CHAPTER 1

INTRODUCTION

1.1 SUPPLY CHAIN MANAGEMENT

Several researchers attempted to define the essence of Supply Chain Management (SCM) into a distinct definition. Its elements are the object of the management philosophy, the target group, the objective(s) and the broad means for achieving these objectives. The objective of SCM is the supply chain (SC) which represents a “network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer” (Christopher 2005). In a wide logic a SC consists of two or more legally separated organizations, being associated by material, information and financial flows. These organizations may be firms producing parts, components and end products, logistics service providers and even the (ultimate) customer. So, the above definition of a supply chain also incorporates the target group - the ultimate customer. SC is a network typically will not only spotlight on flows within a chain, but will have to contract with differing and convergent flows within a complex network resulting from many different customer orders to be handled in parallel. In order to ease complexity, a given organization may concentrate only on a portion of the overall supply chain. As an example, looking in the downstream direction, the view of an organization may be limited by the customers of its customers while it ends with the suppliers of its suppliers in the upstream direction. SCs have become increasingly more global and complex presenting greater
challenges. Contemporary market drifts considerably impact growing complications of supply chains and it is detailed in Figure 1.1.

Because of this growing complications, SC is under fundamental pressure with various elements indicated in Figure 1.2

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**Figure 1.1 Complications in Supply Chain**
Figure 1.2 Various Elements Driving Complexity of Supply Chain

Various decisions to be made cleverly in order to overcome these pressures of supply chain. Two major decision categories are temporal and functional. There are five sub decisions such as sourcing, location, allocation, routing and inventory are involved in functional decision and three sub decisions such as strategic, tactical and operational are involved in temporal decision. The decision framework in complex supply chain is detailed in Figure 1.3.
Figure 1.3 Decision Framework for Supply Chain

There are various elements involved in the decisions and it is highlighted in Figure 1.4. The elements are in two dimensions such as modeling dimension and entity dimensions. In modeling dimensions, there are various elements such as inputs, constraints, outputs, logics, parameters etc are involved. In entity dimension, there are various elements such as product, mode, customer, supplier, plants, lines, warehouses etc.
Among various pressures indicated in Figure 1.2, resource availability is one of the key and recent pressures which driving the organization, society and supply chain as well. As indicated in Figure 1.3, resource allocation is one of the critical decisions which drives the organization in terms of cost and service level.

With the scope of allocation decisions in mind, approximately 120 articles are identified that were published in the last decade, including a few papers that will appear in 2011. Further screening yielded 98 articles from 19 journals that address relevant aspects to our analysis. Of these, 56 were published in 2004 or later, which clearly shows the recent progress this research area is experiencing. For example, compared to the year 2002, the number of publications doubled in 2007 (22 against 11). In particular, the European Journal of Operational Research has been a major forum for the presentation of new developments and research results (in total 44 articles were identified). Other journals such as Computers & Operations Research (18 papers), Interfaces (six papers), Transportation Research (seven papers), and Omega and International Journal of Production Economics (each with six articles) have significantly contributed to this emerging research field.
1.2 RESOURCE ALLOCATION PROBLEMS IN SUPPLY CHAIN

Resource allocation (RA) involves the distribution and utilization of available resources in the system. Because resource availability is usually scarce and expensive, it becomes important to find optimal solutions to such problems. Thus RA problems represent an important class of problems faced by mathematical programmers. Conventionally, such RA problems have been modeled and solved for allocation in single echelon supply chain (SC), single objective allocation, allocation with certainty of static input data, single performance measure driven allocation, disintegrated allocation and routing both in strategic and operational level. Such models that consider the above assumptions / constraints are nominal models and their solutions are denoted nominal solutions. However, in practice, these assumptions are rarely, if ever, true, which raises questions regarding the practicability and validity of the problems and solutions obtained under these assumptions. The allocation problems focusing bi or multiple objectives, dynamic allocation bases on dynamic input data and constraints, multiple performance driven allocation and integrated allocation and routing context are complex combinatorial problems which demand high computational time and effort for deriving compromised near-optimal / optimal solutions. In fact, Mulvey (1981) and Ben-Tal and Nemirovski (2000) showed that such nominal solutions shall become irrelevant in the presence of real-world uncertainty. In this research, RA problems involving flow of resources over a typically, large-scale multi-echelon SC network in an optimal manner is studied. This research focuses on development of models and heuristics for six new and complex sub-classes of RA problems in SC network focusing bi-objectives, dynamic input data, and multiple performance measures based allocation and integrated allocation and routing with complex constraints. These sub-classes have some applications that are of special interest, including those that arise in the areas of warehousing, transportation, logistics, and distribution. These application
domains have important economic value, and high importance is attached to achieve efficient solutions. The diagrammatic representation of resource allocation problem in supply chain is indicated in 1.5.

