CHAPTER - I

INTRODUCTION

1.1 Introduction

This thesis is concerned with the analysis and control of a large ongoing inventory system of an integrated steel plant. It consists of about 87,000 stock keeping units of spares and consumables. The system has an average inventory level of about 280 million rupees and an annual turnover of about 480 million rupees. Specifically, we present a combined qualitative and analytical method of diagnostic analysis technique to identify the problems of the inventory system. The diagnostic analysis, besides bringing out the shortcomings in the existing system also highlights some important problems of inventory control in a developing economy where shortage is a regular feature. Based on these observations, we suggest an alternative approach to the existing system of inventory control. The suggested system is expected to take care of the problems posed by both the internal factors related to material consumption and the external environment of material supply.

1.2 Inventory Planning and Control

Some of the factors which contribute to the complexity of inventory management problems are : large number of items; variations in the characteristics of the individual items (eg., price, colour, volume, shape, weight, shelf life, deterioration rate, obsolescence rate etc.); variations in the methods of storing (like barrels, pallets, boxes, dust-proof, temperature and humidity controlled rooms); variations in the

nature of demand (eg., bulk, fast, slow etc.); variations in the supply pattern (eg., sources of supply, variable or fixed lot size, free or restricted availability, lead time variation etc.); variations in the importance or criticality of usage (eg., vital, essential, desirable etc.); the interdependence between items (eg., joint ordering, price discount, contraints on inventory level, supply quantities, use in the same product or equipment etc.).

It is, therefore, often said and rightly so (see Peterson and Silver [1979]) that the management of inventory is basically a problem of coping with large numbers and with a diversity of factors external and internal to the organization, Whitin [1957], based on a survey of several U.S. Military establishments concluded that "The failure of the National Military Establishment to establish effective inventory control has been to a large extent due to the sheer magnitude of the task". In spite of tremendous progress in both the theory and practice of inventory control including extensive use of digital computers since 1957, the comment that "inventory control is still a problem of managing diversity and coping with the large magnitudes," of Peterson and Silver [1979] brings into focus the continued relevance of the subject.

The inventory planning and control decision is a complex system problem. Due to the bounded rationality of man (Simon [1957]), this decision problem is beyond the intuitive powers of most decision makers in view of the many

interconnected systems, both physical and conceptual, that have to be coordinated, rationalized, adapted to or controlled. The inventory planning and decision problem has to be ideally viewed from several angles simultaneously including the individual item and its relation to other items, the aggregate inventory constraints, the production, distribution and maintenance plan of the organization, production and distribution plan of the suppliers and possibly the economic environment in general. Since, the capability of the individuals to cope with such a diversity is limited, and the individual manager has his own perception, conviction and compulsions in managing an inventory system, it is necessary that a good inventory system should take the existing resources, managerial capabilities and various other internal and external factors into consideration.

A spares and general stores inventory control system is a coordinated set of rules and procedures which allows for routine decisions of when and how much of each item to order in order to meet the demands of the user departments, and which provides the necessary information to make these decisions effectively. The usual objective of a well designed system is to minimize the total cost and to maximize the customer service within the budgetary limit specified by management from time to time. According to Hax and Candea [1984], the inventory management system consists of four distinct modules. They are (i) the transactions and file maintenance module, (ii) the decision rules module, (iii) the

system integrative module and (iv) the system-management interaction and evaluation module. Since, this thesis is mainly concerned with the second module above, we present a brief discussion on some characteristics of this module in the next section.

1.3 Decision Systems for Inventory Control

Inventory control is one of the few topics which has drawn a lot of attention from both the theoreticians and the practitioners of management science. This is also an area where computer is used extensively both in developed and developing countries. A quick survey of inventory control literature will show that several outstanding books (eg., Whitin [1957], Starr and Miller [1962], Hadley and Whitin [1963], Brown [1967,1971,1977], Johnson and Montgomery[1974], Peterson and Silver[1979] and Hax and Candea[1984]) and over 6000 research papers have been published on the subject in the last thirtyfive years. We do not wish to present a critical review of this voluminous literature here for obvious reasons. However, all these publications on the subject can be classified into two broad streams (Brown [1978a]).

The first stream of publications is concerned with the mathematical abstractions and modelling of the inventory systems and a search for optimal operating policies with a view to minimizing total relevant cost. Some of the important ones include classic papers like Arrow et al. [1953],

Dvoretzky et al.[1952, 1953], books like Whitin [1953], Arrow et al.[1958], Scarf et al.[1963a], Hadley and Whitin [1963], and Naddor [1966] and surveys by Scarf [1963b], Lampkin [1967], Clark [1972], Aggarwal [1974] and Brown [1978b] on the general theory of inventory management. Besides there has been a good deal of theoretical work on special inventory systems for spare parts (see Petrovic et al. [1986] for details), and perishable commodities (eg., Cohen [1976], Nahmias[1975a,1975b,1976], Nahmias and Pierskalla[1973]) etc.

