ROLE OF OPTIMAL PRODUCTION PLAN AT THE FOCAL FIRM IN OPTIMIZATION OF THE SUPPLY CHAIN

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ABSTRACT

Supply chain management and optimization is a critical aspect of modern enterprises and an expanding area of research. Modeling and optimization are the traditional tools of supply chain management. The techniques have been used by many companies for planning, manufacturing, and other decision areas in supply chains. Current study is motivated by the fact that optimization studies in supply chain management have mostly considered network optimization. Supply chain management however, requires alignment between the supply chain partners at the tactical level. As a first step towards achieving this goal, current study presents a model that incorporates the activity level planning at the focal firm in a supply chain. This paper presents a new mixed integer programming model that incorporates optimization of production planning at the focal firm while optimizing the strategic alignment of the supply chain entities. The model represents a four step, multi-echelon supply chain including supplier, warehouse, manufacturer, and retailer. The manufacturer in this network represents the focal firm. This model is an attempt to integrate the production planning decisions in the network optimization decisions.

KEYWORDS

Supply chain management, optimization, aggregate production planning, supply chain optimization, network models

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INTRODUCTION

Recent times have seen quantitative supply chain (SC) considerations being incorporated into the strategic planning process of organizations; something which was previously ignored. Contributing factor to this inclusion is the realization on the part of SC managers of the importance of supply chain management (SCM) to the organizational competitiveness and increased amount of interest in fact-based SCM (Shapiro, 2004). Hence in the recent times a large number of studies have modelled various facets of SCs with differing amounts of details (Denton, et al., 2006; Graves & Willems, 2005; Jain & Palekar, 2005; Kremer, et al., 2006; Lashine, et al., 2006; Mohamed & Youssef, 2004; Moon, et al., 2008; Truong & Azadivar, 2005).

Vidal & Goetschalckx (1997) pointed out that production-distribution system designs have been actively researched in the literature. Most studies however, focus only on a single element of the whole system such as procurement, distribution, manufacturing, scheduling or transportation etc. and the research on integration of these components to the whole supply chain is relatively scarce (Li, et al., 2009; Truong & Azadivar, 2005; Vidal & Goetschalckx, 1997). This point was reiterated by Shapiro (2004), who argued that there is a need to expand the scope of strategic SC models in order to present “a more holistic picture” of the organization. Kremer, et al.(2006) also argued that despite the complex SC structures faced by the organizations, modelling research has been concentrated mostly on aggregate levels. Supply chain planning is a complex process where large number of multifacited activities are being performed with entities within and across the supply chain with the goal of achieving higher quality, lower cost, lower inventories etc. (Moon, et al., 2008). This gives rise to the need for collaborative planning instead of separate planning in order to achieve supply chain wide efficiencies. If the long term and short term planning decisions are not considered in SC models simultaneously than the resultant solutions are likely to be inefficient (Sousa, et al., 2008) and may also compromise profitability (Lisboa & Yasin, 1999), while simultaneous consideration of various decisions in the SCs (e.g. production, transportation etc.) may enhance efficiency of all of them (Mula, et al., 2010) and result in cost reduction (Sepehri, 2011).

In line with suggestions mentioned in the recent research, current study explores the possibility of combining aggregate production planning by the focal firm along with the supply chain network design decisions. As a first step towards achieving this goal, a model has been developed. This model contributes to the body of knowledge by proposing an amalgamation of strategic and tactical decisions. Next section presents the literature review on optimization models in SCM and production planning while the proposed model has been presented in the section 3. Section 4 concludes the study and presents avenues for the future research in the area.

