A Review on the detailed Experimental Study of Facility Location Techniques used in Supply Chain Management

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Abstract *Facility location decisions play a vital role in the design of supply chain networks. In this paper, a literature review of facility location models in the context of supply chain management is given. We identify basic features that such models must capture to support decision-making involved in strategic supply chain planning. In particular, the integration of location decisions with other decisions relevant to the design of a supply chain network is discussed. Furthermore, aspects related to the structure of the supply chain network, including those specific to reverse logistics, are also addressed. Significant contributions to the current state-of-the-art are surveyed taking into account numerous factors. Supply chain performance measures and optimization techniques are also reviewed. Applications of facility location models to supply chain network design ranging across various industries are presented. Finally, a list of issues requiring further research is highlighted.*

Keywords — *Supply chain management, Supply chain network, supply chain performance, Optimization technique.*

I. INTRODUCTION

Supply Chain Management encompasses every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer. Supply Chain Management includes managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer.

Facilities are the actual physical locations in the supply chain network where the product is stored, assembled, or fabricated. The two major types of facilities are production sites and storage sites. Decisions regarding the role, location, capacity, and flexibility of facilities have a significant impact on the supply chain's performance. For instance, an auto parts distributor striving for responsiveness could have many warehousing facilities located close to customers even though this practice reduces efficiency. Alternatively, a high-efficiency distributor would have fewer warehouses to increase efficiency despite the fact that this practice will reduce responsiveness.

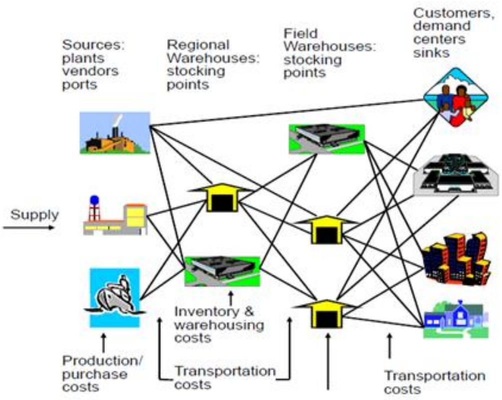

Fig. 1: A Generic Supply Chain

Inventory encompasses all raw materials, work in process, and finished goods within a supply chain. Changing inventory policies can dramatically alter the supply cham's efficiency and responsiveness. For example, a clothing retailer can make itself more responsive by stocking large amounts of inventory and satisfying customer demand from stock. A large inventory, however, increases the retailer's cost, thereby making it less efficient. Reducing inventory makes the retailer more efficient but hurts its responsiveness.

Transportation entails moving inventory from point to point in the supply chain. Transportation can take the form of many combinations of modes and routes, each with its own performance characteristics. Transportation choices have a large impact on supply chain responsiveness and efficiency. For example, a mail-order catalog company can use a faster mode of transportation such as FedEx to ship products, thus making its supply chain more responsive, but also less efficient given the high costs associated with using FedEx. Or the company can use slower but cheaper ground transportation to ship the product, making the supply chain efficient but limiting its responsiveness.

Information consists of data and analysis concerning facilities, inventory, transportation, costs, prices, and customers throughout the supply chain. Information is potentially the biggest driver of performance in the supply chain because it directly affects each of the other drivers. Information presents management with the opportunity to make supply chains more responsive and more efficient. For example, with information on customer demand patterns, a pharmaceutical company can produce and stock drugs in anticipation of customer demand, which makes the supply chain very responsive because customers will find the drugs they need when they need them. This demand information can also make the supply chain more efficient because the pharmaceutical firm is better able to forecast demand and produce only the required amount. Information can also make this supply chain more efficient by providing managers with shipping options, for instance, that allow them to choose the lowest-cost alternative while still meeting the necessary service requirements.

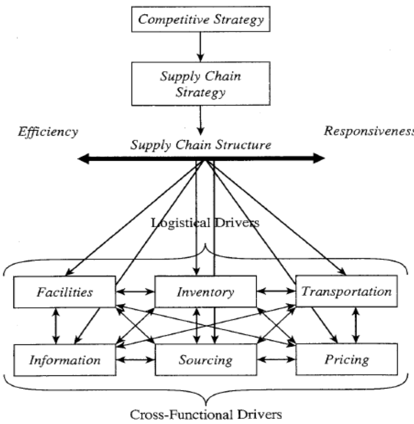

Fig. 2: Supply chain drivers

Sourcing is the choice of who will perform a particular supply chain activity such as production, storage, transportation, or the management of information. At the strategic level, these decisions determine what functions a firm performs and what functions the firm outsources. Sourcing decisions affect both the responsiveness and efficiency of a supply chain. After Motorola outsourced much of its production to contract manufacturers in China, it saw its efficiency improve but its responsiveness suffers because of the long distances. To make up for the drop in responsiveness, Motorola started flying in some of its cell phones from China even though this choice increased transportation cost. Flextronics, an electronics contract manufacturer, is hoping to offer both responsive and efficient sourcing options to its customers. It is trying to make its production facilities in the United States very responsive while keeping its facilities in low-cost countries efficient. Flextronics hopes to become an effective source for all customers using this combination of facilities.

