DECISION SCIENCES INSTITUTE
Supply Chain Network Design to Improve Market Response Time

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ABSTRACT

This research designs a three echelon supply chain network to manage supply, distribution and selling of product. It plans realization of finished product through the local and overseas suppliers. The design model decides number and location of distribution centers to distribute product within optimum time, and number and location of sales outlets to include product availability within optimum distances and thus improve market response. Sales network is designed by considering a set of potential retail outlets and locations for the company operated outlets. It plans mobile distribution between retail and supply chain operated outlets to further improve market response.

KEYWORDS: Design Model, mobile distribution center, optimum response time, sales network design, number of distribution center.

INTRODUCTION

A modern supply chain (SC) must be responsive to customer requirements in addition to their traditional optimum cost objective to become competitive (Melnyk et al, 2010). Such responsiveness has become paramount with the mixed channel shopping behavior of modern customers in e-markets and physical retail outlets (Bell et al, 2014). Considering this changed buying behavior of customers, supply and distribution planning are the vital issues for ensuring timely availability of product and thus improving response to customer. In fact responsiveness, in terms of ability to fill the orders quickly or replenishing retailer's stock may be considered to be one of the crucial factors to become competitive and obtain market growth. Evidences of such responsiveness to create market growth had been studied over 10 years for Nokia's marketing network. It was established that priority should be on responsiveness not the lowest cost for sales growth (Collin et al, 2009). Today most of the progressive businesses plan to supply product to market with ensured quality. In addition, there is negligible difference between the prices for the product of same specifications and features marketed by different organizations. As such, differentiation in the market places may be created by improving service components, such as timely delivery, making the product available at a convenient location (as the customer may desire). In such a business environment SC should concentrate on their core responsibility and strength, such as product design and development to establish their business identity. And realization of finished product according to design may be managed through suppliers to have competitive price. Supplier in this case may be local or global that supply product to planned distribution centers, from where products are distributed to retail outlets. Main challenges for designing such SC network are assignment of suppliers based on cost, quality, supply lead time and realization of product to minimize cost; deciding number and location of distribution centers (DCs) to optimize cost and replenishment time, number and location of sales outlets to facilitate availability of product by customer within a reasonable amount of time. Since response to customer and services are crucial factors, SC needs exclusive outlets operated by them to have direct customer contact through their own outlets in addition to selling through retail outlets. Inclusion of direct channel to create vertical integration is not rare; in fact it has increased during the last two decades to reach the end consumer (David & Adida, 2015; Tsay & Agarwal, 2004). SC operated sales outlets may also serve as a standby mini storage to quickly replenish small amount of product for some retail outlets to fulfill an occasional and urgent requirements of product between schedules for deliveries from the main DCs. Such services for supplying to retail outlets may be planned through mobile DC type arrangement. By including this mobile DC arrangement effective services differentiation may be created for improving response to retailers as customers. It is similar to the lateral transshipment arrangement proposed and established to be an effective approach of services differentiation in Alvarez et al, (2014).

Planning of overall distribution system by including traditional and mobile distribution to replenish customer requirements by sending emergency small loads and planned loads in addition to deciding number and location of DCs will facilitate improvement of customer response time. An integrated SC network design considering supply management for product realization, distribution management together with the decision for location and number of DCs, and deciding location and number of sales outlets (Glock & Kim 2015), may be considered to be the optimum way for improving overall SC cost and customer services in today's complex business situation.

Based on above discussion this study introduces a new strategic SC design model that integrates SC network design and overall decision process to improve SC performance in terms of total SC cost and customer response. This integrated SC network design model is new and unique in the sense that it considers: a) keeping direct contact with market to monitor and communicate customer caring impression to market by including SC operated outlets, b) traditional and a new mobile distribution arrangement to improve customer service level through timely replenishment of products; c) selection of retail outlets and their relative positions in addition to deciding number of SC operated sales outlets to improve customer responsiveness, and d) planning product realization by the local and overseas suppliers by including planned customer service level to optimize cost.

LITERATURE REVIEW

Two streams of literature: a) distribution and SC network planning, and b) supply management and marketing channel planning created the basic background for this research. Supply management literature that considered product realization by local and overseas suppliers (outsourcing) are the relevant ones for this research.

Distribution and SC Network Planning

Distribution management plays a crucial role in improving market response by delivering product to customer timely. Therefore to achieve the aim to be competitive and improve customer service, overall SC network design should be planned to optimize the flow of products from suppliers to DCs and from there to customers (Ambrosino and Scutella, 2005). Spacing of the retail stores and delivery distance between the DCs and sales stores influence customer service and SC cost (Chhetri et al, 2017). Using spatial analytics Chhetri et al studied retail stores for Auto parts and analyzed customer segments (profitable and non-profitable) covered by these stores. For the profitable segment of customers close spacing of the retail stores and shorter delivery distance observed to be beneficial.

