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Integration of Six Sigma and ISM to improve Supply Chain Coordination – A conceptual framework

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Abstract: To achieve competitiveness and to improve supply chain performance, supply chain coordination (SCC) is considered as a key challenge by the companies to satisfy their customers. In today's turbulent economic environment, SCC is a topic of great significance among business houses because SCC creates understanding, molds human behavior and improve competitiveness. As observed from literature that the dynamics of global market has resulted in serious pressure and distraction to activities of various supply chain entities i.e. suppliers, manufacturer, distributors, wholesaler, retailers and customers, which ultimately affects the SC performance. Thus, supply chains are exposed to risks due to uncertain and turbulent economic environment. To overcome these challenges, authors in this study developed a conceptual framework based on Six Sigma and ISM which can be used to study various supply chain dimensions be it human, process or quality dimensions. The main advantage of this framework is that it not only helps to understand information regarding the strength and weaknesses of various supply chain entities in a supply chain but also helps to determine the structural relationship among key dimensions of interest. The proposed framework can be applied by industries to model and analyze their processes effectively, compare their performance both within and outside their industry segment and thus improve competitiveness by following various supply chain management practices.

Key words: Globalization, Supply chain, Six Sigma, ISM.

1. Introduction

In today's turbulent environment supply chain coordination (SCC) is a topic of much significance in organizations because SCC creates understanding, molds behavior and improve competitiveness. Intensive competition in the market place has enforced companies to focus on process performance and coordination between the supply chain network for the customer value of products and services in recent times. To create a customer value in the market, companies has to concentrate on supply chains coordination. In the modern global manufacturing environment, change has become a constant phenomenon. Changes occur due to fluctuation in technology, environmental requirements, regulatory policies, social needs and the economy is the most important things. Since, today's world competition is no longer between individual organizations but between the supply chains. Supply chain includes all the activities related to the processing of materials and the conversion of goods from the stage of raw materials to the stage of delivery to final customer, as well as the informational and financial processes related to them, along with coordinated and integrated management (Shafia *et al.*, 2008; Harrison and van Hoek, 2008). In other words, supply chain defines as, the network of entities through which material flows. Those entities include suppliers, manufacturers, wholesaler, retailers and customers (Lummus and Alber, 1997). Different entities in a supply chain function subject to different sets of constraints and objectives. However, these entities are highly interdependent when it comes to improving performance of the supply chain in terms of objectives such as on-time delivery, quality assurance, and cost minimization. As a result, performance of any entity in a supply chain depends on the performance of others, and their willingness and ability to coordinate activities within the supply chain.

A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also warehouses, distributors, wholesaler, retailers and customers themselves (Chopra and Meindl, 2007). To improve the overall performance of supply chain, the members of supply chain may act as a part of an integrated system and coordinate with each other. Supply chain members cannot compete as independent members. The product used by the end customer passes all the way through a number of entities contributed in the value addition of the product before its consumption. Thus coordination comes into focus.

1.1. Supply chain coordination

According to Lau *et al.*, (2004) and Hervani *et al.*, (2005), supply chain is coordination of independent enterprises in order to improve the performance of the whole supply chain by considering their individual needs. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. Supply chain coordination is a strategic response to the challenges that arise from the dependencies supply chain members (Xu and Beamon, 2006). According to Arshinder (2008), supply chain coordination can be defined as identifying interdependent supply chain activities between supply chain members and devise mechanisms for manage those interdependencies. It is the measure of extent of implementation of such aggregated coordination mechanism, which helps in improving the performance of supply chain in the best interest of participating members.

Lee (2000) proposed supply chain coordination as a vehicle to redesign decision rights, work flow, and resources between chain members to influence better performance such as higher profit margins, improved customer service performance, and faster response time. Simatupang *et al.*, (2002) classified the coordination effort in supply chain into four categories i.e. logistics coordination, information sharing, incentive alignment and collective learning which needs to be further investigated particularly with respect to human dimensions such as information sharing and collective learning. Kim and Oh (2005) presented systems dynamics approach to coordinate supplier and manufacturer decisions regarding improvement in quality and the new product development. According to Cao *et al.*, (2008), supply chain coordination includes every effort of information exchange and integration during the courses of developing, producing and delivering a product or services to end market places. Singh (2011) developed a framework for improving the coordination in supply chain and stressed that coordination cannot be achieved by focusing on only one or two factors of the supply chain. There are many other factors involved in achieving coordination such as human, technology, strategies, relationship, rewards, profits, and risk.

