CHAPTER 2

A SURVEY OF LITERATURE

2.1 Introduction

According to Oxford Dictionary, the meaning of “survey” is “to look closely and thoroughly at something.” A literature survey or literature review is a revisit, study and investigation of relevant literature materials such as books and publications in a specific research area from wide perspectives in relation to a topic so as to identify gaps, issues, and opportunities in a specific research field. The end result is the summary of work done from the beginning till existing state-of-the-art in the research area highlighting gaps and opportunities for future work.

The objectives of literature review in this thesis are to study and analyze in detail what are location-allocation decisions in SC, multi-objective optimization, its applications in industries, different criteria used for trade-offs and the methods that can be used for multi-objective optimization of SCNs etc. To accomplish these objectives, research materials relevant to the following topics are collected and investigated:

• SCM decisions framework
• Location-allocation decisions in SC
• SCN optimization models
• Multi-objective optimization methods
• Particle Swarm optimization methodology
2.2 Review of location-allocation decisions in SC

Location decisions are the most critical and difficult of the decisions needed to realize an efficient SC as these decisions are less-flexible compared transportation, inventory, and information sharing decisions (Daskin, 1995). In literature, importance of location decisions is found to be fourfold. Since a decade or two, technological advancement in areas of communication and travel has dramatically speeded up the process of industrial globalization. Globalization is the process of increased interconnectivity among countries most importantly in the areas of economics, politics, and culture. This has led to higher opportunities but also to increased competition in business. Hence Companies can locate their facilities anywhere in the world and supply to open markets. Owing to globalised evaluation, Location decisions play important role. Secondly, these decisions are of huge investment and have a long time effect on the economy of an organization. Thirdly efficient and effective distribution of goods is critical, as logistics time and cost are the major concerns. Location decisions affect these distribution activities. Fourthly, location decisions are strategic decisions and decide the SC design which in turn decides whether a SC is efficient or responsive. Thus realizing the importance of Location decisions many researchers have focused on related topics in the late mid 19th century.

The study of location theory formally started in 1909 when Alfred Weber worked on how to position a single warehouse so as to minimize the total distance between it and several customers (Weber, 1929). After that, Location theory gained interest again in 1964 with a publication by Hakimi (1964), who focussed on locating switching centers in a communications network and police stations in a highway system. Later many researchers worked on basic facility location problem formulations which in general can be characterized as static and deterministic. These
problems take constant, known quantities as inputs and derive a single solution to be implemented at one point in time. These fundamental static and deterministic location problems are categorized into Median problems, Covering problems, Center problems etc. As noted by Revelle et al., (1970), when demands are not sensitive to the level of service, location effectiveness is measured by weighing the distance between demand nodes and facilities by the associated demand quantity and calculates the total weighted travel distance between demands and facilities. At the same time the facility location theory was applied to locate warehouses considering best movement of products between its facilities and its customers. These are the location-allocation problems built upon a basic location problem formulation to simultaneously locate facilities and dictate flows between facilities and demands. These problems were reviewed by Scott (1970). They combined a standard transportation problem for allocating flow between facilities with a location problem for siting the facilities. Additional variety of problems include models with multiple commodities, unreliable supply etc. Warszawski and Peer (1973) and Warszawski (1973) were among the first to study the multi-commodity location problem. These models considered fixed location costs, linear transportation costs, and assumed that each warehouse can be assigned at most one commodity. Geoffrion and Graves (1974) considered the capacitated version of the multi-commodity location problem in which they assume that each customer must be served with all the products it requires from a single Distribution Center (DC) or directly from a supplier.

Church and ReVelle (1976) measured the effectiveness of a facility location by determining the average distance travelled by those who visit it. Most of these models focus on travel distance or time to evaluate the location. For some facilities, however, selecting locations which minimize the average distance travelled may not be appropriate, for example, locating emergency service facilities such as fire stations or
ambulances. To locate such facilities, the key factor is “coverage”. A demand is said to be covered if it can be served within a specified time. For a more complete review of covering problems, Schilling et al., (1993) can be referred. Another set of problems called P-center problems or minimax problems, minimizes the maximum distance between any demand and its nearest facility. Daskin (1995) discussed different center problem solution algorithms.