For improving distribution efficiency in terms distribution cost optimum number of trips, total distribution distance and consolidation of distribution loads into full loads are some of the options mentioned in literature (Potvin et al., 2006; Huang and Gao, 2012). Number of distribution outlets and retail outlets influence operational efficiency. Increased number of retail

outlets and DCs mentioned to provide increased level of customer service. But such arrangement increases overall SC cost and distribution cost due to addition and opening costs for higher number of facilities. As such SCs need to balance between customer service level and distribution cost to decide optimum number of distribution and retail outlets (Lau, 2013). Similar findings that distribution efficiency and customer responsiveness are the two conflicting performance indices have also been mentioned in Chopra and Meindl (2010).
SC network planning and design decides the physical structure of the SC that ultimately influences its overall business performance. A comprehensive literature review of competitive SC network design has been presented in Farahani et al (2014). The SC network design problem is considered as the most important step for improving SC's performance in terms of profit and loss (Fahimi et al,2017). It is a strategic problem since it addresses number and location of DCs, retail outlets to be used by the SC and their capacities to fulfill anticipated customer demand (Kilbi et al, 2010). Based on this discussed aspects it is obvious that SC network design decisions have long term impacts, especially DCs, and SC's own outlets may last for several years. As such anticipated demand may change, there may be supply failure, and even operation of some DCs or SC's own outlets may be disrupted because of natural calamity or some other disruption reasons. Considering these anticipated changes due to uncertainty , risks, and disruptions the SC network design should be resilient to withstand or recover from such changes and ensure customer service and business continuity. Including flexibility in number of DCs allocated to retail outlets will enable SC network management to supply product to affected customers or retailers whose supply is disrupted due to disruption of distribution route or a DC from an unaffected DC. Similar flexibility should also be there for obtaining supply of product to a DC by one of the supplier when assigned supplier is disrupted due to some natural calamity or manmade problems (Sadghiani et al. 2015). Responsive SC network design has also been addressed in the literature from the point of customer perspectives when customers are sensitive to the delivery lead time. From SC perspective it is defined as the % of potential demand for the customer zones which can be satisfied by the resources allocated to the customer zone by the SC (Fattahi et al, 2017). Fattehi et al. considered a SC network for a multi period planning period and allocated one facility at the beginning of each period for a marketing zone. At each period the customer demand was influenced by supply lead time of the assigned facility which included product processing time, transportation time to supply to customer from the facility. The responsiveness defined above is the % of potential demand of the allocated customer zone that can be fulfilled by the assigned facility with its constituent functions in addition to the uncertainties and risks faced by the facility. Fattahi et al. considered demand to be uncertain. The SC network design also considered impact of uncertainties and risks faced by the facility while computing responsiveness. To achieve certain level of responsiveness they included mitigation and contingency strategies taking a scenario based approach. Fattahi et al. considered practical situations in their scenario analysis to estimate responsiveness. Since this research considered an extension of the paper to include resilience considerations in designing SC network for improved responsiveness, Fattahi et al.'s research is an inspiration to that.

Supply Management and Marketing Channel

A short but relevant literature review is presented here that motivated this study to go for multichannel marketing and planning of product realization through local and global outsourcing in an integrated way. Integration of supplier, distribution and retail network are well covered in the recent literature (Glock and Kim, 2015). Glock and Kim's study illustrated a special scenario of integrating single product supplier with retail networks, where the suppliers finally become merged with one retailer. The study reported influence of such merger on the structure of the

SC and analyzed the advantage of the vendor on overall market volume taking a game theoretic approach.

Since this study includes direct channel marketing by the SC organization by opening their own outlets a review of select articles are included here. Based on the fact that superstores like Walmart, Target, Lowes, Best Buy, and similar others retailers control the consumer choices, some product suppliers like Nike, Apple have opened their own outlets in addition to selling through retail outlets to have direct contact with consumer (David and Adida, 2015). Based on their analysis David and Adida showed that in a two channel supply chain network supplier benefits from the additional competition in the retail market when the supplier is the sole source to the competitors. The study recommended that the supplier should sell through increased number of retail outlets to increase their benefits. Most of the studies including David and Adida on two channel or multichannel marketing are analytical that show comparison of pricing level, volume advantage in these channels and competitions(Arya et al, 2007, Bernstein et al., 2009). Preconditions to make the overall business successful for the SC networks are planning of time for placing the procurement order, deciding receiving schedule, deciding number and location of distribution centers, and selection of retail outlets and their locations.

Literature is very rich on supply management. In recent years study of supply management considering outsourcing of product and other supply items has been getting special attention from academicians and industry professionals. Global outsourcing is considered as an effective strategy for reducing supply cost as well as getting access to worldwide knowledge (Verwaal 2017). But a section of literature express concern on the quality of globally outsourced items(Steven et al, 2014) and problem of knowledge and intellectual rights (Roy & Shivkumar, 2011).Based on empirical findings Verwaal (2017) argued that these negative effects can be influenced through relational capital. By relational capital the author considered close social and business interaction. The firms that plan to outsource entire or partial production may face exchange rate and demand uncertainties. Such uncertainties may be reduced by outsourcing partially to global supply sources and keeping remaining items and quantities with local suppliers (Li and Wang, 2010). Li and Wang termed such arrangement as operational option. Based on their analysis the authors mentioned that operational option increases overall value if the uncertainty in the exchange rate or demand increases. In such option organization can be risk averse by holding more capacity with local suppliers by sacrificing profit from foreign sourcing or negative profit contributions due to higher local supply percentage. It may be mentioned that this research considered such operational option.