BACKGROUND

Supply Chain Management

A supply chain can be defined as;

"All parties involved, directly or indirectly in fulfilling the customer request. The supply chain includes not only manufacturers and suppliers, but also transporters, warehouses, retailers, and even customers themselves". (Chopra, et al., 2013, p. 1)

Initial discussion on supply chain management (SCM) emerged in logistics literature as inventory management approach (Cooper & Ellram, 1993). Organizations realized the importance of their supply chain partners to their success which has led to the culture of cooperation instead of competition with the supply chain partners. According to SC perspective organizations do not seek success at the cost of loss to their SC partners (Romano & Vinelli, 2001). Higher level of synchronization (seamless SC) is the ultimate goal in SCM (Zhang, et al., 2011). SCM focuses on business processes integration (Chan & Qi, 2003) which is not limited to logistics only (Cooper, et al., 1997). SC focused companies seek to integrate all the processes of the business throughout the SC. SCM integrates the information, material and cash flows among supply chain partners that helps to improve the supply chain network's (SCN) efficiency (Paksoy, et al., 2012). The results sought through this effort are improved competitiveness, stability, growth (Chin, et al., 2010) and competitive advantage (Prado-Prado, 2009).

SCM literature reveals that all supply chain partners must closely engage to make supply chain more competitive (Sadjady & Davoudpour, 2012). It has been realized by the managers that an organization operating individually cannot gain and retain its competitive advantage in the current competitive scenario. Modern day organization needs to collaborate with its supply chain partners (i.e. customers, suppliers) in order to better understand the customer requirements and fulfill them in a timely manner. The ability to collaborate (or integrate) with SC partners is thus a source of competitive advantage and long term profitability. SC orientation helps in integration of various functions and units within and outside the firm. This integration leads to accurate and timely order fulfillment. Integration of production activities and sharing of information across firm borders helps to eliminate redundant and non value added activities, thus improves the overall efficiency of the supply chain (Ellinger, et al., 2012). However integration is not required with all the entities in a SC since activities leading towards this integration involve considerable costs in many cases. SC firms need to integrate activities with key suppliers and customers only (Kannan & Tan, 2006). Danese & Romano (2011) in their empirical study found a significant interaction effect between customer and supplier integration suggesting that supplier integration moderates the relationship between customer integration and efficiency. They concluded, based on the results that mere customer integration is not sufficient to achieve efficiencies; instead supplier integration is also a requisite. Organizations thus need to seek both upstream and downstream integration simultaneously in order to become efficient.

In summary SCM entails integration with suppliers and customers in a strategic manner that leads to reduction of SC wide costs while satisfying the customer requirements. In order to achieve this goal, organizations need to make decisions such as supplier selection, information sharing with suppliers and customers, and holding inventories etc. in a strategic manner. Using fact based approaches such as optimization models can help in making these decisions more effective.

The following section presents an overview of optimization models in the area of SCs and how they have evolved overtime. The paper further proposes a model that can contribute towards making these optimization models more comprehensive.

Optimization Models in Supply Chain

Previously in the business firms, strategic decisions like mergers, acquisitions, new facility sites, and introduction of new products were based on personal judgments and did not involve any descriptive or mathematical models (Shapiro, 2004). However with the passage of time fact based decision making has attracted the firms. Increasing competitive forces due to globalization and SCM concept itself has set a platform for SC optimization models. The heritage of modelling studies in the area of operations has been rich. This heritage has been duly transferred to the field of SC where increasing numbers of studies have emerged with ever increasing amount of detailed analyses. Supply chain management comprises of decisions which can be classified into three categories based on the time horizon i.e. strategic, tactical and operational level decisions (Badri, et al., 2012). These levels are distinguishable on the basis of time horizon (Vidal & Goetschalckx, 1997). Strategic planning considers time frame of over one year and usually deals with the aggregated data. Such decisions entail heavy investments and have long term effects on supply chain performance (Badri, et al., 2012). For example, strategic decisions deal with determining the number of warehouses and manufacturing plants, and their appropriate locations etc. Tactical planning decisions such as those dealing with placement of inventories at various locations and inventory levels usually consider time frame of up to one year and support strategic plans. Operational planning deals with the decisions taken in short term. This time might be less than an hour (Vidal & Goetschalckx, 1997). Optimization studies in SC models cater to the challenges of these various types of decisions (Al-e-hashem, et al., 2011; Badri, et al., 2012; Hammami & Frein, 2012; Lee et al., 2010; Mula, et al., 2010; Özceylan & Paksoy, 2012; Padron, et al., 2012; e.g. Sadjady & Davoudpour, 2012).