In literature, another set of problems dealt has fixed charge facility location problems which consider a fixed charge associated with locating at each potential facility site. There are two types of problems capacitated and un-capacitated plant location problems. Extensive references to the un-capacitated and capacitated plant location models can be found, in Mirchandini and Francis (1990), Revelle et al., (2008) and capacitated plant location models in Sridharan (1995). Later basic facility location problems were given a new orientation with an integrated approach. This is due to the realization of the fact that failure to take the related inventory and shipment costs into consideration when determining the locations of facilities can lead to sub-optimality. Hence facility location models were developed considering location associated costs as well as production, inventory and distribution costs. Integrated decision making models are in particular focus at coordination of any two of the three important SC decisions. Based on the factors considered they are categorized into 1) Location-routing (LR) models 2) Inventory-routing (IR) models and 3) Location-inventory (LI) models. These problems are extensively reviewed by Shen (2007).

Decision parameters, such as demands, costs etc. change from the decision phase to the implementation phase. But above discussed models treat all parameters as constants. Hence next generation problems addressed the inherent uncertainties in facility location problems. Shen et al., (2003) integrated inventory risk pooling model with location models. Traditional facility location models implicitly assumed that the
facilities will never fail. But facilities do fail due to poor weather, disasters, changes of ownership, or other factors. Such failures may lead to increased costs due to retailer reassignments. Snyder and Daskin (2005) worked in this direction and presented models for choosing facility locations to minimize cost, taking into account the expected transportation cost after the failures of facilities. They used Lagrangian relaxation algorithm to choose facility locations that were both inexpensive under traditional objective functions and also reliable.

2.3 Review of SCN optimization models

Owing to broad spectrum of the SC concept, numerous multi-stage models for SC design and analysis have been developed. Beamon (1998) classifies all theses generally available SC models based on the nature of the inputs and the objective of the study into following four categories. (1) Deterministic analytical models, in which the variables are known and specified (2) Stochastic analytical models, where at least one of the variables is unknown, and is assumed to follow a particular probability distribution, (3) Economic models, and (4) Simulation models. An exhaustive literature survey has been carried out to understand the present status of the work in this area. Brief summary of the literature is presented below.

2.4 Deterministic models

One of the pioneering works to integrate SC activities is done by Glover et al., (1979). They developed a computer-based Production, Distribution, and Inventory planning system for a single period that integrated three SC segments comprised of supply, storage/location, and customer demand planning. The main objective of the proposed system was a network model and diagram that increased the decision maker's insights into SC connectivity. Cohen and Lee (1989) present a deterministic mixed integer, nonlinear mathematical programming model, based on economic order
quantity techniques to maximize the total after-tax profit for the manufacturing facilities and distribution centers. This model is extended by Cohen and Moon (1990) by developing a constrained optimization model, to analyze the effects of various parameters on SC cost considering the additional problem of determining which manufacturing facilities and distribution centers should be open.

Lee and Billington (1993) developed a SC model operating under a periodic review base stock system at Hewlett Packard, and employed a search heuristic to find the optimal inventory levels across the SC. Arntzen et al., (1995) presented an uncapacitated mixed-integer programming model, called Global Supply Chain Model, to evaluate global SC alternatives involving multiple products and multiple echelons. It took into account the interdependence of production, inventory and delivery processes to minimize activity days and costs associated with production, inventory, material handling, and transportation. Min and Melachrinoudis (1999) configure multi-echelon SCNs connecting material flows among suppliers, manufacturers, break-bulk terminals, and customers. Their analytic hierarchy process-based model considers contingency planning associated with SC reconfiguration.

Melachrinoudis and Min (2000) extended their previous work by designing a multi-objective, multi-period mixed integer programming model that determined the optimal relocation site and phase-out schedule of a combined manufacturing and distribution facility from SC perspectives. In an effort to integrate inventory, transportation and location functions of a SC, Nozick and Turnquist (2001) proposed an approximate inventory cost function and then embedded it into a fixed-charge facility location model considering a trade-off between demand coverage and cost associated with the location of automobile Distribution centres. The review of Vidal and Goetschalckx (1997) focuses on production-distribution models
2.5 Stochastic models

A real SC contains many stochastic elements in manufacturing and transportation processes because of uncertainty that are associated with parameters such as customer demands, lead times and costs. In this regard credit goes to Midler (1969), for introducing first time stochasticity in integrated SC models. He developed a dynamic programming model based on optimal control theory for selecting an optimal combination of transportation modes, commodity flows, and re-routing of carriers from customers to suppliers over a multi-period planning horizon. Tapiero and Soliman (1972) utilized optimal control theory to solve multi-commodity transportation, multi-regional production and inventory planning problems over time with uncertain demand. Williams (1981) presents heuristics algorithms for scheduling production and distribution operations in an assembly SCN and also developed a dynamic programming algorithm for simultaneously determining the production and distribution batch sizes at each node within a SCN.