Most of the literatures focus on coordination issues in supply chain from an operational or tactics sense. How to integrate the mechanism and methods of coordination from a comprehensive or holistic sense have been rarely discussed. The static operation reference based on best practice cannot support the new intra and inter-enterprise collaboration. It is necessary to develop a systematic methodology to help enterprise to develop their requirement, to analyze the target system, to structure the coordination system and to monitor its operational performance. In this paper, authors have tried to develop a conceptual model based on Six Sigma and ISM to improve the coordination between the dimensions so as to have better understanding to inter- organizational coordination within a holistic supply chain network from the view of an industry in turbulent environment. Paper is organized as follows: A brief introduction of paper presented in section 1, Section 2 presents a Six Sigma approach. Section 3 presents the ISM approach. In the section 4 benefits of Six Sigma and ISM are presented. Research methodology is presented in section 5. Integrated framework of Six Sigma and ISM for improving SCC performance is presented in section 6. Finally conclusions are presented in section 7.

2. Six Sigma

Six Sigma is a well- structured knowledge management methodology that focuses on reducing variation, measuring defects, and improving the quality of products, processes and services. Six Sigma is a statistical quality goal that equals no more than 3.4 defects per million opportunities. Six Sigma is also a business improvement program that targets process variation. Six- Sigma is not only for manufacturing, but any process where an opportunity exists for error. Six Sigma projects are based on a problem solving methodology called DMAIC (Define, Measure, Analyze, Improve, and Control).

Motorola created the Six Sigma methodology in 1986, in order to increase its competitiveness against Japanese companies in the electronics industry by improving quality levels. The name of the Six

Sigma methodology is derived from the Greek alphabet symbol utilized in statistics for standard deviation, a measurement to quantify variation and process inconsistency (Pande *et al.*, 2000). The DMAIC is the classic Six Sigma problem solving process. DMAIC resolve issues of defects or failure, deviation from a target, excess cost or time, and deterioration. Six Sigma reduces variation within and across the value-adding steps in a process. DMAIC identifies key requirements, deliverables, task, and standard tools for a project team to utilize when tackling problem. For solving any problem in the Six Sigma methodology is done by formulating a team of people associated with the process. The Six Sigma organizational structure includes such as Leadership is provided by a team of champions: senior champion, deployment champion and projects champion at corporate, unit and department level, respectively, supported by a team of experts. The experts are referred as Master Black Belts (who provides mentoring, training and expert support to the Black belts.

Table 1. Literature related to ISM.

S. No.	Use of ISM in literature	Authors
1	Knowledge management in engineering industry	Singh *et al.*, (2003)
2	ISM for the barriers in IT enablement of supply chain	Jharkharia and Shankar (2005)
3	ISM for improving competitiveness of SMEs	Singh *et al.*, (2007)
4	Enablers of Six Sigma	Soti *et al.*, (2010)
5	ISM methodology for TQM practices	Talib *et al.*, (2011)
6	Developing the framework for coordination in SC of SMEs	Singh (2011)
7	Framework for vendor managed inventory adoption in Indian industries	Borade and Bansood (2012)

Black Belts who usually work full time on projects at process level to solve critical problems and achieve bottom- line results and Green belts are the employees who take up Six Sigma implementation along with their job responsibilities, operating under the guidance of Black Belts. Yellow belts employees that have basic training in Six Sigma tools.

Several studies have investigated how Six Sigma methodology can effectively be employed in SCM to measure, monitor and improve the performance of the whole supply chain network. Dasgupta (2003) make out the application of Six Sigma metrics as a complete and flexible framework for evaluating and benchmarking the performance of supply chain and its entities beside world class standards. Wang *et al.*, (2004) investigated how quality management can be employed in SCM to improve the performance of various issues in the whole supply chain network using Six Sigma methodology. Knowles *et al.*, (2005) concluded that Six Sigma does have something novel to offer organizations over the contribution of existing approaches to supply chain improvement. They proposed a conceptual model that integrates the Balanced Scorecard, SCOR model (Supply Chain Reference model) and Six Sigma DMAIC methodology in a strategic and operational level cycle. Liu (2006) presented an application of Six Sigma to reduce cycle time and defects in clinical report entry. Yousef *et al.*, (2008) stated the importance of introducing the concept of Six Sigma as an effective methodology for monitoring and controlling supply chain variables. Nabhani and Shokri (2009) presented a case study to reduce the delivery lead time in food distribution with the implementation of DMAIC procedures based on the Six Sigma methodology. Chang *et al.* (2012) applied the Six Sigma (DMAIC) to manage and improve the performance of the production planning procedures. Wei and Yi-zhong (2013) proposed a framework using Six Sigma metrics which is comprehensive, flexible and easy to measure and improve supply chain performance.