Pricing determines how much a firm will charge for goods and services that it makes available in the supply chain. Pricing affects the behavior of the buyer of the good or service, thus affecting supply chain performance. For example, if a transportation company varies its charges based on the lead time provided by the customers, it is very likely that customers who value efficiency will order early and customers who value responsiveness will be willing to wait and order just before they need a product transported. Early orders are less likely if prices do not vary with lead time.

Facility location decisions are one of the most important decisions in supply chain design. An increasing number of companies are recognizing the need to re - plan their networks as an efficient and effective movement of goods is critical in today’s competitive economies. Facility location decisions are often fixed and difficult to change in the short term. For example, a distribution center with millions of dollars of material handling equipment is very difficult to relocate unless it is planned for the long term. “Facilities are expensive to build and modify while other factors such as routing and inventory decisions can be modified frequently without too much difficulty [4]”. It is important to note that there is a considerable amount of uncertainty such as consumer demand, transportation costs, inventory carrying costs, etc.

II. The Role of Transportation in Supply Chain

Supply chains use a combination of the following modes of transportation:

- Air
- Package carriers
- Truck
- Rail
- Water
- Pipeline
- Intermodal

A. Air

Air carriers offer a very fast and fairly expensive mode of transportation. Small, high-value items or time-sensitive emergency shipments that have to travel a long distance are best suited for air transport. Air carriers normally move shipments under 500 pounds, including high-value but lightweight high-tech products. Given the growth in high technology.

B. Package Carriers

Package carriers are transportation companies such as FedEx, UPS, and the U.S. Postal Service, which carry small packages ranging from letters to shipments weighing about 150 pounds. Package carriers use air, truck, and rail to transport time-critical smaller

C. Packages

Package carriers are the preferred mode of transport for e-businesses such as Amazon.com and Dell, as well as for companies such as W.W. Grainger and McMasterCarr that send small packages to customers.

D. Truck

Trucking is more expensive than rail but offers the advantage of door-to-door shipment and a shorter delivery time.

E. Rail

Rail carriers incur a high fixed cost in terms of rails, locomotives, cars, and yards. There is also a significant trip-related labor and fuel cost that is independent of the number of cars (fuel costs do vary somewhat with the number of cars) but does vary with the distance traveled and the time taken. The price structure and the heavy load capability makes rail an ideal mode for carrying large, heavy, or high-density products over long distances. Transportation time by rail, however, can be long. Rail is thus ideal for very heavy, low-value shipments that are not very time sensitive.

F. Water Transport

Water transport is ideally suited for carrying very large loads at a low cost, however, the slowest of all the modes and significant delays occur at ports and terminals. This makes water transport difficult to operate for short-haul trips. In global trade, water transport is the dominant mode for shipping all kinds of products. Cars, grain, apparel, and other products are shipped by sea.

G. Pipeline

The pipeline is used primarily for the transport of crude petroleum, refined petroleum products, and natural gas. A significant initial fixed cost is incurred in setting up the pipeline and related infrastructure that does not vary significantly with the diameter of the pipeline.

H. Intermodal

Intermodal transportation is the use of more than one mode of transport to move a shipment to its destination. A variety of intermodal combinations is possible, with the most common being truck/rail. Intermodal traffic has grown considerably with the increased use of containers for shipping and the rise of global trade. Containers are easy to transfer from one mode to another, and their use facilitates intermodal transportation.

III. Literature Review

Innumerate research journals have been authored over the years to explore ways in finding the optimum possible way for facility location. However, it's a no-brainer that the models they constructed or the policy they executed varied from one another. The literature survey of some of these journals is enumerated below:

Djafar Wihdat, Amer Yousef, Lee Sang-Heon, et al. (2013) [1] brought on a review paper on long distribution channel's problems. They stated on the basis of a tedious and lengthy overview of literature for quite some time that if the product were to be delivered en route a long distribution channel, the supply chain analysis was none but a moiling task. The fundamental intent revolved around distribution costs and delivery times and the conspicuous problems governing these had to be monitored. Consequently, an optimum long distribution channel could be designed effectively by subjugating problems like a bottleneck, variability, bullwhip effect, high logistics and transportation costs.