Lee and Feitzinger (1995) and Swaminathan and Tayur (1999) also presented stochastic models by considering postponement (delayed product differentiation) strategies. In an attempt to capture imbalance between supply and uncertain demand in the SC, Fisher et al., (1997) developed a stochastic program to minimize underproduction and overproduction costs. Metters (1997) developed a dynamic programming model that aimed to minimize the expected costs of production, inventory holding, and excess demand penalty, subject to production capacity constraints.

2.6 Simulation models

Uncertainties hamper the SC performance and hence need to be reduced. This, demands for coordination of activities and processes within and between
organizations in the SC to reduce uncertainties and add more value to products. To achieve this, the interdependent relations between decision variables of different processes, stages and organizations need to be established. These relations are dynamic in nature and are very difficult to model analytically. However, the simulation provides a much more flexible and reliable means to model the dynamic and complex networks. Simulation also provides an effective tool to evaluate SC reengineering efforts in terms of performance and risk.

Towill et al., (1992) used simulation techniques to evaluate the effects of various SC strategies on demand amplification. The just-in-time strategy and the echelon removal strategy were observed to be the most effective in smoothing demand variations. Bhaskaran (1998) analysed a SC reengineering project for a blanking and stamping operation at General Motors, using simulation. Swaminathan et al., (1998) provide a SC modelling framework, which enables rapid development of customized decision support tools for SCM, for rapidly reconfiguring the SC based upon studies of several different SCs. The approach uses library-based SC modelling components and utilizes a multi-agent paradigm for modelling and analysis of SC.

SC concepts aim at coordinating the procurement of raw material, production and the distribution of final products to customers to form a single integrated process. The positive impact of optimizing the SC is continuously reported in the literature. Companies such as Dow Brands (Robinson and Muggenborg, 1993), Libbey-Owens-Ford (Martin et al., 1993), General Motors (Blumenfeld et al., 1987) and Digital Equipment Corporation (Arntzen et al., 1995) achieved substantial cost savings through the optimization of the SC. Recent review papers on the SC design problem include Beamon (1998), Slats et al., (1995) and Thomas and Griffin (1996). Von and Nyhuis (2007) concluded that despite spending considerable effort on the design and operation of production planning and control systems, manufacturing companies
experience lower logistic performance. Nyhuis et al., (2007) illustrated the fundamental concepts in designing the production and logistics operations in SCN.

Most of the reviews agree on the benefits of integrating the various echelons of the SC. Being aware that this leads to very complex decision problems, they emphasize the need for good analytical models and efficient solution methods to help decision-making.

2.7 Review of multi-objective optimization methods

Minimizing total cost has been the primitive objective in most of the SC network design models (Cohen and Lee, 1989; Tsiakis et al., 2001). But for a SC, producing products at minimum cost is not the only objective, satisfying the customer is also equally important. Later some researchers started incorporating more than one competing objectives such as improving customer service and reducing cost in their models. Different methodologies found in literature for treating multiobjective optimization problems are the weighted-sum method, the ε-constraint method, the goal-programming method and fuzzy method etc. (Azapagic and Clift, 1999; Zhou et al., 2000; Chen et al., 2003, Chen and Lee, 2004). Sabri and Beamond (2000) formulated a model that incorporated production, delivery and demand uncertainty and provided a multi-objective performance vector for the entire SC network. They adopted multi-objective decision analysis and optimized simultaneously cost, fill rate and flexibility.

Nozick and Turnquist (2001) presented an optimization model which minimizes cost and maximizes service. They used a linear function to approximate the safety stock inventory cost function, which was then embedded in a fixed-charge facility location model. For a review of other multi-objective location models, publication by Shen et al., (2003) can be referred. Chen and Lee (2004) proposed a model which
simultaneously optimized conflicting objectives such as each participant’s profit, the average customer service level, and the average safe inventory level. Guilléna et al., (2004) formulated a multi-objective stochastic Mixed Integer Linear Programming model for SC design, which was solved by using the standard $\varepsilon$-constraint method, and branch and bound techniques. This formulation took into account not only SC profit and customer satisfaction level, but also uncertainty by means of the concept of financial risk, which was defined as the probability of not meeting a certain profit aspiration level.