3. ISM Methodology

ISM was first proposed by Warfield (1974). It is an interactive learning qualitative tool in which a set of different and directly related elements are structured into a comprehensive systematic model (Warfield, 1974 and Sage, 1977). It helps to improve orders and direction to the complexity of relationship among various element of the system (Sage, 1977). The ISM process transform unclear, poorly articulated mental models of system into visible and well defined models useful for many purposes (Ahuja *et al.,* 2009). According to the Sharma *et al.* (2011), it is a method for developing the hierarchy of system enablers to represent the system structure. Thus it is a models technique as the specific relationship and orders structure are portrayed in a graphical model (Singh and Kant, 2008, Borade and Bansod, 2012).

Hence, ISM is a powerful technique, which can be applied in various fields. The application of ISM has been applied by many researchers in various literatures. Mandal and Deshmukh (1994) used the

ISM methodology to analyze some of the important vendor selection criteria and have shown the interrelationship between criteria and their levels. Singh *et al.* (2003) applied ISM for knowledge management in Indian industry. Singh *et al.* (2007) applied ISM for improving competitiveness of SMEs. Soti *et al.* (2010) used the ISM to study the enablers of six-sigma and to establish the relationship among them. Talib *et al.* (2011) utilize the ISM methodology to understand the mutual relationship among the TQM practices and presented a hierarchy-based model of the practices. Singh (2011) employed ISM approach to develop the structural relationship among different factors of coordination and responsiveness in supply chain to take strategic decision. Borade and Bansod (2012) applied ISM based framework for vendor managed inventory adoption in Indian industry. Few of the literature related to ISM are shown in Table 1.

The various steps involved in the ISM technique are shown in Figure 1:

Step 1: Literature review of SCM dimensions

Step 2: Identification of dimensions

Step 3: Prioritization of dimensions on the basis of six-sigma value

Step 4: Establish contextual relationship between dimensions

Step 5: Develop a structural self-interaction matrix

Step 6: Develop a Reachability matrix

Step 7: Partition the Reachability matrix into different levels

Step 8: Prepare the ISM

Step 9: Calculate driver and driven power of dimensions

Step 10: MICMAC analysis

Figure 1. Flow diagram for research methodology of ISM.

4. Benefits of Six Sigma

Six Sigma benefits are related to various areas such as reduction in process variability, reduction in in-process defect levels, reduction in maintenance inspection time, improving capacity cycle time, improving inventory on time delivery, increasing savings in capital expenditures, increase in profitability, reduction of operational costs, reduction in the cost of poor quality, increase in productivity, reduction cycle time, reduction of customer complaints, improved sales and reduce inspection (Antony *et al.*, 2005, 2007, Knowles *et al.* 2005). It is also a customer and data driven problem solving methodology and provide training and development to the organizations widely.

Although Six Sigma has been established highly successful in many industries and functional applications, one of the critical weaknesses of Six Sigma is the lack of a fundamental methodology for leveraging strategic and operational opportunities to drive the selection and execution of high priority projects. The Six Sigma approach also relies upon the existence of fundamental process capabilities and some levels of organizational maturity around the process. Six Sigma focuses on reducing the variability in order to improve the process, but it does not believe an early possibility to replenish them. Six Sigma is data dependent tools and techniques difficult to use in situations where data is not available or readily collected. So, if we come across at the strength and weakness of each of these methodologies it is apparent that they need each other. The strong fact-based, data-driven problem solving approaches that Six Sigma has helps to discover root causes. So it needs to develop integrated framework in turbulent environment to improve the supply chain performance and satisfy the customers.

5. Research Methodology

In this paper authors has considered two methodologies from a management point of you, by investigating snag and opportunity. The approach to enable this study has been a qualitative one. The secondary data ranging from 2000 to 2014 has been studied to work upon the gaps and subsequently to identify the dimensions. On the basis of the identified dimensions, a conceptual framework has been proposed based on Six Sigma and ISM by considering various supply chain dimensions i.e. human, process and output dimensions such as quality, cost etc. The section presents summary of some significant studies with reference to supply chain coordination. The various supply chain coordination issues ranging from administrative to technical i.e. management commitment, supplier selection, information processing, information technology, order fulfillment, EDI, VMI etc. which help in coordination among various supply chain entities and improve supply chain performance as shown in Table 2.