Optimization of the whole SC is the "most comprehensive optimization problem". Various studies have highlighted important decision areas in SC optimization models (See for example Daskin, et al., 2005; Truong & Azadivar, 2005; Vidal & Goetschalckx, 1997). This problem requires the determination of;

- Locating the plants, warehouses, manufacturing facilities and warehouses (SC nodes) and determining their optimal capacity and number;
- Choosing the most appropriate suppliers and the modes/channels of transportation;
- Quantities of raw materials/goods to be moved between these SC nodes;
- Inventory at various nodes of the SC;

This optimization problem is unique in the sense that it incorporates decisions about issues that are strategic (e.g. plant location) and hence less flexible in short term and those that are tactical (e.g. inventory management) and more flexible in the short term (Daskin, et al., 2005). This is probably one of the reasons why researchers in the field of SC modeling have considered different optimization models for these problems. Daskin, et al. (2005) discussed that even though decisions like facility location are not changeable even in the intermediate terms and decisions such as inventory or vehicle routing etc are flexible even the short term, empirical studies have shown that the problems that consider these decisions seperately give drastically different results to those that consider them together.

Sousa, et al.(2008, p. 2644) argued that;

"…the fact that supply chain planning problems address strategic decisions, such as product and customer allocation, design and investment decisions, aggregate inventory profiles, etc. that affect the system over a long term scale, so detailed short term planning of individual sites is not relevant as detailed operational data (e.g. orders) may not be available. However, it is our belief that there are cases where supply chain design and strategic planning should not be performed separately from short term scheduling, or the adopted solution may prove inefficient at the operational level."

Optimization models during the last few decades have moved from considering internal value chain based optmization decisions to the network wide decisions. This inclusion of increased number of variables has been gradual and has been achieved at the cost of computational simplicity and time. However as the SCs have become global and more complex,

Table 1: Progression of SC Optimization Models

Proposed Model	Study	Decisions
Network Location Models	Hakimi (1964, 1965)	• Location of facilities while minimizing the total distance covered to fulfill the customer demand
Fixed Charge Problem	Balinski (1965)	• Location of facilities • Pattern of shipment between facilities and customers
Integrated location/Routing Problem	Perl (1983), Perl and Daskin (1985)	Extends the above model by incorporating multiple stop tours to the customers but uses single commodity
Capacity expansion and technology selection	Verter and Dincer (1992), Revelle and Laporte (1996)	• Multiple production echelons • Plant loading • Economies of scale and scope • Supplier selection • Make Vs. Buy
Location/Routing Problem	Berger (1997)	A modification to above model that allows for the vehicles to not return to the DC after delivery to the last customer.
Integrated location/Inventory model	Shen (2000)	Extends the fixed charge problem by adding the working & safety stock considerations at the DCs,
Global Supply Chain	Truong & Azadivar (2005)	Extends the previous models beyond the geographic boundaries of the country Incorporates; • Make Vs. Buy Decisions • Supplier selection • Production planning policy
Manufacturing Network Design Model	Paquet, et al.(2008)	Incorporates; • Worker and processor capabilities • Transfer of resources between plants • Equipments to be used • Bill-of-material
Multilevel Planning Integration	Sousa, et al.(2008)	Presents a detailed production and distribution plan along with the assessment of customer service level in a global SC. Includes Multilevel modeling in 2 stages and incorporates; • Design of Global SC network • Optimizes the production & distribution plan for 1 year • Tests of the feasibility of the model at the operational level
Supply Chain Network Design / Enterprise wide optimization	Bidhandi, et al.(2009), Li, et al.(2009)	Incorporates the strategic level SC planning decisions such as facilities selection with those at tactical level such as; supplier, production, warehouse, and customer allocation.