Shen Max Zuo-Jun, et al. (2007) [2] worked on a research paper based on integrated supply chain design models. He stated that whenever the number and location of facilities are known with certainty, the sole objective on hand for the decision maker is to prioritize inventory costs and transportation costs. Integrated supply chain design models are generally taken care of by non-linear optimization models whose greatest objective is nothing but cost reduction. He had undergone a survey in the aforesaid research area to materialize his intentions.

Escalante Rocio, Maier-Speredelozzi Valerie et al. (2008) [3] focussed on a research paper on facility location decision model used by multinational companies and the transportation factor influencing it. They opined that even though the transportation factor seems to be a plain one but in reality it comprises of nodes, routes, costs, time, distance, capacity, and demand. They suggested a model for the same and performed a case study on it.

Bidhandi M. Hadi, Yusuff M. Rosnah, Abu Bakar Rizam Mohd et al. (2009) [4] proposed a research paper on mixed integer linear programming model and solution algorithm in multiple contexts to solve network design problems in a supply chain. They prepared a binary mixed integer linear programming problem wherein the binary decision variables are the open-or-close decisions for the facilities and the continuous ones are the transportation flow decisions. They suggested Bender's decomposition to solve the model, but the genuine barrier they encountered was the cracking of the master problem. Also, steps were taken to lessen the number of iterations by finding a near optimal initial solution.

Korpela Jukka, Kylaheiko Kalevi, Lehmusvaara Antti, Tuominen Markku et al. (2002) [5] proposed a supply chain design assembly incorporating some features like pitfall governing a customer-retailer combo, desired service level of customers and blueprint of the supplier company. The target was to provide a restrained production capacity allocation to customers and generate a requisite sales strategy. They explained the model with the aid of a numerical problem via some complex integration methods.

Afshari Hamid, Amin-Nayeri Majid, Ardestanijaafari Amir et al. (2010) [6] suggested a paper on facility location problems with the core theme being the application of inventory decisions to such problems. The root methodology of their research was to execute a case study which helps in minimizing inventory cost, setup cost, and transportation cost. However, the experimentation was undergone on a multi-commodity single period distribution system with a deterministic customer wish.

Teimoori Shima, Zare Khademi Hasan, Nehzad Saber Fallah Mohammad et al. (2014) [7] created a framework for location routing problem with Fuzzy time windows and Traffic time. The objective of the developed framework was to locate suitable spots for warehouses and explore the befitting routes of transportation from these warehouses to customers. They used Fuzzy servicing time window to delve into the routing problems. Also, the delay time in providing service was within the premises of their study. Hence an optimal distribution system was developed by creating a mathematical model.

Rahmaniani Ragheb, Saidi-Mehrabad Mohammad, Ashouri Hojjat et al. (2013) [8] developed an optimization model and solution algorithms for robust capacitated facility location problems. They took into account the uncertainty in demand and costs. They claimed that facilities have limitations on the demand service level and so hindrances may result in customers' contentment. Hence they introduced penalty costs for unsatisfied demands by forming mathematical models. The location for a predefined number of capacitated facilities was optimized by the model reducing the cost of transportation, penalty, and construction of uncovered demands. In each circumstance, the relative regret was non-negative($x>=0$). To solve the problem, an effective heuristic solution algorithm was introduced due to the diverse complexity of the model. They used simulated annealing algorithm to compare the results. Finally, it was found that that the algorithm they suggested was more efficacious and potent in regard to the quality of solutions.

Holo Ba Birome, Prins Christian, Prodhon Caroline et al. (2015) [9] took an initiative in optimizing models and invoking performance evaluation of biomass supply chains. They focused on the gambit of logistics on biomass production and conversion techniques. So, efficient and handsome supply chain designs were recommended to provide conversion facilities with an adequate amount of biomass at sound prices. Some of the resources like costs, energy consumption and environmental aspects were to be optimized. They went through 124 references since 2010 to nurture ideas for the planned proposal. They performed a review study on a number of models to evaluate simulation or mathematical optimization. Eventually, they concluded their study on the basis of the findings and the loopholes were addressed subsequently.

Selim Hasan, Ozkarahan Irem et al. (2006) [10] wrote a research paper elaborating the build-up of a supply chain distribution network design model. The numero uno goal of the research was to minimize cost maintaining rich customer satisfaction level while selecting the best possible number, location and capacity levels of warehouses and plants for product dissipation. The approach of the model was unique from the rest. A Fuzzy modeling approach was the hallmark of this research which took care of the varied demands and ambitiousness of customers and retailers. An interactive fuzzy goal programming (IFGP) solution approach was proposed to evaluate the predestined solution.