Table 2. Dimensions of supply chain coordination.

			Dimensions																					Methodology			
No.	Authors	Year	Managerial support	Coordination	Information technology	Supplier selection	Distribution system	Information sharing	Leadership	Order fulfillment	Customer satisfaction	Feedback and Reward	Vendor management inventory	Training and Education	Communication & Cooperation	Forecasting	Quality management/improvement	Lead time	Self-management	Innovation performance	Team flexibility	Employee participation	Process improvement orientation	Literature review	Conceptual model / framework	Case study	Empirical analysis
1	Kanji and Wallace	2000	√								√				√		√				√	√	√				√
2	Brah *et al.*	2000	√						√		√	√		√			√					√	√	√			
3	Romano and Vinelli	2001					√								√		√	√					√			√	
4	Tracy *et al.*	2001												√					√								√
5	Chen and Paulraj	2004	√		√	√	√		√		√				√						√		√				√
6	Lin *et al.*	2005	√			√					√			√								√	√		√		√
7	Sila and Ebrahimpour	2005	√			√			√		√	√		√	√		√			√	√	√	√	√			
8	Robinson and Malhotra	2005	√		√	√			√						√		√			√			√	√			
9	Burgess *et al.*	2006			√			√	√						√								√	√			
10	Li *et al.*	2006						√									√			√					√		√
11	Li and Lin	2006	√	√	√	√				√	√							√									√
12	Samat *et al.*	2006	√					√						√	√							√	√				√
13	Hsu *et al.*	2007			√			√											√						√		√
14	Koh *et al.*	2007						√						√													√
15	Ooi *et al.*	2007	√							√				√	√		√		√			√					√
16	Yousuf *et al.*	2007							√		√	√		√	√	√	√					√					√
17	Arshinder & Deshmukh	2008		√	√		√	√																√			
18	Kaynak and Hartley	2008	√		√	√					√			√			√					√	√		√		√
19	Tews and Tracey	2008										√		√					√								√
20	Chang	2009				√			√		√						√		√			√	√	√			
21	Sit *et al.*	2009	√						√		√	√					√						√				√
22	Khang *et al.*	2010			√			√	√					√													√
23	Li *et al.*	2010			√													√	√		√						√
24	Wu and Weng	2010				√				√							√								√		√
25	Srikantha *et al.*	2010	√		√						√											√					√
26	Chong *et al.*	2011			√			√						√						√			√		√		√
27	Mishra & Sharma	2011	√					√	√			√		√											√		
28	Singh	2011	√	√	√			√				√		√	√	√									√		
29	Talib *et al.*	2011	√			√					√	√		√	√		√			√		√	√		√		
30	Agus and Hajinoor	2012															√	√							√		√
31	Borade and Bansood	2012					√						√			√		√							√		
32	Vanichchinchai	2012															√					√			√		√
33	Bala	2013		√	√						√						√						√				√
34	Luai and Sawalha	2013															√									√	
35	Karimi and Rafiee	2014						√									√	√	√	√							√

The technical dimensions includes use of information technology, Six Sigma, E-business technology, JIT and lean practices, use of EDI, VMI for inventory management. The implementation of IT technologies, such as EDI, enterprise resource planning and CRM systems can improve supply chain performance. IT helps supply chain members to share information in real time (Chong *et al.*, 2011).

6. Integrated framework of Six Sigma and ISM for improving SCC performance

Figure 2 presents an integrated framework of Six Sigma and ISM for improving supply chain coordination (SCC) performance. The framework consists of three phases i.e. (i) Identification, (ii) Prioritization, (iii) Modeling. In order to achieve customer satisfaction, companies need coordination, both in internal process/functions and between different players in the supply chain network. As a consequence, the organization of the company must be considered in an integrated way through staff involvement and the sharing of objectives between the different dimensions. Six Sigma and ISM focus on these fundamentals. Thus the integrated framework is ideal for discovering a new convergent approach. It helps in achieving coordination between different dimensions such as human dimensions, process dimensions and output dimensions as it is described in literature as the most promising model for supply chain strategic decisions making. SCM practices are defined as the set of activities undertaken by an organization to promote effective management of its supply chain and are recognized as one of the most