Shen (2006) addressed profit-maximizing SC design model wherein a company can choose whether to satisfy a customer’s demand. Work of Babu and Gujarathi (2007) focused on solving three stage SC problem using Multi-Objective Differential Evolution algorithm. In their study, three cases of objective functions were considered and Pareto optimal solutions were obtained for each case. The results were compared with those reported using Non-Dominated Sorting GA (NSGA-II) in the literature. Pokharel (2008) developed a two-objective decision-making model for the choice of suppliers and warehouses for design of a SCN for single product. The author considered estimated demand from various retail units, capacity commitment by suppliers, assemblers and third party warehouses as constraints. This work showed that compared to the optimal solutions generated by considering only one objective, the choice of suppliers and warehouses in the network differs when two objectives are considered simultaneously. A literature review by Melo et al., (2009) presents applications of facility location models to the SC network design ranging across various industries highlighting a list of issues requiring further research.

Shu-Hsien et al., (2009) formulated a multi-objective location inventory problem model that integrated the effects of facility location, distribution, and inventory issues and solved that model using NSGA-II. Chia-Lin and Shu-Hsien (2010) developed an
integrated model to solve the distribution network design problem incorporating inventory control decisions into typical facility location models. They developed a multi-objective evolutionary algorithm to arrive at best trade-off solutions. They applied their algorithm for practical data and proved their approach to be efficient. Another work in multi-objective modelling for location decisions was done by Weibing Weng et al., (2011) considering location quality, cost and flexibility from the view of whole SC. Ultimately they concluded that their model can help deciding the right plant location. Work of Bouzembrak et al., (2011) captured a compromise between the total cost and the environment influence. They simultaneously optimized two objective functions; total cost and total CO₂ emission in entire SC. Their work helped to take strategic decisions such as warehouses and distribution center location, building technology selection and processing/distribution planning. Classical GA was improved by Prakash et al., (2012) who presented a Knowledge Based Genetic Algorithm for the network optimization of SC. Their methodology considered three new genetic operators, knowledge based: initialization, selection, crossover, and mutation. The results showed that their methodology improved the performance of the classical GA by obtaining the results in fewer generations. Liu et al., (2012) modelled production, distribution, capacity planning of a global SC considering three objectives; cost, responsiveness and customer service level. The authors solved their model using ε-constraint method which generated a set of Pareto-optimal solutions and the lexicographic minimax method which found a fair solution on Pareto-optimal.

2.8 Review of PSO methodology

The PSO method is a member of the wide category of Swarm Intelligence methods for solving Global Optimization problems. It is originally proposed by Kennedy as a simulation of social behavior, and it is initially introduced as an
optimization method in 1995 (Kennedy and Eberhart, 1995). PSO can be easily implemented and it is computationally in-expensive, since its memory and CPU speed requirements are low. The main difficulty in MOPSO is to pick suitable global best (gbest) and personal best (pbest) to move the particles through search space. In general, a good MOPSO method must obtain solutions with (a) a good convergence, and (b) a diversity and spread along the Pareto-optimal front (Coello, 1999). Parsopoulos and Vrahatis (2002) were one among to study first the performance of the PSO in multi-objective optimization problems and found Pareto front in weighted aggregation cases. Hu and Eberhart (2002) presented a MOPSO that uses dynamic neighbour-hood strategy to obtain the best local guide for each particle in multi-objective optimization problems.

Coello and Lechuga (2002) proposed a MOPSO where the objective space is divided into hyper cubes before selecting the best local guide for each particle in the population. Mostaghim and Teich (2003) worked on a sigma method and “turbulence” operator to improve the convergence and diversity for multi-objective optimization. Hu et al., (2003) introduced a secondary population called extended memory to improve their previous dynamic neighbour-hood PSO approach presented in 2002. Li (2003) proposed an approach in which the main mechanisms of the Non-dominated Sorting Genetic Algorithm (NSGA)-II were adopted in a PSO algorithm. Mostaghim and Teich (2004) proposed a new method which divided the population of the covering MOPSO into sub-swarms. The sub-swarms tried to cover the gaps between the non-dominated solutions found in the initial run. In later research in the field of MOPSO, different approaches have been introduced to identify the local best solution based on memorizing all the non-dominated solutions. These approaches when implemented on standard test problems show that keeping the particle archive improves significantly the effectiveness of technique (Branke and Mostaghim, 2006).
Mehdi Mahnam et al., (2009) developed an inventory model for an assembly SC network wherein the performance of the SC is assessed by two criteria total cost and fill rate using a fuzzy expert system. To solve this bi-criteria model, hybridization of multi-objective particle swarm optimization and simulation optimization were considered. Results indicated the efficiency of the proposed approach in performance measurement. Later Guo and Hou (2010) developed a simulation model to describe the operations of a third-party logistics provider. They developed an MOPSO algorithm combining with the simulation model to identify non-dominated solutions that constitute the trade-off curve between fill rate and total inventory.