Study of Koatabe et al (2008) considered an inverted U-shaped model for firm profitability and degree of outsourcing and mentioned that there is an optimal degree of outsourcing level for the business portfolio of a firm. Kotabe et al recommended considering asset specificity, uncertainty, firm competences, industry trends, and firm nationality and location for deciding such optimal degree of outsourcing.

In addition to reduction of cost, outsourcing provides the option to the buying firm to concentrate on their core business functions. Literature mentions an increasing trend in outsourcing is not only due to cost reduction or taking the option of concentrating on core businesses by the SC but due to increasing capability of the supplying or outsourcing global firms (Levy, 2005). Capability improvement or enhancement has come to a level that some outsourced international subcontractor like Foxconn, Flextronics has been reliably producing and supplying complex intricate parts to Apple, Dell, and HP with competitive price (Liker & Choi, 2004, Heese, 2015).

Above literature review covered several SC network design factors and their influences on SC's performances. This study considered similar factors and relevant recommendations from the literature and contributed by adding some more factors for improving market response.

METHODOLOGY

SC network design is a strategic level decision process which is crucial for the success of the overall SC organization over a long time period. This research proposes a mathematical modeling based approach for designing the SC network. The proposed model is unique compared to the other models in the extant literature. It creates differentiation by designing a modern SC network to make it competitive over a long period of time by achieving optimum cost and customer confidence by keeping direct contact in the market places through SC's own sales outlets. It plans number and location of DCs, mobile distribution arrangement, number and location of retail and SCs own sales outlets, in addition to realizing finished product through local and overseas suppliers to optimize overall SC operation cost and customer response time.

Model Development

This subsection includes Problem Statement, Notations used to define model equations, Model Constraints and the Objective Functions.

Problem Statement

The SC network design considers a set of potential distribution centers (DCs) $w \in W$ as nodes of the network, arcs (w, o) to distribute product to customer outlets at ending nodes $o \in O$; $o \in O^r$ denotes a set of retail outlets and $o \in O^c$ denotes the set of company operated outlets; SC's own operated outlets ($o \in O^c$) includes provision of replenishing a limited amount of product to neighboring retail outlets through a mobile distribution type arrangement. Distances between potential locations of DCs and sales outlets (retail and own operated; to be mentioned as own, henceforth); and distances between the potential sales outlets are assumed to be known. The SC includes a set of enlisted pre-approved suppliers S($s \in S$) from local and global sources for product realization that supply the product to DCs. Supply lead times for supplying product to DCs by the suppliers are also assumed to be known. Supply orders are assigned to local and global sources by considering inventory for supply lead time and a predefined customer service level for lead time variation. The SC markets their product in a set of markets, average demand for each market is assumed to be known. Based on their recent market research they have identified potential retail outlets to make contract for selling their product, potential locations for opening their own sales outlets, DCs and mobile DC provision for each market that they may use. Objectives of this integrated planning model are to decide number of DCs, sales outlets (retail and own) including their locations to have expected customer response in terms of distribution time and time to travel between sales outlet by a customer; and optimizing cost considering product realization, inventory keeping, and distribution. The integrated model plans for one typical market such that the plan can be suitable to be used for other markets as well.

Notations Used in the Model Equations

Indices

O: set of sales outlets, $o \in O$; $o \in O^r$ denotes a set of retail outlets and $o \in O^c$ denotes the set of company operated outlets; O^c and O^r are partitions of set O.
S : set of suppliers; $s \in S$.
W : set of DCs, $w \in W$.

Decision Variables

a_{sw} :1, if order is assigned to supplier s to supply to DC w; 0 otherwise.

$ct_{oo'}$: 1, if customer travel route from outlet o ($o \in O^r$, $o \in O^c$) to o'($o' \in O^r$, $o' \in O^c$),$o \neq o'$ is selected; 0 otherwise.

$dcou_{wo}$: distance in minutes between the selected DC w and outlet o ($o \in O^r$, $o \in O^c$)

k_w : 1, if DC w is opened, 0 otherwise.