Source: Adapted from Daskin, et al. (2005)

incorporation of more and more decision variables into the optimization models has been inevitable in order to make the problem more realistic and accurate. Table 1 shows the evolution of SC optimization models during the last five decades or so. The studies cited in the table are neither exhaustive nor the sole representative studies of the type of models. However these studies give a overview of how SC optimization models have progressed over time.

Production Planning Optimization Models In Supply Chains

Production/manufacturing planning & control or aggregate production planning deals with developing plans and controls related to various aspects of manufacturing such as materials, schedules of machines and personnel, coordination with suppliers and customers (Vollmann, et al., 2005). It might involve a single product or a group of products with slight differences which justifies the use of aggregation. Objective in such problems is to meet the forecasted demand while minimizing the costs. Costs in such problems usually include payroll, hiring/firing, shortage, inventory holding, demand backlog and overtime/undertime (Silva, et al., 2006).

Since last one and a half decade, organizations are going beyond their national borders and trend of globalization is noticeable. Due to this, competition among firms has tremendously increased. On the other hand customer preferences are becoming very dynamic and putting pressure on firms to match the customer needs and demands in timely manner and at relatively lower costs (Kannan & Tan, 2006). In such situations the role of aggregate production planning in order to meet customer demands on time and in a cost effective way is crucial. In traditional business environment, aggregate production planning was an important element in the determination of organizational success (Swinehart, et al., 1996). In the contemporary business environment the role of aggregate production planning has increased even further (Lisboa & Yasin, 1999). Aggregate production plan proposes the level of production quantity, and inventory through a particular level of work-force in order to meet the varying demand over a period of time (Silver, et al., 1998). Generally the planning horizon ranges from six to twelve months period. Before 1960's, most of the production related planning was accomplished using manual systems. Some of the most common techniques used at that time included "stock replenishment; reorder point, economic order quantity, and ABC" (Brinkley, et al., 1999). However with the passage of time and development in the field, various new techniques were introduced to handle aggregate production planning in a better way. Linear programming, mixed integer, fuzzy linear programming are some of the famous techniques which may help to handle issues related to aggregate production planning (Gomes da Silva, et al., 2006)

Optimization models of production planning have a long history. One of the earlier applications of linear programming in production planning was presented by Jones & Rope (1964) who developed a multi period model for food factory. Van de Panne (1965) proposed a simplistic model of production planning for glass-fiber manufacturing company using a single period approach without considerations of inventory holding. Traditional variables considered in these optimization models are all the aspects mentioned above. In more recent times many other aspects of production planning have been incorporated in the models. For example Silva, et al. (2006) proposed a model based on "multiple criteria mixed integer programming". Multiple criteria were simultaneous maximization of profit, minimization of late orders and work force level changes. This model incorporated the lack of flexibility in the workforce caused by the legal restriction, workers under training etc. This model covered a planning horizon of 12 months. Lee & Kang (2008) proposed a multi period inventory model in thin film transistor-liquid crystal display (TFT-LCD) manufacturing. This model incorporated the aspects such as batch-sized purchase, large product size, quantity discount, and forbidden shortage in the plant. Moon, et al., (2008) & Paquet, et al., (2008) while considering the manufacturing network design incorporated the processor and worker capabilities along with the information of bill-of-material (BOM) and operations in a multi-period planning model. The model also incorporated equipment selection, resource mobility between facilities and decisions on facilities to operate in each period within the current and potential sites. Recent models in the area have considered production planning decisions in the SC network design models. Sousa, et al.(2008) developed a production and distribution plan for the SC that was tested at operational level. Bidhandi, et al.(2009) presented a model that incorporates many characteristics of the previous models and optimizes the strategic & tactical level SC planning decisions for a SC consisting of supplier, manufacturer, warehouse and customer. Similar model was presented by Li, et al.(2009) while incorporating multiple periods. Other more recent studies presenting similar models with variations in the certain decision areas or applications include Alemany, et al. (2010), Lee, et al. (2010), Al-e-hashem, et al. (2011), Sousa, et al.(2011), Badri, et al. (2012), and Sadjady & Davoudpour (2012).