Figure 1.5 Diagrammatic Representation of Resource Allocation in Supply Chain

The basic elements and position involved in RA problem with basic formulation is detailed:

Set of elements (e.g., personnel, facilities, tasks): \( A = \{a_1, \ldots, a_i, \ldots, a_n\} \)

Set of positions (e.g., locations, processors) \( B = \{b_1, \ldots, b_j, \ldots, b_m\} \)

(now let \( n = m \))

Effectiveness of pair \( a_i \) and \( b_j \) is: \( c(a_i, b_j) \)

\( x_{ij} = 1 \) if \( a_i \) is located into position \( b_j \) and 0 otherwise \( (x_{ij} \in \{0,1\}) \)

The problem is: \[ \max \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} \tag{1.1} \]
Subject to \[ \sum_{i}^{a} x_{ij} = 1 \quad \forall j \] (1.2)

\[ \sum_{j}^{b} x_{ij} = 1 \quad \forall i \] (1.3)

1.3 MOTIVATION OF RESOURCE ALLOCATION PROBLEMS

Semi-structured interview with 40 global manufacturing and service SC executives was conducted to understand and explore the new, critical and challenging constraints and variants of RA problems in the current trend of SC network. Based on the semi-structured interview, the pressing constraints and issues in RA problems are collected. Keeping that as a base, a detailed business and research literature review is executed and six critical RA variants in various dimensions of SC are identified for the current research.

1.3.1 Resource Allocation Variant in Bi-Objective Capacitated Supply Chain Network

Logistics quality is often measured by the logistics manager’s ability to distribute products on specific time and on budget. Thus, the main drive to improve logistics productivity is the enhancement of customer services and asset utilization through a significant reduction in order cycle time (lead time) and logistics costs. Goal of reducing order cycle time often conflicts with the goal of reducing logistics costs. So, a compromised allocation solution is needed for logistics manager. But, at times, priority is dynamic for the objectives based on the situation and so the managers should need set of compromised and non-dominated solutions to choose the best which suits the need (Zhou et al 2003). The allocation is purely based on the minimization of cost and time with equal varying (equal and unequal) capacity and capacity restriction in the source. This RA variant is termed as Bi-Objective Resource Allocation Problem with Varying Capacity (BORAPVC). Applications of BORAPVC are in automotive and process industry which
include warehouse allocation to customers in distribution, supplier allocation to manufacturing plant in sourcing and distributor allocation to retailer in delivery.

1.3.2 Resource Allocation Variant in Bi-Objective Bound Driven Capacitated Supply Chain Network

In the current competitive trend, organization running multiple business units shall face extreme performance variations due to sub-optimal allocation of destination nodes to source nodes. Many companies would like to have a balanced service for all the resources in order to improve the asset utilization and cost reduction in terms of having lower and upper bound service limit for each resource. The goal of allocation of resources with bi-objective and bound conditions is a complex action. Logistics manager is in the need of obtaining a compromised bound driven non-dominated allocation solution to balance the performance variations of resources (Teng et al 2007). The allocation is purely based on the minimization of two objectives namely; cost and service level with varying and bounded capacity (equal and unequal) and capacity restriction in the source. This RA variant is termed as Bi-Objective Resource Allocation Problem with Bound and Varying Capacity (BORAPBVC). Applications of BORAPBVC are in automotive, process and health care industry which include customer allocation to warehouses and patient allocation to hospitals.

1.3.3 Resource Allocation Variant in Multiple Measures Driven Capacitated Multi Echelon Supply Chain Network

When properly designed and operated, the traditional SC has offered customers three primary benefits - reduced cost, faster delivery and improved quality. But managers are increasingly recognizing that these advantages, while necessary, are not always sufficient in the modern business world. A new paradigm is emerging of a more sophisticated SC - one that also
serves as a vehicle for developing and sustaining competitive advantage under a variety of performance measures (Melnyk et al 2010). Allocation in old SC was strategically decoupled and price driven, the allocation in new SC is strategically coupled and value driven with multiple performance measures. The allocation is purely based on the multiple performance measures for multi echelon SC with the consideration of inventory and shortage. This RA variant is termed as Multiple Measures Resource Allocation Problem for Multi-echelon SC (MMRAPMSC). Applications of MMRAPMSC are in manufacturing and process industry.