$l_{oo'}$: travelling distance in minutes between selected outlets o ($o \in O^r$, $o \in O^c$) and o'($o' \in O^r$, $o' \in O^c$),$o \neq o'$

mw_o: 1, if SC operated sales outlet $o \in O^c$ included mobile distribution arrangement, 0 otherwise

m_{sw} : product supplied by supplier s to DC w

inv_{sw} : inventory maintained at DC w for the items supplied by s

pr_o: product sold by retail outlet $o \in O^r$

rsm_{sw} : actual ordered quantity of product to a supplier s to supply to DC w without considering inventory for lead time

sco_o: product sold by company operated outlet $o \in O^c$

u_o : 1, if sales outlet o ($o \in O^r$; $o \in O^c$) opened;(SC operated outlet is opened by organizing own resources; retail outlet opening is organized under an agreement with retailer for selling product); 0 otherwise.

v_{wo} : 1, if DC w is open and is allocated to sales outlet o; 0 otherwise.

$yb_{o'o}$: product distributed in a mobile distribution mode from SC operated outlet $o \in O^c$ to retail outlet $o \in O^r$

z_{wo} : product distributed to sales outlet o from DC w.

Parameters

$ATTL$: Minimum travelling time/distance limit set by the SC between two sales outlets.

$ATTH$: Maximum travelling time/distance limit between two sales outlets set by the SC.

BM : a big number.

C_s : capacity for supplying product by supplier s.

CYb_o : capacity to distribute by SC operated outlet o ($o \in O^c$)in a mobile mode.

Dav: average daily demand for product.

DL_{oo} :distance between two sales outlets o and o' in terms of driving time.

DLT_{sw} : lead time for supplier s to supply to DC w.

$DISL$: distribution distance limit set by the SC in terms of time taken by a distribution truck to travel from a DC to customer outlets.

$DISC_{wo}$: cost of distributing product from DC w to sales outlet o.

DS_{wo} : distribution distance in terms of travelling time between DC w and customer outlet o.

$FCMB_o$: fixed cost including mobile distribution arrangement in SC operated outlet $o \in O^c$.

FCO_o: fixed cost for opening sales outlet o or making contractual arrangement for retail outlet o.

FCW_w: fixed cost for opening DC w.

FC_s: fixed cost for assigning supply orders to a supplier s.

h: inventory carrying cost per product per period.

$MDIS_{oo'}$: cost for distributing product from $o \in O^c$ to $o' \in O^r$ by mobile distribution option.

SC_s : supply cost of product from supplier s.

σDLT_{sw}: standard deviation for the lead time for supplier s supplying to DC w

z: number of standard deviations for supply lead time for a defined service level assuming lead time variation follows normal distribution.

Model Constraints

Constraint (1) balances average demand of product in a market with the demand of product from retail and SC's own operated outlets.

$$OVD = \sum_{o \in O^r} pr_o + \sum_{o \in O^c} sc_o \tag{1}$$

Constraint (2) decides the distance for the selected DC-sales outlet combinations (retail and SC operated).

$$v_{wo} DS_{wo} = dcou_{wo} \qquad \forall w, o \in O^r; o \in O^c \tag{2}$$

Constraints (3) ensure deciding product distribution from an opened DC to an opened sales outlet.

$$v_{wo} \le \{k_w, u_o\} \qquad \forall w, o \in O^r; o \in O^c \tag{3}$$

Constraint (4) ensures opening a DC within the distance limit set by the SC from an allocated outlet.

$$dcou_{wo} \le DISL \qquad \forall w, o \in O^r; o \in O^c \tag{4}$$

Constraint (5) decides the distance between two sales outlets.

$$l_{oo'} = ct_{oo'} DL_{oo'} \qquad \forall (o,o') \in O^r, (o,o') \in O^c; o' \ne o \tag{5}$$

Constraint (6) ensures selection of travel routes between two neighboring opened sales outlets.

$$ct_{oo'} \le u_o \qquad \forall (o,o') \in O^r, (o,o') \in O^c; o' \ne o \tag{6}$$

Constraint (7) establishes maximum and minimum acceptable distance limit between two neighboring sales outlets.

$$ATTL \le loo' \le ATTH \qquad \forall (o,o') \in O^r, (o,o') \in O^c; o' \ne o \tag{7}$$

Constraint (8) ensures that a sales outlet is supplied by at least one DC. Constraint (8) provides DC flexibility to include some degree of resilience for an outlet by ensuring supply to the outlet by more than one DC.

$$\sum_{w \in W} v_{wo} \ge 1 \qquad \forall o \tag{8}$$

Constraint (9) ensures that a DC can supply to more than one sales outlet.

$$\sum_{o \in O} v_{wo} \ge 1 \qquad \forall w \tag{9}$$

Constraint (10) balances distribution of product to sales outlets with the product received from suppliers.

$$\sum_{s \in S} m_{sw} = \sum_{o \in O} z_{wo} \qquad \forall w \tag{10}$$

Constraint (11) assigns supply order to the suppliers (local or overseas) based on the capacity limitation of the supplier.

$$m_{sw} \le a_{sw} C_s \qquad \forall s, w \tag{11}$$

Constraint (12) balances total procured quantity from an assigned supplier with the actual ordered quantity and the Lead time inventory.

