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An Analytical Study on Modeling And Assessment of Supply Chain Responsiveness

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Abstract:

Responsiveness of a supply chain has become an essential measure of how well each of the individual companies performs in fulfilling their customer needs quickly and efficiently. It has become the differentiating factor between competing supply chains. Understanding the interrelationship between responsiveness and its underlying factors throughout the supply chain is crucial for any industry. The determinants which influence the supply chain responsiveness will give greater insight into the capabilities of the supply chain in fulfilling the customer needs and staying ahead of the competition. The objectives of this study are (1) to develop a model of supply chain responsiveness depicting the inter-relationships between various factors across the supply chain, (2) to assess the supply chain responsiveness using SCOR metrics through a system dynamics model and (3) to use data envelopment analysis (DEA) that assumes deterministic inputs and outputs under steady and fluctuating demand conditions to evaluate the relative resource utilization efficiencies at both stage and supply chain, at optimal responsiveness. In this work, after a preliminary industrial study, survey data from 204 pump industries and 246 textile industries was collected through detailed industrial studies. A model of responsiveness was developed for each supply chain using exploratory factor analysis. The developed models were validated using fitness measures of Structural Equation Modeling. A combination of both the models by grouping of the variables was performed using one of the widely used non-metric multidimensional scaling techniques called Structural Similarity Analysis (SSA) and their underlying structural elements were found. This resulted in a generalized model of supply chain responsiveness which encompassed factors across all the echelons of the supply chain.

1. Introduction:

To ascertain problems in the supply chain, particularly with regard to inventory control, leadtime and responsiveness, a preliminary industrial study was conducted using a contact survey methodology. This study was conducted in five companies. Three of the industries were pump manufacturers. Two of the pump industries are manufacturing submersible pumps and cater to the needs of the Indian and middle-eastern markets especially agricultural sector. The other pump company is engaged in manufacturing pumps and castings for industrial and automobile applications. The company produces industrial range of centrifugal pumps and mono block pumps for the domestic market. The fourth company is a medium scale foundry unit supplying to local pump industries. The fifth company was a garment manufacturing unit (Saleeshya et al, 2012). In this preliminary study, inventory control mechanisms, lead time, responsiveness, quality, supplier-manufacturer relationship and supplier selection practices were examined and analyzed. Based on our preliminary industrial study and discussions with the experts, several problems were found in implementing the supply chain that would minimize its time to respond. Few problems and the corresponding reasons stated by the experts are listed below. There was a lack of supplier quality, resulting in 10% to 30% defective castings. There was an uncertainty in the supply and delays due to a lack of supplier partnerships. Hence this 2 resulted in larger orders and accumulation of raw material inventory. Practically, zero inventories are not attainable, due to lack of reliability of supplier, with regard to both the quality and the quantity. There was no formal selection and evaluation of suppliers resulting in too many suppliers. There was no compliance to lead times leading to uncertainty and the manufacturers were completely dependent on the suppliers. The customers expect improved quality with continual cost reduction, since manufacturing the same product involves a learning curve which facilitates decrease in manufacturing costs and vendor quality inspection costs. Improved service and timely delivery of the product are required. Cost competitiveness is a major factor in determining the sales of the company. Techniques like cost analysis, value analysis may help in reduction of costs and passing on the benefits to the customers. Though the companies are aware of advanced operations management techniques like lean manufacturing, they are reluctant to implementing them fearing the cost that may be incurred.

The textile industry faces high demand variations from the customer. There is a lack of direct communication between the manufacturer and the supplier because the complete ordering and delivery system is through intermediate agents. There are huge penalties in case of late deliveries or quality issues, especially in the export market. Hence there is a sense of urgency in the production due to the short and strict timelines and the focus on delivery. There is a lack of synchronization between different levels of the supply chain. The suppliers should also develop the capability to innovate, improve reliability and be flexible to changing volumes. These issues can be overcome with a better understanding of responsiveness not only by the manufacturer, but his suppliers and distributors as well.

2. Objectives:

(1) To develop a model of supply chain responsiveness depicting the inter-relationships between various factors across the supply chain.

