

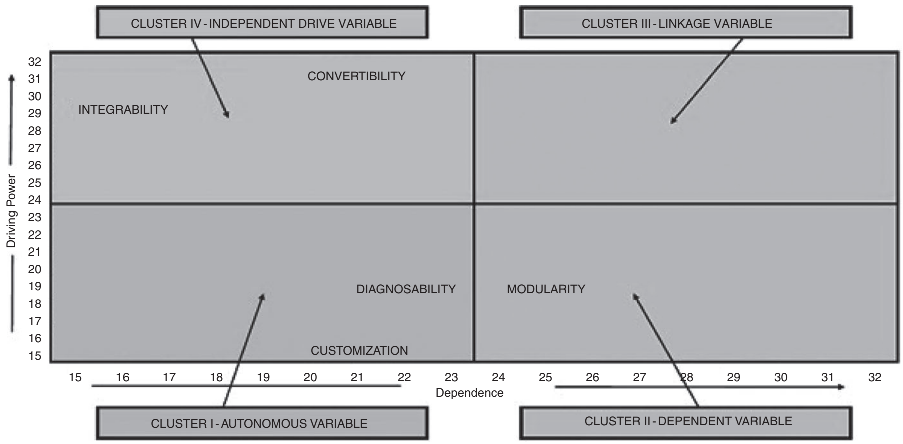

Figure A2.
Dimensions in cluster of variables

Table AI.
Sample of interpretive logic-knowledge base (without N)

Sl. no.	Enabler no.	Factors linked	Y/N	In what way an enabler will influence/enhance other enabler? Explain
1	E_1-E_2	Network structure design will influence or enhance responsiveness	Y	An appropriate network structure design will facilitate a faster or a proactive response
2	E_1-E_3	Network structure design will influence or enhance total cycle time	Y	One of the many objectives of network structure design is to attain a reduction of total cycle time
3	E_1-E_7	Network structure design will influence or enhance adaptability	Y	Strategically designed network structure will allow the adaptability
4	E_1-E_{10}	Network structure design will influence or enhance visibility	Y	Appropriate network structure design can help quick response and track the products in transit
5	E_1-E_{11}	Network structure design will influence or enhance data reliability	Y	Accuracy of designing structure can be attained if the data are reliable
6	E_1-E_{12}	Network structure design will influence or enhance resilience	Y	Adequate network structure can be designed depending on appropriate risk planning and improved resiliency
7	E_1-E_{14}	Network structure design will influence or enhance customer satisfaction	Y	Customers will be satisfied if his/her demand is fulfilled, with the network, which is purposefully designed to respond customer request
8	E_1-E_{15}	Network structure design will influence or enhance sustainability	Y	Network structure can be rightly designed by integrating environmentally sound choices
9	E_2-E_7	Responsiveness will influence or enhance adaptability	Y	Responsiveness being the ability to respond to demand changes will influence adaptability
10	E_2-E_{14}	Responsiveness will influence or enhance customer satisfaction	Y	Customers will be satisfied if his/her demand is fulfilled within an appropriate timeframe

Table AII.
Reachability matrix

Elements	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}
E_1	1	1	1	0	0	0	1	0	0	1	1	1	0	1	1
E_2	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
E_3	0	1	1	0	1	0	0	0	0	0	0	0	0	1	1
E_4	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0
E_5	1	1	0	1	1	1	1	1	1	1	0	1	1	0	0
E_6	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0
E_7	0	0	1	1	0	1	1	1	1	1	1	1	0	0	1
E_8	0	1	1	0	0	0	1	1	1	1	1	1	1	0	0
E_9	0	1	0	0	0	1	1	0	1	1	1	1	1	0	0
E_{10}	1	1	1	0	0	0	0	0	0	1	0	0	1	1	0
E_{11}	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0
E_{12}	0	1	0	0	0	1	0	0	1	1	0	1	1	0	0
E_{13}	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
E_{14}	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
E_{15}	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1

Elements	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}
E_1	1	1	1	0	0	0	1	0	0	1	1	1	0	1	1
E_2	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
E_3	0	1	1	0	1	0	0	0	0	1*	0	0	0	1	1
E_4	1	1	1	1	1	1	1*	1	1	1	0	1	1	0	0
E_5	1	1	1*	1	1	1	1	1	1	1	0	1	1	0	0
E_6	0	0	0	0	0	1	0	1	1	1	0	0	0	0	1*
E_7	0	1*	1	1	0	1	1	1	1	1	1	1	0	0	1
E_8	0	1	1	1*	0	1*	1	1	1	1	1	1	1	0	0
E_9	0	1	0	1*	0	1	1	0	1	1	1	1	1	0	0
E_{10}	1	1	1	0	0	0	0	0	0	1	0	0	1	1	0
E_{11}	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0
E_{12}	1*	1	0	0	0	1	0	0	1	1	0	1	1	0	0
E_{13}	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
E_{14}	0	0	0	0	0	0	0	0	0	0	0	0	1*	1	0
E_{15}	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1