$$m_{sw} = rsm_{sw} + inv_{sw} \qquad \forall s, w \tag{12}$$

Constraint (13) computes Lead time inventory for an assigned supplier by considering average lead time consumption of product and safety stock for lead time variation for a predefined service level.

$$inv_{sw} = (DLT_{sw}Dav + z.Dav.\sigma DLT_{sw})a_{sw} \qquad \forall s, w \tag{13}$$

Constraint (14) balances product distributed from DC to retail outlet with the product sold by the outlet and the product received by the outlet from SC operated outlet through mobile DC.

$$\sum_{w \in W} z_{wo} = pr_o - yb_{o'o} \qquad o \in O^r, o' \in O^c \tag{14}$$

Constraint (15) balances product distributed from DC to a SC operated outlet by considering sales by the outlet and amount of product distributed from the outlet by mobile DC to retail outlet.

$$\sum_{w \in W} z_{wo} = sco_{o'} + yb_{o'o} \qquad o \in O^r, o' \in O^c \tag{15}$$

Constraint (16) distributes product to an opened sales outlet or an outlet with which SC has agreement to sell their product.

$$\sum_{w \in W} z_{wo} \le BNu_o \qquad o \in O^r, o' \in O^c \tag{16}$$

Constraint (17) ensures distribution of product from a SC operated outlet in a mobile mode when the outlet is opened with arrangement for mobile mode and based on its capacity for distribution.

$$yb_{oo'} \le mw_o CYb_o \qquad o \in O^c, o \in O^r \tag{17}$$

Constraint (18) imposes integrality.

$$\begin{aligned} &cyb_o \in \{0,1\}, \forall o, o \in O^c; u_o \in \{0,1\}, \forall o, o \in O^r, o \in O^c; k_w \in \{0,1\}, \forall w \in W; \\ &v_{wo} \in \{0,1\}, \forall w; o; a_{sw} \in \{0,1\}, \forall s \in S, ct_{oo'} \in \{0,1\}, \forall o, o', (o,o') \in O^r, (o,o') \in O^c \end{aligned} \tag{18}$$

Objective Functions

The objectives of the model are to improve responsiveness to market requirements and minimize overall SC cost.

Objective Function 1 defined in equation (19) minimizes market response time (*RET*) and thus improves responsiveness to customer. *RET* defined in equation (20) computes product replenishment time from DC to sales outlets and time a customer needs to go from a sales outlet to another one to get their product.

Objective Function 1: **minimize** *RET* (19)

$$RET = \sum_{w \in W} \sum_{o \in O^r, o \in O^c} dcou_{wo} + \sum_{\substack{o \in O^r \\ o \in O^c}} \sum_{\substack{o' \ne o, but \\ o' \in O^r, o' \in O^c}} l_{oo'} \tag{20}$$

Objective Function 2 defined in equation (21) minimizes overall SC cost (*OSC*). *OSC* defined in equation (22) considers : a) fixed cost for opening a DC ; b) fixed cost for opening a sales outlet or going for a contract with a retailer to sell the SC product; c) costs for distributing product from DCs to sales outlets; d) fixed cost for including mobile distribution arrangements by SC operated sales outlets; e) cost for procuring product from the suppliers; f) fixed cost for assigning orders to supplier; g) cost for carrying lead time Inventory computed in constraint (12); h) cost for distributing a product through mobile DCs.

Objective Function 2: **minimize** *OSC* (21)

$$OSC = \sum_{w\in W} FCW_w k_w + \sum_{o\in O} FCO_o u_o + \sum_{w\in W}\sum_{o\in O} DISC_{wo} z_{wo} + \sum_{o\in O^c} FCMB_o mw_o + \sum_{s\in S} SC_s \sum_{w\in W} m_{sw}$$
$$\sum_{s\in S} FC_s \sum_{w\in W} a_{sw} + \sum_{s\in S} inv_{sw} h + \sum_{o\in O^c}\sum_{o.\in O^r} yb_{oo'} MDIS_{oo'} \quad (22)$$

NUMERICAL EXAMPLE

An example business that would like to design their SC network as a part of their overall strategy for one of their product (similar to hand grinder) in one of their market is considered to illustrate applicability of the proposed Integrated Strategic SC Network Design Model. The example SC in this market conducted a market research and identified suitable locations for 20 potential sales outlets, out of which 15 for retail outlets which are already operating retailers of this market, and 5 potential locations for opening SCs own sales outlets. Based on their market survey the SC estimated 100,000 units/year overall demand for their product for this market. The SC is planning to sell 70 % of their product by selecting suitable retailers and 30% through the outlets operated by them in suitable locations out of the potential ones by considering distances between the sales outlets. The SC found out distances between the potential sales outlets using highway and street map of this market in terms of travelling time by the customers. SC has identified 8 potential locations for opening DCs that will warehouse product to be realized through suppliers and distribute the products to sales outlets. Distribution distances for each DC- sales outlet combinations are known from the market survey. The organization has 7 enlisted local and 5 overseas suppliers for realizing quality ensured finished product to satisfy market requirements. The SC maintains inventory of product for supply lead time and safety stock for variation of lead time. To address lead time variation the SC plans safety stock for 98% customer service level. For their strategic level planning, the SC takes an integrated approach for selection of DCs, retail sales outlets, SC’s own outlets, assigning DCs to sales outlets and assigning orders to suppliers to optimize cost and customer response time. The SC network plan also includes mobile distribution option to distribute limited amount of product from SC’s own outlets to retail outlets to improve customer response time. To obtain improved response time, the SC sets maximum and minimum travelling distances between sales outlets to be: 20 and 60 minutes; and maximum distribution distance between sales outlets and DC to be 150 minutes.