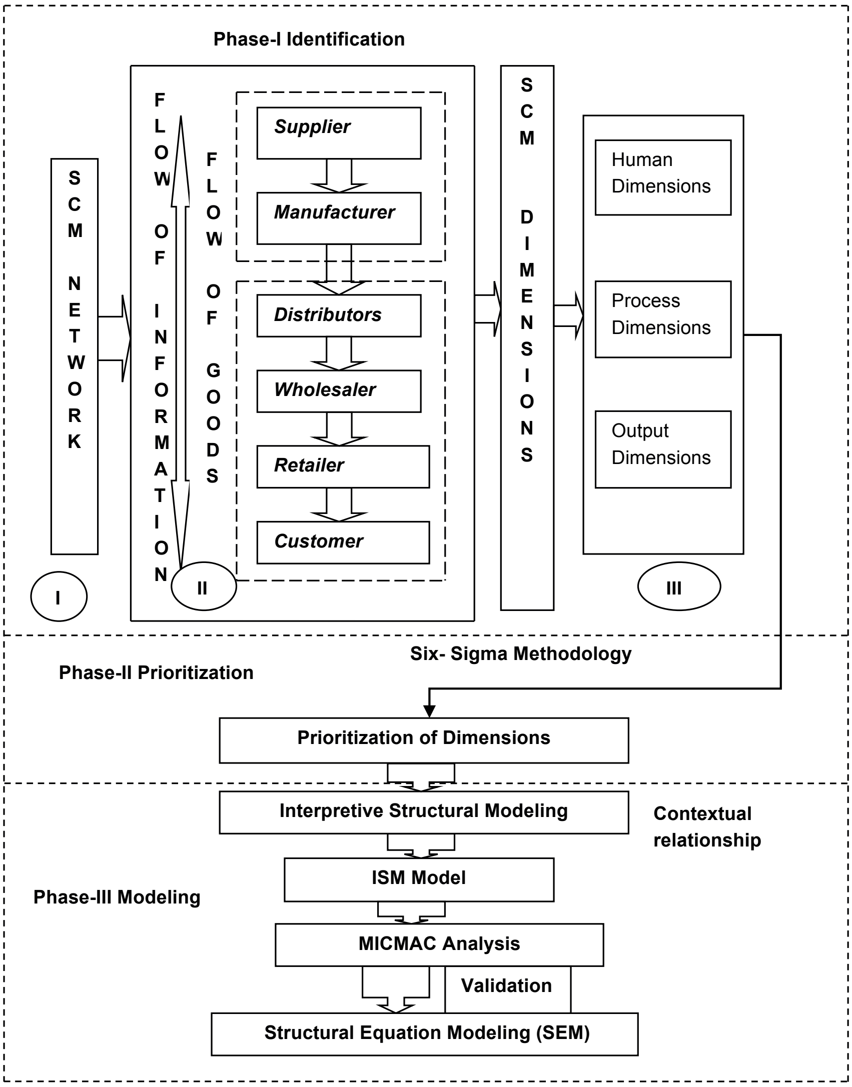

Figure 2. Integrated framework for effective SCC with focus on dimensions.

important areas for competitiveness and growth of the industries. In literature authors (Gunasekaran, 2001; Wang *et al.*, 2004; Knowles *et al.*, 2005; Li *et al.*, 2011) developed various frameworks based on balanced scorecard (BSC), Supply Chain Operations and Reference model (SCOR), Analytic Hierarchy Process (AHP), and maturity models to integrate and analyze SCM dimensions. At the same time they stressed upon the need for development of integrated type of framework for measuring SCM performance. Due to growing importance of SCM in global market, large business houses are heavily dependent on small to medium sized enterprises for good quality of products at low costs. Thus, forcing the enterprises to imbibe & practice quality culture in their business activities which may help to minimize waste & reduce variability, improve consistency, and increase efficiency and productivity (Gunasekaran, 2001; Wang *et al.*, 2004; Li *et al.*, 2011).

The different steps of the framework are presented below in following paragraphs.

Phase-I: Identification: Phase–I consists of four sub steps i.e. SCM network, SCM process, SCM dimensions.