The second stream of publications are concerned with the issues of (i) applying complex inventory theoretic results to practical situations, (ii) estimating demand and various cost factors, (iii) system design and (iv) relating inventory control to other functional areas including manufacturing, marketing and finance. An excellent treatise on the inventory and other related functions like production planning and scheduling is given in Buffa and Taubert[1972]. As this thesis is concerned with the second stream of studies and particularly with the issues in (i) above, we now present a brief review of some of the important literature. Some details of related literature will also be reviewed in appropriate places later.

A good number of excellent books are available which primarily deal with the problems of applying complex theory to practical inventory control settings. Some of the important ones are those of Starr and Miller [1962], Brown [1967, 1971 and 1977], Peterson and Silver [1979] and Hax and Candea

[1984]. In particular, the last but one mentioned above deals with the experiences of the authors in applying the inventory theory in an organization - The Midas Canada Corporation. A good number of papers also deal with the practical aspects of dealing with the inventory control. Some of the important ones are Burgin and Wild [1967], Brown [1978a], Orlicky [1975], Bitran et al.[1982], Conners et al. [1972], Hax et al. [1980], Welch [1969], Girling and Morgan [1973], Lewis [1981] and Murdoch [1965]. This class of literature can be classified into the following important categories:

1.3.1 Diagnostic Studies

This class of literature is concerned with the identification of problems in ongoing inventory systems. The main purpose of a diagnostic study is to uncover potential areas of improvement and to determine if more formal optimization/ simulation models would be useful to identify potential problems within limited time, effort and other resources. This area has perhaps drawn the least attention from researchers and practitioners (Hax and Candea [1984]). Exceptions, however exist in the works of Bitran et al. [1981, 1982], Hax et al.[1980] and Hax and Candea[1984]. While Bitran et al.[1981] used a statistical approach to diagnostic analysis of inventory systems, they have used an optimization approach for the same in their later paper (Bitran et al. [1982]). Further, Hax et al.[1980, 1984] carried out the diagnostic analysis of a production and distribution system. In this thesis (Chapter II) we present a combination of statistical,

optimization and opinion survey approaches to the diagnostic study of a large ongoing inventory system.

1.3.2 Aggregate Controls of Inventory Systems

In this class of literature, the emphasis is either on the evaluation of an ongoing inventory system at aggregate levels or on exploring alternate policies for control of individual items such that the new system satisfies some management specified constraints (space, budget, number of orders etc.). While Girling and Morgan [1973], Peterson and Silver [1979] and Hax and Candea [1984] advocate the use of exchange curve methodologies for the lot-size determination and aggregate inventory performance evaluation, Murdoch [1965] suggests the use of coverage analysis. Yet another method is the aggregate optimization approach (see Lewis [1981] for details). In this thesis(Chapter III), we consider and compare all the three approaches above for the diagnostic study of the existing inventory system and for the ordering policy determination of all independently ordered items.

1.3.3 Inventory Control Policies for Independently Ordered Items

Several authors have dealt with the practical problems of determining ordering policies (when to order and how much to order) for independently ordered items with probabilistic demands and stochastic lead times. Some of the important ones are Burgin [1970], Brown [1967], Herron et al.[1974], Lu et

al. [1962], Schneider [1978], Archibald et al.[1974], Hax and Candea [1984] and Peterson and Silver [1979]. Some authors have also concentrated on the development and evaluation of approximate methods of controlling inventory for large number of independently ordered items. Some of the important ones include Wagner et al.[1965], Erhardt[1979, 1981], Archibald et al. [1974], Kottas and Lau [1979], Peterson and Silver [1979] and Hax and Candea [1984]. Mainly three different approximate approaches are used in practice. They are (i) the normal approximation for fast moving items and Laplace approximation for slow moving items (see Archibald et al.[1974], Peterson and Silver[1979] and Hax and Candea[1984] for details), (ii) power approximation method of Erhardt [1979, 1981] and (iii) four moments method of Kottas and Lau [1979]. In Chapter IV of this thesis we have presented two modifications, one for the power approximation method of Erhardt [1979, 1981] to suit to the requirements of the steel plant inventory under consideration and to give a physically meaningful analogy to the approximating equations and the other a correction for the four moments method of Kottas and Lau [1979]. Besides these modifications, this chapter also presents a comparative study of the three approximation techniques, namely, the power approximation method, the four-moments method and the normal approximation method.