In this section maximum emphasis is given on the analysis of model results to provide managerial insights based on the following: 1)Influence of responsiveness (market response time) on overall SC operation cost considering the two channel marketing, and mobile distribution option; 2) Influence of responsiveness (market response time) on overall SC operation cost considering the two channel marketing when mobile distribution option is excluded; 3) Analyzing one tradeoff solution for model decisions

Very limited input data are presented in this section. Since market response time and overall SC operation cost are decided mainly by the distances (travelling times) for DC- Sales outlet combinations and distance between Sales outlets, such typical distances are presented in Tables 1 and 2.

Table 1: Typical distribution time in minutes between distribution center (DC) to sales outlets								
DC	Sales outlet	Distance (Mins)	DC	Sales outlet	Distance (Mins)	DC	Sales outlet	Distances (Mins)
1	1	47	5	1	82	8	1	115
1	2	48	5	2	74	8	2	126
1	3	72	5	3	79	8	3	97
1	4	70	5	4	63	8	4	107
1	5	75	5	5	71	8	5	130

Table 1 presents distances in minutes for typical DC-Sales outlet combinations. For an example, distance between DC1 to Sales outlet 5 is 75 minutes but between DC 8 to sales outlet 5 is 130, as may be observed in Table 1. For improving Model objective 1 for customer response time (*RET*) the shorter distances for DC-sales outlets are preferable. But distribution cost from a remotely located DC is comparatively lower (Suburb to city) in some cases. This is because most of the cases distribution cost contract is made based on distributing per packet of product not based on distances. For an example, such distribution cost for DC 8 to sales outlets is assumed to vary in the range of U$(1, 4) but for shorter distances, say DCs 1,2, and 5, the distribution cost assumed to vary in the in the range of U $(3,5), for an example.

Table 2: Typical travelling time in minutes between sales outlets								
From	Distances(Minutes) to Sales outlets							
Sales outlets	1	2	3	4	5	6	7	8
1	0	35	46	47	31	44	45	23
2	34	0	41	38	28	34	40	36
7	33	30	24	43	22	42	0	41
8	34	30	33	32	26	46	42	0
15	22	26	40	42	25	41	40	46

Table 2 shows typical assumed travelling time between sales outlets. For an example, travelling time between 1 and 5: 31 min, 2 and 5 is 28 min, but 7 and 5 is 22 min. As discussed, the integrated model considered data similar to typical ones in Tables 1 and 2 for computing market response time *RET*.

Table 3: Data on Supply Management										
Data items	Data on local suppliers					Data on overseas suppliers				
Suppliers	1	2	..	6	7	8	9	..	11	12
Supply LT (days)	4	3	..	9	3	45	40	..	45	37
LT-Std. Deviation (days)	2.5	1.5	..	0	1	3	4	..	2	1
Supply cost $	14.2	17.5	..	14.6	15.9	11.8	12.2	..	12.6	11.5
Capacity (units)	12,935	13,080	..	14,029	14,791	13,661	11,406	..	12,157	11,365

Table 3 presents typical supply management data based on which the model decides procurement of product by assigning supply orders to local and overseas suppliers. Supply lead times (LT) for 7 local suppliers are in the range of 3 to 9 days but for overseas suppliers supply lead times are in the range of 35 to 45 days, as may be seen in Table 3. Assumed randomly standard deviations for supply LT are also presented Table 3. For an example, supply LT for local supplier 1 is 4 days with standard deviation 2.5 days; supply cost and capacity for supplier 1 are: $14.2 and 12,935 units, respectively (Table 3). Similar explanations are applicable for overseas suppliers 8 to 12. The model considers supply cost and LT to select a local or overseas supplier to achieve its cost and response time objectives. Since the SC maintains inventory for supply time LT in addition to safety stock for LT deviations (see constraint (13)), supply LT time is an important consideration here. After selection of supplier based on supply cost and LT, the model decides order quantity based on supply capacity constraint (11).