(2) To assess the supply chain responsiveness using SCOR metrics through a system dynamics model.

3. Problem Statement:

The lack of understanding of responsiveness and the factors influencing it are detrimental to the capacity to earn greater profits for the individual companies and the supply chain as a whole. The ability to meet customer demands promptly and improving the frequency of financial turnover, as seen through the case studies of Zara textiles and H&M, are the direct consequence of responsiveness of their supply chains. A comprehensive model considering the entire supply chain may lead to an improved responsiveness and greater financial turnover. Also, we need to assess the responsiveness of an industry and take suitable measures across the supply chain to become more responsive to the customer.

4. Literature review:

(Zhang and Reimann, 2014; Moreno et al, 2016), This model provides guidance to understand and measure the core attributes of the supply chain viz., reliability, flexibility and responsiveness, costs and asset management, which are briefly defined here. Reliability is the performance of the supply chain in delivering the right product at the right place at the right time. Flexibility is the agility of the supply chain in production, operations and transport in addressing the customer's demand variations.

(Zhang and Reimann, 2014), the total supply chain costs depend on the productivity and logistics costs including inventory and transit costs. Asset management is to measure the effectiveness of an organization in using its assets to drive customer satisfaction. These attributes along with responsiveness are related to the key performance indicators given as level one and level two metrics and are associated with the manufacturer, suppliers and the procurement process.

(Aslam, 2013), a system dynamics model helps in defining the interrelationships between the variables through equations representing the future state and the current state and the modification of the variable in the particular period between the current and future state of the system. The holistic system's dynamic complexity is taken into consideration. It is built as a series of stocks and flows and whenever we change the value of any variable, there is a corresponding change in the other variables through these underlying equations.

Pishvaee and Rabanni (2011) have developed models for optimizing supply chain networks considering cost efficiency and network responsiveness with both direct and indirect shipments. The performance of the supply chain networks is evaluated by customer needs such as on time delivery and cost.

5. Research Methodology:

The data was collected from 204 pump manufacturers and related supply chain . The respondents interviewed were senior and middle level managers in purchase, production, planning, marketing, logistics and supply chain departments. When the top level managers

viz., CEOs, Managing Directors were approached, they were aware of the general information about the company and then most of them, directed the other questions to several middle level managers of various departments to get the details. The questionnaire was also placed on the internet through a website and this link was mailed to individual industries. The form could be filled online and then submitted. Table gives the detailed statistics of the response to the survey questionnaire. The different modes of approach are given in the second and third columns of Table. Out of this, 185 mailers were sent to different companies for online form filling. Out of the 24 entries collected online, two were not usable, as they were incomplete. Also, 500 printed questionnaires were prepared. Out of them, 200 were sent to companies by post and followed up with phone calls. The rest of the 300 questionnaires were taken directly to the offices and plants of the manufacturers. Most of the completed responses were through exhaustive in-person interviews and plant visits, and had a better outcome vis-à-vis the completeness and usability of the survey.

Table Statistics of Survey Questionnaire Response

Description	Through Internet	Through post / In-person	Total
Issued questionnaires/mailers	185	500	685
Collected Responses	24	205	229
Valid Responses	22	182	204
Valid Response Rate	11.89%	36.40%	29.78%

6. Data Interpretation:

TableInputs and Outputs associated with each echelon derived from SD model

Echelon	Input	Output
Supplier	RM Requirement	Supply lead time
Manufacturer	Manufacturing Capacity	Manufacturer Lead time
	Customer demand	FG Stockout
		FG Inventory
		Shipment
Logistics	FG Quantity to be delivered	Delivery lead time
	Customer demand	