- **SC network:** Supply chain network is a co-ordinate system of organizations, people, activities, information and resources involved in moving a product or service in physical or virtual manner from supplier to customer. In the study a SCN model is developed (Figure 1) to show various entities such as suppliers, manufacturer, distributors, wholesaler, retailers and customers through which raw materials are acquired, transformed and are distributed to the customers. The objective of each entity is to make easy the schedule of materials from upstream to downstream and, in turn, deliver products to customers. In order to improve supply to the end customer, it is important to develop strong coordination and partnership within the SCN.
- **SCM process:** SCM process depicts flow of goods/ flow of information in a network consisting of supplier, manufacturer, distributor, wholesaler, retailer and customer linked together via the feed forward flow of materials and the feedback flow of information. These entities are involved in providing and delivering final products from supplier's to the customer's in the whole process.
- **SCM dimensions:** SCM practices are a set of activities undertaken in an organization to promote effective management of various supply chain dimensions may be classified as (i) human, (ii) process and (iii) output dimensions. Based upon critical review of literature, authors have identified various human dimensions such as (i) Managerial Support, (ii) Information sharing, (iii) Leadership, (iv) Feedback & Reward, (v) Communication & Co-operation, (vi) Training & Education, (vii) Self-management, (viii) Team flexibility, (ix) Employee participation, (x) Process improvement. Process dimension of paint industry has been considered for improving the SCM performance. Output dimensions such as perfect order fulfillment, quality level and cost will be considered for measuring supply chain performance.

Phase-II: Prioritization: It consists of application of six sigma methodology to prioritization of dimensions.

- **Six Sigma:** Six Sigma methodology be required to be applied to reduce defect and improve job successful. By their nature, they appear to be systematically at predetermined processes to improve. Hence, once the supply chain objectives are accomplished, they provide solutions at every stage of detail by eliminating the non-value added activities and reducing the process variability. The dynamic effects like changes in production rate, poor quality in raw materials and other effects related to the bullwhip behavior of a supply chain. Six Sigma completes a process, by aligning the strategic opportunities with the capability to execute them.

Phase -III: Modeling: It makes use of Interpretive Structural Modeling (ISM) framework to establish contextual relationships among SCM dimensions and SEM is used to validate the model.

6.1. Interpretive structural modeling (ISM)

After that authors tried to measure and investigate the structural relationships between key dimensions for effective SCC. It makes use of Interpretive Structural Modeling (ISM) framework to establish contextual relationships among SCM dimensions. ISM model developed after removing the transitivity as described in ISM methodology. In order to determine driving power and dependence of each dimension MICMAC analysis has been done. MICMAC is "*Matrice d' Impacts Croises Multiplication Appliquee A un Classement*". The objective of Cross-Impact Matrix Multiplication Applied to the Classification (MICMAC) analysis is to analyze driving and dependence power of each dimension. According to Singh *et al.*, 2007; Talib *et al.*, 2011; and Borade and

Bansod 2012, MICMAC analysis is a classification based on driving power and dependence of each dimensions. Although various dimensions are critical to organization competitiveness, research so far has tended to focus on SCOR, BSC, total quality management (TQM), activity based costing (ABC), just in time (JIT), etc., but in literature hardly any description of an integrated framework which prioritize and establish structural relationship between various dimensions using ISM methodology is presented. As none of the previous research has grouped or analyzed SC dimensions critical to SCC which can be structured into any framework or model for analyzing the structural relationship among them. However, the ISM model needs to be statistically validated. The model can be validated with some empirical data and case studies with the help of structural equation modeling (SEM).

7. Conclusion

The purpose of this paper is to propose a conceptual supply chain integrated framework based on Six Sigma and ISM methodology to improve an entire supply chain performance. A three level framework for achieving the integration has been proposed which is in the form of (i) Identification, (ii) Prioritization, (iii) Modeling. The focus of the Six Sigma and ISM is to develop the concept of an integrated deployment models, refine the Six Sigma deployment methodology, add metrics, tools, technologies and capabilities through ISM to address the relationship and integrate a highly structured Six Sigma an implementation methodology with the ISM approach. The integration of Six Sigma is based on the ISM supply chain strategic approach, simplified by the tools of the DMAIC problem solving method. Six Sigma beliefs recommend the potential to refine current approaches to supply chain improvement. It offers likely benefits in delivering reduced variations over and above the elimination of waste and non-value added activity delivering by existing approaches. The application of Six Sigma methodology in the network model helps us to understand information regarding the strength and weaknesses of various supply chain entities in a supply chain. The model can be applied in practice by organizations in near future by following case study approach. Hence, this framework allow the companies to evaluate their own processes effectively, compare their performance with others i.e. companies both within and outside their industry segment. Main contribution of this study is that framework developed will be very useful for the management in selecting suitable dimensions for cultivating coordination in a supply chain and getting competitive advantage. The present model can be statistically validated with use of structural equation modeling (SEM) which has the ability to test the validity of such models. The model also can be validated with some empirical data and case studies.

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