Model Results

The proposed model is a Bi-objective mixed integer programing model. The model involved 2,598 total variables, 682 integer variables, and 2,970 constraints. The model is solved by using commercial solver LINGO 14 in a standard PC with 64 bit operating system, processor speed 2.80 GHz, and 8 GB RAM. The model is solved for Pareto optima or Efficient Frontier solutions presented in Table 1 and 2 following Rardin (1989). Each of the solution at an average took nearer to 1 minute solver time.
Table 4 presents seven (2 to 8) Pareto optima solutions for Total SC operation cost (*TC*) vs Market response time (*RET*) when the model considered mobile distribution option. Solution 1 minimizes Response time (*RET*) and solution 9 minimizes Total cost (*TC*), as such these are not considered Pareto optima solutions. Based on the Pareto optima solutions 2 to 8, as the model improved customer response (reducing *RET* values) from 15.6 minutes (for solution 8) to 14.4 minutes for (solution 2) cost increased from $1.15 million (solution 8) to $1.37 million (solution 2), as may be observed in Table 4. This increasing trend of *TC* with decreasing of *RET* value is also depicted in Figure 1(please see the legend, it is the firm line). In the Figure these solutions 2 to 8 are identified as S2 wD to S8 wD. wD denotes considerations of mobile distribution option by the solution. Cost increment between solutions 8 and 2 is $(1.37-1.154) million =$0.216million which is almost 18.7% increase but customer response is improved by (15,484-14,068) = 1416 minutes (9.15%). Although this cost increase is a considerable amount, the increase in customer response will improve customer impression about the company to create potential to increase market share which may ultimately decrease cost.

Table 4 : Pareto optima solutions for Total Cost vs Response time with Mobile distribution option

Solution	Response time (RET) in Minutes	Total Cost (TC)	Model Definitions
1	14,068	1.62	minimize Response Time (*RT*)
2	14,068	1.37	minimize *TC* s.t. *RT* ≤ 14,068
3	14,304	1.248	minimize *TC* s.t. *RT* ≤ 14,304
4	14,534	1.211	minimize *TC* s.t. *RT* ≤ 14,534
5	14,776	1.184	minimize *TC* s.t. *RT* ≤ 14,776
6	15,097	1.165	minimize *TC* s.t. *RT* ≤ 15,097
7	15,247	1.161	minimize *TC* s.t. *RT* ≤ 15,247
8	15,484	1.154	minimize *RT* s.t. *TC* ≤$1.154 Million
9	15,484	1.154	minimize Total Cost (TC)

Figure 1: Pareto optima solutions for Total cost vs Response time

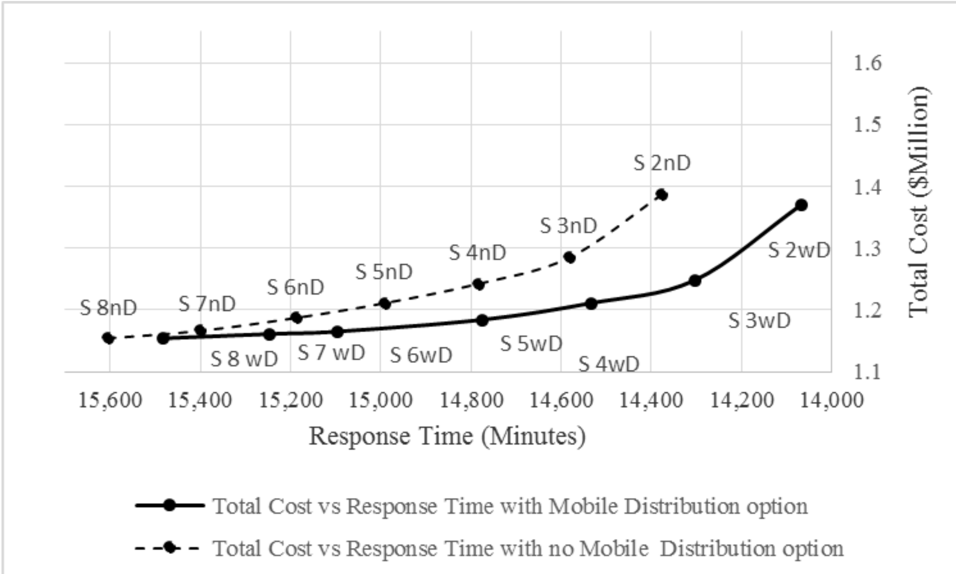

Table 5 presents Pareto optima solutions 2 to 8 with no mobile distribution option, keeping all other model parameters of Table 2 same. For the similar reasons of Table 4, Solutions 1 and 9 of Table 5 are also not Pareto optima solutions. As may be observed in Table 5, as the model improved customer response by reducing *RET* value by (15,604 for solution 8 -14,376 for solution 2) =1,228 minutes, a 7.93% decrease; the total cost increased to $ 1.387 million for solution 2 from $1.154 million for solution 8, making total increment $0.233million, a 20.2% increase. Compared to Pareto optima solutions for similar situations in Table 4, solutions in Table 5 depict a slower decrement (7.93%≤9.15%) in the market response rate but a faster increment rate (20.2%≥18.7%) for the total cost, which is also clearly depicted by trend line shown in Figure 1 (Please see the dotted line in Figure 1).