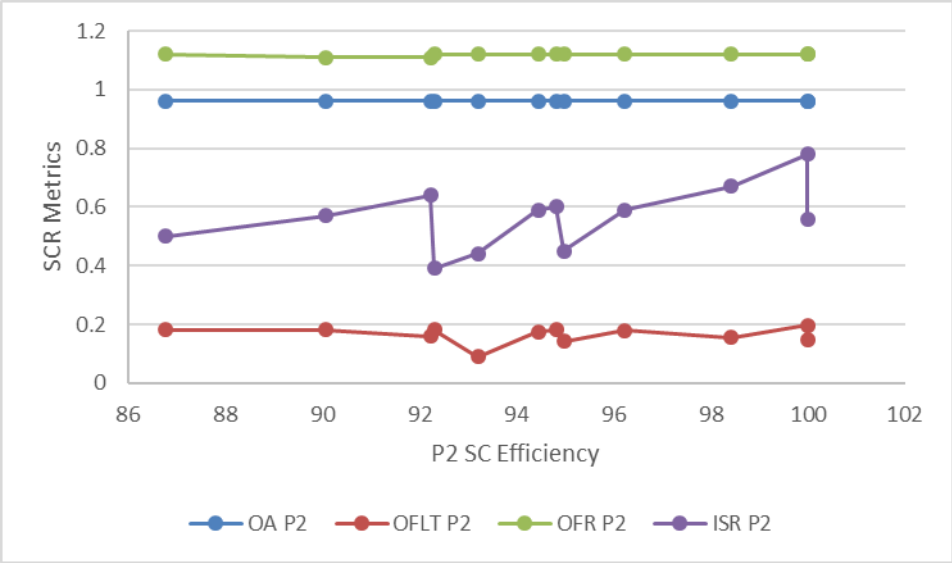
Interpretation:

Demand and capacity related DEA inputs, and lead time and delivery related DEA outputs are derived for each echelon at the optimal responsiveness values, as given in Table, for calculating the utilization efficiency of product P1, which has a fluctuating demand. Similarly, the utilization efficiencies are estimated for product P2, which has stable demand conditions. The echelon in which each set of inputs and outputs are considered is also shown in the table.These input and output variables have been obtained at a particular customer demand and manufacturing capacity corresponding to the optimal responsiveness metrics. From Table we can observe that the inputs at each echelon are given by the demand requirements and the capacity. The outputs are given by the lead time and the inventory levels at each echelon. These data are collected for each echelon from the system dynamics model for each DMU.

Supply Chain Resource Utilization Efficiency and SCR Metrics

– Product 2 (Steady demand)

Utilization efficiency (P2 SC Efficiency)	Order Accuracy OA P2	Order fulfillment lead time OFLT P2	Order Fulfillment rate OFR P2	Inventory-Sales Ratio ISRP2
87	0.96	0.18	1.12	0.5
90	0.96	0.18	1.11	0.57
92	0.96	0.16	1.11	0.64
92	0.96	0.18	1.12	0.39
93	0.96	0.09	1.12	0.44
94	0.96	0.17	1.12	0.59
95	0.96	0.18	1.12	0.6
95	0.96	0.14	1.12	0.45
96	0.96	0.18	1.12	0.59
98	0.96	0.16	1.12	0.67
100	0.96	0.20	1.12	0.78
100	0.96	0.15	1.12	0.56



Plots of resource utilization efficiencies against SCR Metrics for Product P2 (Steady demand)

We can note that there are slight variations in the inventory-sales ratio for fluctuating demands. We can also infer that all the other responsiveness metrics for both the fluctuating as well as steady demand, viz., order accuracy, order fulfilment lead time and order fulfilment rate are almost constant at various resource utilization efficiencies. Thus, the variations in resource utilization efficiencies for the entire supply chain are found by aggregating the echelon efficiencies at the supplier, manufacturer and logistics. The resource utilization at optimal responsiveness values are studied to compare the DMU efficiencies.

7. Conclusion:

The resource utilization efficiencies are found using network model of data envelopment analysis. It is used to compare the DMUs at capacities having optimal responsiveness metrics at steady and fluctuating loads. It is found that all the DMUs exhibit high efficiencies. In DMUs where the shipment is not able to meet the demand, the utilization efficiencies are lower compared to other DMUs. Also, higher finished goods inventories and longer lead times contribute to lower efficiencies. Hence the manufacturer needs to work on improving the order fulfillment lead time. As expected, in steady demand conditions, the utilization efficiencies are uniformly high.

8. Scope for further research

The current study is based on two industry studies to develop the model and a simple case study for assessing the responsiveness of the supply chain. There are a number of ways in which the research work can be improved.

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