Hlyal M., Bassou A.AIT, Soulhi A., Alami J.EL, Alami N.EL et al. (2015) [11] designed a distribution network using a two level capacity location allocation problem (TLCLAP). They stated that a quantity must be delivered through a number of intermediate warehouses while it is being shipped from seaports to fulfill the demand of stores. The foremost aim of the network was the allocation of warehouses and then the allocation of stores to the warehouses. Reduction of global cost was a priority and so a TLCLAP was constructed and utilized. An efficient Genetic Algorithm in distribution logistics network has been furnished for optimal network distribution design.

Dzupire Christopher Nelson, Nkansah-Gyekye Yaw et al. (2014) [12] proposed a research paper on multi-stage supply chain network optimization using genetic algorithms. In the case study undertaken, they designed a bi-objective model to reduce the system-wide costs of a supply chain. They formulated the model keeping in mind the cost reduction policy, uncertainty in demand and cost of products, lead times to name a few. The process demanded hale and effective techniques to choose a set of Pareto fronts used in complex optimization problems. Moreover, evolutionary algorithms were found to be quite useful in this regard.

Melkote Sanjay, Daskin S. Mark et al. (2001) [13] proposed a theory and methodology for capacitated facility location and network design problems. According to them, the designed model finds enormous application in regional planning, distribution, telecommunications, energy management and other allied fields. A classical capacitated facility location problem was included in their developed model. Also, a mixed integer programming formulation of the problem was presented to go with numerous classes of mathematical inequalities. It was essential to boost the Linear Programming relaxation. A study on sensitivity analysis to provided the necessary sagaciousness into the model behavior in reply to the alteration in root problem characteristics.

Giri Sunil, Rai Shankar Siddharth et al. (2013) [14] wrote a research paper on the dynamics of garment supply chain in Indian industries. India is one of the largest garment producers in the world. So their focus of study centralized on the entire supply chain of garment production starting from the import of raw materials to garment export. They tried to explore all the miniature aspects of expostulations encountered in the supply chain and its framework. Data was collected both from secondary sources as well as literature survey from accessible sources. Some visible drawbacks in the supply chain of Indian garment industries were listed thereafter which included visibility, lead time, inventory management, technology, and collaboration. They concluded the study by suggesting appropriate supply chain strategies for every combination of product and industry type.

Sharma Vishal, Giri Sunil, Rai Shankar Siddharth et al. (2013) [15] proposed a research work on the supply chain management of rice in India. They investigated all the practical limitations of the supply chain of rice in India. A huge number of issues are taken care of during the study like inventory management, demand consolidation, inventory reduction etc to throw light on the generalized obstacles in the elongated supply chain. Moreover, procurement issues are also well dealt with and finally they suggested a redesigned supply chain for the same.

Melo M.T., Nickel S., Saldanha-da-Gama F. et al. (2009) [16] gave a literature review on the facility location and supply chain management. They made a detailed study of various facility location models and its basic features and discussed the structure relating to the supply chain network. Elaborated review was also done on supply chain measures and optimization techniques. Furthermore, they presented applications of facility location models to supply chain network design spread across a number of industries.

Jayakumar A. Anand, Krishnaraj C. et al. (2015) [17] suggested a research journal for solving supply chain network gravity location model using LINGO. They stated that the gravity models are the ones used by any manufacturer to locate an industry or factory so as to minimize the transportation cost from both the raw material acquisition route and the finished products shipment route. They also assumed the transportation cost to be growing linearly with the quantity of shipped goods. The distances were calculated as geometric distances between two points on a plane. In this study, they used LINGO to fulfill the aforesaid objectives.

Shukla Abhinav, Vimal Jyoti, Chaturvedi Vedansh et al. (2013) [18] proposed a research work for the analysis of plant layout for reducing production cost. Their intended work was the improvement of plant layout of steel flat manufacturing factory to remove the hindrances in material flow and to reach the pinnacle of productivity level at a relatively subpar cost. They studied the present plant layout and the operation processes of each section like preheating, furnace, rough rolling, intermediate rolling, finish rolling, cutting and inspection. They diagnosed the problems in terms of processing time, slack time, distance moved, material handling cost and processing cost of all the operating sections. Finally, the results revealed that the machine center rough rolling, intermediate rolling, cutting machine and inspection sections must be allocated for the flow of fine materials. They proposed a new plant layout to minimize the distance of material flow and eventually the production cost.

IV. CONCLUSIONS

In this paper, we reviewed the most recent literature on facility location analysis within the context of SCM and discussed the general relation between facility location models and strategic supply chain planning. Moreover, we identified the characteristics that a facility location model should have to adequately address SCM planning needs. We dedicated separate sections to the relation between facility location and SCM, facility location models within SCM, and solution methods as well as application.

As can be easily seen from the various tables throughout the review, many research directions still require intensive research. Stochasticity in SCM is one of them. The literature integrating uncertainty in SCM with location decisions is still scarce. In particular, very few papers address stochastic parameters combined with other aspects such as a multi-layer network structure.

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