In terms of decision variables, in any supply chain the success of one firm is dependent on the success of the other supply chain partners. Thus in the current business environment selecting a right supply chain partner for example supplier or a distributor is inevitable for success. Competitive forces where put pressure on supply chain firms, they also play a role in reshaping the structure of the industry. Outsourcing has gained much importance in recent times. It helps firms to cut costs, and gain capacity flexibility, enabling them to gain competitive advantage (Größler, et al., 2013). Inventory management has always remained a challenge for managers. It plays a key role in making any supply chain competitive (Natarajarathinam, et al., 2012). Managers have to take decisions regarding appropriate levels of inventories. Because in the case of any shortage, they may lose the customers while in case of excess they have to bear inventory carrying costs. Distribution of goods also play crucial role in the success of supply chains. According to a research, firms generally have to spend around 20% of the total manufacturing cost of the firm in terms of distributions cost (Lau, 2012). In short from supplier selection to production to inventory levels to warehousing to distribution of goods to choosing the right amount of workforce in a period, supply chain managers have to take crucial decisions at every step. These decisions contribute significantly in the success of any supply chain. Current study attempts to formulate a mixed integer linear programming model that incorporates all these decisions. This model will help managers in selecting suppliers, determining optimal production outsourcing and inventory quantities, appropriate locations for production facility, warehousing, and distribution channels, and optimal distribution quantities between warehouses and distribution channels. Moreover this model is also capable of dealing with workforce level challenges. This model extends previous studies in the area by combining strategic level decisions with the tactical ones. This will help in simulating the decision situation more accurately and provide more accurate results than the situations where these decisions are considered separately. Following section presents the proposed model.

MODEL FORMULATION

Problem Description

The model proposed in this study has been formulated from the perspective of the focal firm in the SC. The manufacturer has been selected as the focal firm. Manufacturer is faced with the decisions such as supplier selection, warehouse sites and choice of markets at the strategic level. At the operational level the firm needs to decide in each period about the inventories, workforce levels and subcontracting decisions. Model employs mixed integer programming which is the most frequently applied methodology in the SC optimization models (Mula, et al., 2010). Following are some of the considerations in the model formulation;

- There is a single operational manufacturing site (the focal firm in the supply chain) which can source from number of suppliers and can serve number of markets using different warehouses.
- Focal firm produces products that require similar resources and hence can be aggregated to be treated as single product in the model.
- Focal firm may serve the market by manufacturing in regular and over time or subcontracting.
- Manufacturing site does not hold inventory, hence all the units produced are sent to the warehouses for storage.

Mathematical Model

Following notation is used to formulate the model:

Indices:

h = Set of supplier (1, 2,…..H), where H is the total number of suppliers

r = Set of raw materials (1, 2,…..R), where R is the number of types of raw materials used

e = Set of warehouse sites (1, 2,..…E), where E is the number of warehouses

i = Set of markets (1, 2,..…I), where I is the number of customers or markets

t = Time periods in the planning horizon (1, 2,…..T), where T is the total number of time periods

Parameters:

Dit = Demand from market i in period t

Kt = Capacity of manufacturing site in time period t

Shrt = Supply capacity at supplier h for raw material r in time period t

Wet = Warehouse capacity at site e in time period t

Fht = Setup cost for selecting the supplier h in time period t

Fet = Setup cost for operating a warehouse at site e in time period t

Crht = Cost of shipping one unit of raw material r from supplier h to the manufacturing site in time period t

CTet = Cost of shipping one unit of finished product from manufacturing site to warehouse e in time period t