Tsou et al., (2011) presented a bi-objective model to represent a fixed order system under lost sales. They considered cycle stock investment and service level to be simultaneously optimized. They utilized a solver based on MOPSO to find the inventory management policies. Study of Qi (2011) focussed on swarm intelligence where particles adjust their flying time adaptively through generations. This ensures escape from local minima. They called this algorithm as Improved Discrete Particle Swarm optimisation and applied it to optimize capacitated vehicle routing problem. An integrated optimization approach using an artificial neural network and a bidirectional particle swarm was proposed by Navalertporn and Afzulpurkar (2011). They applied the approach to the real-life ceramic tile pressing process where multiple responses were considered and their experimental results indicated superior performance of the proposed approach over the conventional ones.

Recently Prasanna and Kumanan (2012) proposed discrete particle swarm algorithm to optimize the SC network with the objectives of minimization of SC coast, minimization of demand fulfilment lead time and maximization of volume flexibility. In the first stage the performance of two global guide selection techniques was evaluated and in the second stage proposed algorithm was compared with Non-
dominated sorting genetic algorithm-II. The results indicated that the proposed approach was effective in producing high-quality Pareto-optimal solutions. The work of Mukhopadhyay and Banerjee (2012) emphasized the stochastic nature of chaotic carrier by embedding the merits of it in a Swarm Intelligence optimization technique. The outcome was a modified improved version of Particle Swarm Optimization and they applied this for global optimization of the unknown parameters of a laser system derived from Maxwell-Bloch’s Equations. Their comparative analysis revealed that the proposed version is effectively tackling the problem of premature convergence with enhanced convergence speed. Mousa et al., (2012) proposed a hybrid multi-objective evolutionary algorithm combining two heuristic optimization techniques, GA and PSO. They applied a hybrid algorithm to various kinds of multi-objective benchmark problems to stress the importance of hybridization algorithms in generating Pareto optimal sets for multi-objective optimization problems. Che (2012) introduced a modified PSO method for multi-echelon unbalanced SC planning. The experimental results inferred that the modified method they developed obtained a better quality solution compared to classical GA and PSO.

2.9 Concluding Remarks

2.9.1 Research Gap and opportunities

After conducting an extensive literature survey, the following observations are made:

- In practice, a SC is likely to be much more complex and several challenging problems are associated with integrated SC multi-objective optimization. These are combinatorial optimization problems and NP-hard in nature.
- Owing to the complexity and large search space involved, the optimal solution cannot be found within a reasonable amount of computational time using traditional methods of optimization.
• Hence, since a decade, researchers are in constant search of meta-heuristic solution procedures to arrive at near-optimal solutions for such complex problems.

The existing SC literature identifies a gap in the development of comprehensive SC models and solution methodologies employed. This gap results in following opportunities:

• Only one investigation by Sabri and Beamon (2000) considers modelling and analysis of general SCs, consisting of suppliers, plants, DCs and customer zones, which are catering to the needs of the majority of the real time industries from medium to large scale. But authors solve it using the alternative iterative procedure using LINGO solver.

• Many of the models consider optimization of only strategic (facility location, demand allocation) or strategic and one tactical (production) decision. Only Sabri and Beamon (2000) consider strategic and tactical decisions such as raw materials and finished goods flow, raw material and product inventory, transportation, production decisions. Hence there are some more opportunities in optimization of integrated decisions.

• No literature is found where in particle swarm intelligence is used for Multi-objective optimization of multi-echelon SCNs. Only Kadadevaramath et al, (2007) have considered in their work single objective optimization of multi-echelon SCNs using PSO.

• Demand is assumed to be stochastic only in four investigations (Shen & Daskin, 2005; Sabri and Beamon, 2000; Nozick & Turnquist, 2001; Chen and Lee, 2004). In particular only one work (Sabri and Beamon, 2000) considers both demand and lead time uncertainty. As real life industries always face uncertainty, related research needs to be strengthened.
2.9.2 Focus of the Study

This literature gap and thereon opportunities created has motivated to carry out, some studies on multi-echelon SCNets focussing on

✓ Design (location or strategic) decisions,

✓ Procurement plan and distribution decisions (allocation & flow decisions), along with production and inventory decisions,

✓ Multi-objective optimization (simultaneous optimization of two or more conflicting objectives) using particle swarm intelligence,

✓ Uncertainty in demand or lead time or both,

Covering general requirement of a majority of real-life manufacturing industries.