Note: *Transitivity

Table AIII. Final reachability matrix

Element (E_i)	Reachability set: R (E_i)	Antecedent set: A (E_i)	Intersection: R (E_i) ∩ A (E_i)	Level
1	1, 2, 3, 7, 10, 11, 12, 14, 15	1, 4, 5, 10, 11, 12	1, 10, 11, 12	V
2	2, 7, 14, 15	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12	2, 7	III
3	2, 3, 5, 10, 14, 15	1, 3, 4, 5, 7, 8, 10, 11	3, 5, 10	IV
4	1, 2, 3, 4, 5, 7, 6, 8, 9, 10, 12, 13	4, 5, 7, 8, 9	4, 5, 7, 8, 9	VI
5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13	3, 4, 5	3, 4, 5	VI
6	6, 8, 9, 10, 15	4, 5, 6, 7, 8, 9, 12, 15	6, 8, 9	V
7	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 15	1, 2, 4, 5, 7, 8, 9, 11	2, 4, 7, 8, 9, 11	VI
8	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13	4, 5, 6, 7, 8	4, 6, 7, 8	VI
9	2, 4, 6, 7, 9, 10, 11, 12, 13	4, 5, 6, 7, 8, 9, 12	4, 6, 7, 9, 12	VI
10	1, 2, 3, 10, 13, 14	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 3, 10	IV
11	1, 2, 3, 7, 10, 11	1, 7, 8, 9, 11	1, 7, 11	V
12	1, 2, 6, 9, 10, 12, 13	1, 4, 5, 7, 8, 9, 12	1, 9, 12	V
13	13, 14	4, 5, 8, 9, 10, 12, 13, 14	13, 14	I
14	13, 14	1, 2, 3, 10, 13, 14, 15	13, 14	I
15	6, 14, 15	1, 2, 3, 6, 7, 15	6, 15	II

Table AIV. Levels of reconfigurability enablers in supply chain

Sl. no.	Enabler no.	Factors linked	Mean	SD	t-value	Sig (1-tailed)	Accept/ Reject
1	E_1-E_2	Network structure design will influence or enhance responsiveness	4.04	0.419	6.453	0.0000	Accept
2	E_1-E_3	Network structure design will influence or enhance total cycle time	4.37	0.366	11.832	0.0000	Accept
3	E_1-E_{11}	Network structure design will influence or enhance data reliability	3.82	0.459	3.527	0.0017	Accept
4	E_1-E_{14}	Network structure design will influence or enhance customer satisfaction	4.19	0.597	5.741	0.0000	Accept
5	E_1-E_{15}	Network structure design will influence or enhance sustainability	3.53	0.396	0.399	0.6932	Reject
6	E_2-E_{15}	Responsiveness will influence or enhance sustainability	4.40	0.274	16.517	0.0000	Accept
7	E_3-E_{10}	Total cycle time will influence or enhance visibility	4.25	0.521	7.203	0.0000	Accept
8	E_3-E_{14}	Total cycle time will influence or enhance customer satisfaction	3.50	0.440	−0.041	0.9677	Reject
9	E_4-E_6	Real-time integration will influence or enhance transfer pricing	4.20	0.502	6.949	0.0000	Accept
10	E_4-E_8	Real-time integration will influence or enhance leagility	4.22	0.395	9.101	0.0000	Accept
11	E_4-E_{10}	Real-time integration will influence or enhance visibility	4.17	0.498	6.755	0.0000	Accept
12	E_4-E_{12}	Real-time integration will influence or enhance resilience	4.14	0.533	5.972	0.0000	Accept
13	E_5-E_6	Collaboration will influence or enhance transfer pricing	4.26	0.417	9.129	0.0000	Accept
14	E_5-E_8	Collaboration will influence or enhance leagility	4.02	0.601	4.286	0.0003	Accept
15	E_5-E_{10}	Collaboration will influence or enhance visibility	4.19	0.472	7.317	0.0000	Accept
16	E_5-E_{13}	Collaboration will influence or enhance new product development	4.10	0.545	5.486	0.0000	Accept
17	E_7-E_8	Adaptability will influence or enhance leagility	3.97	0.517	4.559	0.0001	Accept
18	E_7-E_{10}	Adaptability will influence or enhance visibility	4.08	0.467	6.169	0.0000	Accept
19	E_7-E_{11}	Adaptability will influence or enhance data reliability	3.93	0.589	3.650	0.0013	Accept
20	E_7-E_{12}	Adaptability will influence or enhance resilience	4.07	0.546	5.244	0.0000	Accept
21	E_8-E_9	Leagility will influence or enhance trust	4.04	0.534	5.075	0.0000	Accept
22	E_8-E_{11}	Leagility will influence or enhance data reliability	3.94	0.482	4.578	0.0001	Accept
23	E_8-E_{12}	Leagility will influence or enhance resilience	3.99	0.525	4.688	0.0001	Accept
24	E_8-E_{13}	Leagility will influence or enhance new product development	3.91	0.510	3.988	0.0005	Accept
25	E_9-E_{13}	Trust will influence or enhance new product development	3.79	0.639	2.298	0.0306	Reject
26	E_{10}-E_{14}	Visibility will influence or enhance customer satisfaction	3.98	0.543	4.379	0.0002	Accept
27	E_{12}-E_{13}	Resilience will influence or enhance new product development	3.75	0.579	2.159	0.0411	Reject
28	E_{13}-E_{14}	New product development will influence or enhance customer satisfaction	3.90	0.636	3.112	0.0048	Accept