1.3.4 Resource Allocation Variant in Integrated Decision and Upper Bound Driven Capacitated Multi Echelon Supply Chain Network

A SC is a system of facilities and activities that functions to procure, produce, allocate and distribute goods to customers. SCM is basically a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and end-customers, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs (or maximize profits) while satisfying service level requirements. Although it would be ideal from a research standpoint to develop large scale integrated models consisting of multiple entities with integrated decisions while trying to understand effective SC practices, it is often very difficult to get any useful insights from such large models because they are intractable. When two logistical decisions of the SC namely allocation (a tactical decision) and routing (operational decision) are combined with the varying (equal and unequal) capacity from the source, demand from the destination and with a upper bound on the service quantity or distance, the problem of integrated decision and upper bound driven capacitated multi echelon SC network is formed (Shen 2007). The integrated allocation and routing is purely based on the upper bound on service quantity
for a varying demand oriented multi echelon SC with the consideration of limitation on the number of supply catalyst resource. This RA variant is termed as Integrated Resource Allocation and Routing Problem with Upper Bound (IRARPU). Applications of IRARPU are in manufacturing and service industry which include refuse (waste) collection, urban solid waste management, winter gritting, postal distribution, meter reading and school bus routing.

1.3.5 Resource Allocation Variant in Integrated Decision and Time Driven Capacitated Multi Echelon Supply Chain Network

Time is of the utmost importance in logistics. Time can even be the decisive factor for efficiency and effectiveness of the SC. The Just in Time concept for example, successfully streamlined the inbound logistics for production companies. Service lead times are another well known element in logistics. Agreed service lead times can force choices in the SC processes which are not necessarily the most cost effective or environmentally friendly. The integrated decision with allocation and routing in a time window driven scenario in the capacitated SC network is a challenging problem. The integrated allocation and routing is purely based on the time window for the service at the demanding node with the consideration of travel time of vehicle for a varying demand oriented multi echelon SC with the consideration of limitation on the number of supply catalyst resource (Ronald 1999). This RA variant is termed as Integrated Resource Allocation and Routing Problem with Time Window (IRARPTW). Applications of IRARPTW are in manufacturing and service industry which include urban solid waste management, taxi cab routing, postal distribution and school bus routing.
1.3.6 Resource Allocation Variant in Integrated Decision, Bound and Time Driven Capacitated Multi Echelon Supply Chain Network

Decisions at SC are driven by multiple constraints. The expectation on the service from the customer is multifold but the execution is driven by various practical and real-life constraints. The allocation decision integrated with routing by considering the time constraints of service and bound on the service limit is a challenging scenario in the current trend of SC. The integrated allocation and routing is purely based on the time window for the service at the demanding node with the contemplation of bound on the service for a multi echelon SC with the consideration of limitation on the number of supply catalyst resource (Brauer and Backholer 2009). This RA variant is termed as Integrated Resource Allocation and Routing Problem with Bound and Time Window (IRARPBTW). Applications of IRARPBTW are in manufacturing and service industry which include milk collection and distribution, blood collection and distribution, components collection and distribution, etc.

1.4 SCOPE OF THE PRESENT STUDY

The current study addresses six complex variants of RA problems in multi echelon supply chain with the application to manufacturing and service industry. The objective is to develop solution methodologies for these variants of RA problems in supply chain.

The aim of this research is to address various variants pertain to resource allocation problems in the supply chain context and to develop comprehensive solutions to solve the problem in a reasonable computation time. The objective of this research to address all the below new variants and to propose suitable comparative solution methodologies leveraging heuristics of meta-heuristics or combination approaches:
• resource allocation variant in bi-objective capacitated supply chain network
• resource allocation variant in bi-objective bound driven capacitated supply chain network
• resource allocation variant in multiple measures driven capacitated multi echelon supply chain network
• resource allocation variant in integrated decision and upper bound driven capacitated multi echelon supply chain network
• resource allocation variant in integrated decision and time driven capacitated multi echelon supply chain network
• resource allocation variant in integrated decision, bound and time driven capacitated multi echelon supply chain network