Ceit = Cost of shipping one unit from warehouse e to customer i in time period t

CRt = Cost of regular time employee in time period t

COt = Labor cost per hour for overtime production in time period t

Cht = Cost of hiring an employee in time period t

CLt = Cost of laying off an employee in time period t

Cet = Inventory holding cost per unit at warehouse e at the end of time period t

CBt = Subcontracting cost per unit incurred by the focal firm in time period t

CSt = Stock out cost per unit incurred by the focal firm in time period t

Crt = Cost of Raw Material i in time period t

A = Number of units an employee can produce in an hour

Hr = Number of productive hours per time period t

Decision Variables:

Xrht = Number of units of raw material r shipped from supplier h to the manufacturing site in time period t

Xt = Number of units produced at the manufacturing site in time period t

Xet = Number of units shipped from manufacturing site to warehouse e in time period t

Xeit = Number of units shipped from warehouse e to market i in time period t

Wt = Workforce size for time period t at the focal firm

Ht = Number of employees hired at the beginning of time period t by the focal firm

Lt = Number of employees laid off in the beginning of time period t by the focal firm

Iet = Number of units in the Inventory at warehouse e at the end of time period t

SBt = Number of units subcontracted by the focal firm in time period t

St = Number of units stocked out in time period t by the focal firm

Ot = Number of overtime hours used by the focal firm in time period t

Yht = 1 if supplier h is selected in time period t, 0 otherwise

Yet = 1 if warehouse is setup at location e in time period t, 0 otherwise

Objective: Minimize (Cost)

$$\sum_{h=1}^{H}\sum_{t=1}^{T} F_{ht} Y_{ht} + \sum_{e=1}^{E}\sum_{t=1}^{T} F_{et} Y_{et} + \sum_{r=1}^{R}\sum_{h=1}^{H}\sum_{t=1}^{T} C_{rht} X_{rht} + \sum_{t=1}^{T} CR_t W_t + \sum_{t=1}^{T} CO_t O_t + \sum_{t=1}^{T} Ch_t H_t + \sum_{t=1}^{T} CL_t L_t + \sum_{e=1}^{E}\sum_{t=1}^{T} C_{et} I_{et} + \sum_{t=1}^{T} CB_t SB_t + \sum_{t=1}^{T} CS_t S_t + \sum_{t=1}^{T}\sum_{e=1}^{E} CT_{et} X_{et} + \sum_{e=1}^{E}\sum_{i=1}^{I}\sum_{t=1}^{T} C_{eit} X_{eit} \quad (1)$$

Subject To

$$X_{rht} \le Y_{ht} S_{rht} \quad (2) \quad \forall r = 1, \ldots, R, \; h = 1, \ldots, H, \; t = 1, \ldots, T$$

$$W_t = W_{t-1} + H_t - L_t \quad (3) \quad \forall t = 1, \ldots, T$$

$$X_t \le A\, Hr\, W_t + A\, O_t \quad (4) \quad \forall t = 1, \ldots, T$$

$$\sum_{e=1}^{E} X_{et} \le X_t \quad (5) \quad \forall t = 1, \ldots, T$$

$$I_{et} = I_{et-1} X_{et} + SB_t - \sum_{i=1}^{I} X_{eit} + S_t - S_{t-1} \quad (6) \quad \forall e = 1, \ldots, E; t = 1, \ldots, T$$

$$\sum_{i=1}^{I} X_{eit} \le Y_{et} W_{et} \quad (7) \quad \forall e = 1, \ldots, E; t = 1, \ldots, T$$

$$\sum_{e=1}^{E} X_{eit} = D_{it} \quad (8) \quad \forall i = 1, \ldots, I; t = 1, \ldots, T$$

$$Y_t, Y_{et} \in \{0,1\} \quad (9)$$

$$X_{rht}, X_t, X_{et}, X_{eit}, S_{bt}, S_t, O_t, W_t, I_{et}, H_t, L_t \ge 0 \quad (10) \quad \forall r, h, e, b, i, t$$