Note: Accept, if significance value < 0.025 (one-tailed)

Table AV.
Results of hypothesis testing

Table AVI. Driving and dependence power in reachability matrix

Sl. no.	Enablers	Abbrs.	Elements	E_{13}	E_{14}	E_{15}	E_2	E_3	E_{10}	E_1	E_6	E_{11}	E_{12}	E_4	E_5	E_7	E_8	E_9	Driver	Rank
1	New product development	NPD	E_{13}	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	IX
2	Customer satisfaction	CSF	E_{14}	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	IX
3	Sustainability	SNB	E_{15}	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	3	VIII
4	Responsiveness	RPN	E_2	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	4	VII
5	Total cycle Time	TCT	E_3	0	1	1	1	1	1	0	0	0	0	0	1	0	0	0	6	V
6	Visibility	VBT	E_{10}	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	6	V
7	Network structure design	NSD	E_1	0	1	1	1	1	1	1	0	1	1	0	0	1	0	0	9	III
8	Transfer pricing	TRP	E_6	0	0	1	0	0	1	0	1	0	0	0	0	0	1	1	5	VI
9	Data reliability	DRT	E_{11}	0	0	0	1	1	1	1	0	1	0	0	0	1	0	0	6	V
10	Resilience	RES	E_{12}	1	0	0	1	0	1	1	1	0	1	0	0	0	0	1	7	IV
11	Real-time integration	RTI	E_4	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	12	I
12	Collaboration	CBR	E_5	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	12	I
13	Adaptability	ADP	E_7	0	0	1	1	1	1	0	1	1	1	1	0	1	1	1	11	II
14	Leagility	LGY	E_8	1	0	0	1	1	1	0	1	1	1	1	0	1	1	1	11	II
15	Trust	TST	E_9	1	0	0	1	0	1	0	1	1	1	1	0	1	0	1	9	III
		Dependence		8	7	6	11	8	11	6	8	5	7	5	3	8	5	7		
		Ranks		II	III	IV	I	II	I	IV	II	V	III	V	VI	II	V	III		

Table AVII.
Interaction matrix (interpretive matrix)

		Network structure design	Responsiveness	Total cycle time	Real-time integration	Collaboration	Transfer pricing	Adaptability	Leagility
		E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8
Network structure design	E_1	–	An appropriate network structure design will facilitate a faster or a proactive response	One of the many objectives of network structure design is to attain a reduction in total cycle time				Strategically designed network structure will allow adaptability	
Responsiveness	E_2		–					Responsiveness being the ability to respond to demand changes will influence adaptability	
Total cycle time	E_3		Proactive response is possible with reduced total cycle time in the supply chain	–		Total cycle time can be reduced with proper collaboration			
Real-time integration	E_4	Real-time integration should be kept in mind while designing the network structure	Real-time integration can enhance fast response	Real-time integration will reduce the cycle time considerably	–	Real-time data and process integration can be achieved by collaboration	Real-time integration will help relocate facilities with profitable transfer pricing	*Real-time integration is required in case of implementing adaptability*	Leagility is possible in supply chain if the integration is on real-time basis

(*continued*)

Collaboration	E_5	Collaboration is a feature that needs to be incorporated while designing the network structure	Collaboration can help attain fast response	*Proper collaboration strategies will reduce the total cycle time*	Without collaboration, real-time integration cannot be achieved	–	Profitable transfer pricing is a vital feature that can be utilized with collaboration	Collaborative planning is a step toward adaptability	Leagility is dependent on collaboration
Transfer pricing	E_6						–		Transfer pricing with profitability can be strategically used in leagility.
Adaptability	E_7		*Adaptability is bound to enhance responsiveness as changing market needs can be understood*	Adaptability feature is generally used to reduce the total cycle time	Adaptability is achieved with real-time integration		Lower transfer prices will enhance companies to adapt to other business changes	–	Leagility can be achieved if and only if the chain has adaptability
Leagility	E_8		Leagility enhances responsiveness with lower cost and higher flexibility	Leagility aims at reducing total cycle time	*Leagility is partially agility and uses real-time integration feature*		*Leagility will help to utilize the benefits from lower transfer prices and easily shift to newer locations*	Leagility will help supply chains adapt to change in demand faster and with minimum cost	–
Trust	E_9		Trust is very important among partners		*Trust among partners will help attain real-time integration*		Trust is very important to utilize the benefits of transfer	Trust can help supply chain adapt easily to	

(*continued*)

Table AVII.