Table 5 : Pareto optima solutions for Total cost vs Response time with no Mobile distribution option

Solution	Response time (RET) in minutes	Total Cost (TC) in $ Millions	Model Definitions
1	14,376	1.556	minimize Response Time (*RT*)
2	14,376	1.387	minimize *TC* s.t. *RT* ≤ 14,376
3	14,581	1.285	minimize *TC* s.t. *RT* ≤ 14,285
4	14,785	1.242	minimize *TC* s.t. *RT* ≤ 14,785
5	14,991	1.211	minimize *TC* s.t. *RT* ≤ 14,991
6	15,188	1.187	minimize *TC* s.t. *RT* ≤ 15,188
7	15,400	1.166	minimize *TC* s.t. *RT* ≤ 15,400
8	15,604	1.154	minimize *RT* s.t. *TC* ≤$1.154 Million
9	15,602	1.154	minimize Total Cost (*TC*)

It may be observed that for the solutions in Table 5, the best Customer response value is 14,376 for solution 2 with no mobile distribution, compared to 14,068 for solution 2 (Table 4) with mobile distribution option. Here overall customer response improvement rate 7.93% with the increment in cost rate by 20.2%. Since inclusion of mobile distribution option does not increase cost significantly (cost increase is $(1.387-1.37) Million =$ 0.017 million only to obtain improvement in Customer response time by (14376-14068)=308 minutes for the best customer response solution 2 of Tables 4, SC management may plan in favor of including such option for selecting a tradeoff solution.

Solution 2 of Table 4 is selected as an example trade-off solution to illustrate overall decisions for the integrated strategic level SC network design model. For this solution, the model opened: DCs: 1, 2, 4, and 6 out of eight potential locations for DCs; and the model selected all the retail outlets: 1 to14 out of potential fourteen retail outlets considered , and SC operated outlets 15 to 20 out of potential five locations. The model used mobile distribution for each of SC operated outlets to supply product to retail outlets. As decided earlier, model sold 30,000 products through SC operated outlet and 70,000 through retail outlets. Out of sold 70,000 units sold by retail outlets, 15,000 are obtained through mobile DC option from SC's own outlet. It is apparent that these 15,000 units travelled to supply chain operated outlets with the planned overall distributed amount of product (30,000) for the SC operated outlets, and later these products travelled only between the sales outlets for distributing to retail outlets through mobile distribution option. Since, distances between sales outlets are in the range of U (22, 48) minutes compared to distances between DC and sales outlets U (45, 130) minutes, reduction of travelling distance by mobile distribution contributed in improving response time.

The model assigned supply orders to suppliers 1, 3,4,6,8, 9, 10, 11, and 12 out of twelve enlisted suppliers. Out of these 8, 9, 10, 11 and 12 are overseas suppliers. The model procured 73,562 products out of 100,000 from the overseas suppliers and 26,438 products from local suppliers. The model considered constraint (11) to find feasible supplier based on capacity of a supplier. For assigning supply orders the model considered supply cost for each item through equation (22) while computing OSC and cost of inventory carrying for the INV computed in equation (13).Since supply costs for the product from overseas suppliers are more attractive than costs from local suppliers, even with stock carrying cost for high LT of overseas suppliers, the model decided to order more items to overseas suppliers. For an example, based on supply management data in Table 3, lowest supply cost for local suppliers is $14.2 from supplier 1(Table 3) which is higher than the highest supply cost $12.6 of overseas supplier 11, as may observed in Table 3. The model needed to assign order to local supplier to manage overall supply quantity requirements. The model spent $1,744 as inventory carrying cost out of $753,842 for total supply cost. Out of total supply cost, the model spent $370,125 for overseas supply.
As is evident the integrated strategic model effectively designed overall SC network to comply with customer requirements within optimum SC operation cost and responsiveness to customers.

DISCUSSION AND CONCLUSIONS

The research introduced a new and unique strategic level SC network design model for improving market responsiveness and optimizing overall SC operation cost. It decides optimum locations and number of DCs out of the potential locations. The model also plans number of retail outlets and SC operated sales outlets including their locations to obtain optimum customer response time. The model takes an integrated approach for assigning orders to suppliers to optimize cost for overall cost competitiveness of the SC. The design considers two channel marketing to facilitate direct customer contact by opening SC operated sales outlets. The network design model have the option to extend the model for three channel marketing by including e-commerce. The model includes the mobile distribution option to distribute limited amount of product from SC's own outlets to retail outlets to improve customer responsiveness. As such the research proposes a comprehensive strategic level SC design considering multichannel marketing to have direct customer contact by the SC, and improved market responsiveness by deciding number and location of DCs and sales outlets. It improves competiveness in terms of SC operation cost by keeping provision of product realization from local and overseas suppliers and deciding locations and number of DCs for optimum distribution cost.

The research has the scope to explore SC network design for global sourcing and marketing and incorporation of resilience planning to handle global uncertainties as well as business disruptions from natural calamity in a future study.

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