The objective function (1) minimizes the setup costs of supplier selection, warehouse operation as well as variable costs of sourcing raw material, regular time labor costs, over time labor costs, inventory holding costs, costs of hiring/laying off regular time workers, subcontracting costs, stock out costs, costs of transporting units from manufacturing site to warehouse and from warehouse to the market. (2) ensures the raw material sourced from the supplier does not exceed the supplier's capacity, (3) balances the regular workforce in each time period, (4) imposes the capacity constraint at the manufacturing site based on the availability of regular and overtime workforce (5) suggests that units shipped to warehouse in any period cannot exceed the units produced at the manufacturing site in the same period, (6) balances the inventory at the warehouse against the demand and stock outs, (7) ensures that units shipped out from warehouse cannot exceed its capacity, (8) ensures that the demand in each market is met; (9) provide the binary constraints on the supplier selection and warehouse setup variables whereas (10) enforces the non negativity restriction.

DISCUSSION AND CONCLUSION

This study proposes a model for a focal firm to optimize its SC network incorporating production planning considerations. The proposed model is based on mixed integer linear programming approach which deals with strategic and tactical level decision making. For example at strategic level it helps in determining the production facility sites while at tactical level it provides production and distribution plans for different products. This model aims to minimize the total cost by minimizing the different cost factors associated with the process of selecting suppliers, operational costs of warehousing, and different variable costs for example sourcing raw material, regular and overtime time labor costs, inventory holding costs, costs of hiring/laying off regular time workers, subcontracting, stock outs, and costs of transporting units from manufacturing site to warehouse and from warehouse to the market. In this way a broader scope of SC optimization models has been considered.

Implications for Managers

In recent times, competitive forces have significantly changed the business dimensions. Various orientations exist amongst the organizations while seeking optimization of their business processes to respond to the competitive environment in an appropriate manner. Chopra (2013) suggest that some organizations may fall in the trap of taking the intra-operational, intra-functional, or inter-functional view of their processes. This results in optimization of a single stage of SC or all the operations within a single function or all the functions within an organization respectively. An alternative view is to consider intercompany or SC optimization scope. According to this view SC firms are no more rivals; instead they must work in collaboration to achieve SC wide goals (Kannan & Tan, 2006). It is imperative for a firm in the SC to make strategic choices in such a way so as to minimize the costs of overall SC while maximizing the service levels. The model suggested in this study provides an illustration of how this goal could be achieved by optimally taking decisions related to supplier selection, appropriate sites for production facility and warehouses, inventory levels, and distribution channels. In developing models targeted towards the optimization of SCs, it has to be considered though that these models do not incorporate the impact of strategic alignment or strategic fit upon the SC firm's success. For example various authors (e.g. Fisher (1997) and Lee (2002)) have pointed out that SC strategy needs to be tailored according to the product type and degree of demand un-certainty. Failure to tailor the SC strategy according to these factors leads to SC failure to create a balance between demand and supply regardless of SC optimization techniques employed. Furthermore SC strategy is a functional strategy that is derived from the business strategy. A firm seeking competitive advantage on the basis of differentiation strategy is more likely to achieve this through a responsive SC strategy than efficient strategy. Thus an important dimension to be considered while using the mathematical models for the optimization of SCs is strategic alignment between business strategy, SC strategy, product types being offered, and the nature of demand for these products.

IMPLICATIONS FOR FUTURE RESEARCH

Future research may move further in the area by incorporating more tactical and operational dimensions e.g. vehicle routing from the focal firm, short term scheduling, multiple products, reverse logistics, etc. Conducting computational studies related to this model is another avenue for future studies. Furthermore considering the strategic dimension is another prospect for future research in the area. For example it is the understanding of the authors that modelling based research is more beneficial for the organizations following "efficiency" based SC strategy than the ones seeking "responsiveness". Future studies may seek to develop a better understanding about the impact of strategic fit on the optimization models.

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