Table AVII.

			to attain responsiveness				prices in other countries	changing scenarios
Visibility	E_{10}	Without visibility, network design is impossible task	Visibility will enhance responsiveness by understanding the real demand	Visibility will reduce the total cycle time by removing the unwanted processes				
Data Reliability	E_{11}	Data reliability is very important while designing the network structure	Data reliability can improve the response of the chain	Data reliability can reduce the total cycle time by reducing the bullwhip effect				Easy adaptability can be achieved using current and complete data
Resilience	E_{12}	*Resilience must be incorporated while designing the structure to cater to any type of risk*	Higher levels of responsiveness is attained with a resiliency in the chain				Benefits from lower transfer pricing should be used to increase resilience	
New product development	E_{13}							
Customer satisfaction	E_{14}							
Sustainability	E_{15}						Sustainability issues can be taken up using the benefits from lower transfer prices	
		Trust	Visibility	Data reliability	Resilience	New product development	Customer satisfaction	Sustainability

(*continued*)

		E_9	E_{10}	E_{11}	E_{12}	E_{13}	E_{14}	E_{15}
Network structure design	E_1		Appropriate Network structure design can help quick response and track the products in transit.	Accuracy of designing structure can be attained if the data are reliable	Adequate network structure can be designed depending on appropriate risk planning and improved resiliency		Customers will be satisfied if his/her demand is fulfilled, with the network that is purposefully designed to respond to customer request	Network structure can be rightly designed by integrating environmentally sound choices
Responsiveness	E_2						Customers will be satisfied if his/her demand is fulfilled within an appropriate timeframe	Responsiveness will reduce the cost and can initiate financially sustainable operations
Total cycle time	E_3		*Timely and accurate information can reduce total cycle time*				Customers satisfaction in the supply chain is very much dependent upon reduced total cycle time. Lesser the lead times, the more the customer satisfaction.	Reduction of total cycle time will initiate sustainability
Real-time integration	E_4	Trust is an important feature for real-time integration	Real-time integration will increase the visibility of the market demand		Real-time data integration will help mitigate risk and thus enhance resilience	New product can be developed if the running cost can be reduced by integrating the processes		
Collaboration	E_5	Without trust, no collaboration	With collaboration, the actual market		Disruptions and risks can be predicted using	With collaboration, new product development can be initiated		

(*continued*)

Table AVII.

Table AVII.

		can be achieved	demands can be visible		collaboration strategies			
Transfer pricing	E_6	Transfer pricing with profitability can increase trust	Transfer pricing with profitability can increase market and also visibility					*Transfer pricing with profitability can help supply chains to shift for environmentally sustainable products*
Adaptability	E_7	Without trust, no adaptability can be attained	With right visibility, adaptability will be easy	Reliable data are required to execute the adaptability feature	Adaptability feature is meant to cater to risks, thus enhance resilience			Adaptability being a feature to adjust to longer term changes will initiate sustainability
Leagility	E_8	Leanness and agility requires trust and will also influence it.	Leagility requires visibility for its implementation.	Without reliable data, leagility cannot be executed.	Leagility is to make sure that the supply chain is Resilient.	Leanness and agility requires will definitely initiate new product development.		
Trust	E_9	–	Trust will help partners to integrate and thus understand the actual position of the market and the product	Reliable data can be gathered by the basic factor of trust.	Trust among partners will reduce uncertainty in chains and will enhance resilience	The state of readiness for unguarded interaction between partners will promote responding to demand of new products in the market.		
Visibility	E_{10}		–			The visibility of real demand will enhance the new	The visibility of real demand will lead to customer satisfaction	

(*continued*)

Table AVII.

						product development		
Data reliability	E_{11}		Data reliability is the input source of visibility	–				
Resilience	E_{12}	Resilience needs a high amount of trust among partners	Resilience is dependent on higher visibility		–	Without the fear of risk, new products can be developed		
New product development	E_{13}					–	New product development will keep the customer satisfied and bring goodwill	
Customer satisfaction	E_{14}					*Customer satisfaction will achieved with customer input-based new product development*	–	
Sustainability	E_{15}						Sustainability with environmentally sound chains will bring high level of customer satisfaction	–

Note: Italics, significant transitive link