1.3.4 Inventory Management by Exception Rules

Application of Pareto principle to the management of

large inventory systems is a sound concept where emphasis is placed on the desirability of stricter control on only a few important items and relatively less stringent control on the vast majority of items. ABC classification of multiple items based on annual consumption (Dickie [1951]), FSN classification based on the number of movements and VED classification based on the essentiality (or importance from users' point of view) considerations are widely used techniques of separating important items from the less important ones. According to these classifications, while the items belonging to A, F and V categories require very close control, the items belonging to C, N and D categories require the least of resources for control. Further, while ABC classification is very important in retail inventory systems, the later classifications cannot be ignored in spares and consumable inventory systems.

In large multi-item inventory systems, though it is widely believed (and perhaps practised) that differential control is desirable for different items, the literature on inventory is silent about the way practical inventory control rules (i.e., the review period, the order quantity, the reorder level and safety stock decisions etc.) are to be formulated considering the various classifications and their combinations, different users' requirements, protection against shortages and inventory investment constraints. In Chapter V of this thesis, we present a novel approach to finding a satisfactory solution to the problem of inventory policy determination considering the above aspects.

1.3.5 Inventory Policies for Dependent Items

Most literature on inventory control deal with independently ordered items. In reality, however, there are several factors which make the independent ordering of items unrealistic. Some of these factors are, (i) dependent demand structure for discrete manufactured items (see Orlicky [1975] and Plossl and Wight [1971] for details) and spares for important equipment, (ii) dependence introduced because of the storage space or inventory investment constraints (see Lewis [1981], and Peterson and Silver [1979] for details of this aspect), (iii) joint ordering of several items from a single source (see Peterson and Silver [1979], Silver [1965, 1973, 1974, 1975, 1976], Goyal [1974, 1975] and others for details), (iv) procurement of an items from more than one source and (v) procurement of multiple items from multiple sources. The last two types of dependence have not been given their due importance in the literature with the exception of Fabrycky and Banks [1966].

Though several authors have considered the joint replenishment of items forming a group, the problems of delivery schedule and price discount negotiations in joint ordering has not been considered in the literature. We have presented an approach to these problems in Chapter VII of this thesis.

Though split-ordering (i.e., division of total requirements and placement of orders to more than one vendors) is widely practiced in Indian industries to cope up with the

material shortages and uncertainty in delivery, no model exists in the literature to arrive at an optimal or near optimal solution to find how the fraction of the total demand that each of the suppliers should supply, particularly when there are differences in unit prices, and the delivery lead times of the vendors. In Chapter VI of this thesis, we have presented a model that finds a near optimal split-ordering solution to one item and two suppliers problem.

1.4 An Outline of the Thesis

In this section we present a brief outline of the thesis. As pointed out earlier, this thesis is concerned with the analysis of a large ongoing inventory system of spares and consumables of an integrated steel plant. Further, its emphasis is on the development and testing of inventory decision rules considering the peculiarities of steel plants and their internal and external environments. Though the relevance (including their relationship to the existing literature in the field) of this exercise have been discussed earlier, in this chapter, for completeness we present a brief chapterwise summary of the thesis.

Chapter II presents a combined analytical, and subjective approach to diagnostic study of the steel plant's spares and consumable inventory system. Apart from bringing out the shortcomings of the existing system, we present here outline of an alternative approach for finding appropriate inventory decision rules for the system.

Chapter III deals with the aggregate inventory management. Three different approaches (exchange curve, coverage analysis and aggregate optimization) have been applied to groups of items randomly selected for the purpose with a view to assessing the performance of the existing inventory system. Also presented here is a comparative analysis of the three approaches to aggregate inventory management.

Chapter IV is concerned with the approximate methods of finding inventory decision rules for large number of independently ordered regular consumption items. Three alternatives, namely, power approximation method, four-moments method and normal approximation method, have been considered for a comparative study. The suitability (or otherwise) of these approaches have been determined by applying each of them to a sample of randomly selected items.

Chapter V deals with the complex problem of finding satisfactory inventory policies for a large number of independently ordered items whose characteristics like annual consumption, number of movements (occurance of demand) and importance could vary widely. In this chapter, we present a novel approach to find an inventory policy that gives a compromise solution acceptable to finance, stores and consuming departments whose objectives are often conflicting.

In Chapter VI we deal with the problem of procuring the total requirements of an item from several sources where the delivery lead time, unit price and other supply conditions

could significantly differ from one source to another. This practice of split-ordering is often followed to take care of shortage and uncertainty of delivery which is a common feature in most developing countries including India. For this problem, we present a method to find the minimum cost inventory policy of an item procured from two different sources such that the vendor supplies only a fraction of the total requirement.

Chapter VII is concerned with the inventory decision rules when several items are procured from a single source. Here, we develop a joint ordering policy that minimizes the total relevant costs including the transportation cost. Further, it proposes a methodology for adjusting the delivery schedule with a view to encouraging the supplier to supply in full truck loads. It also presents a basis for the price discount and delivery schedule negotiations between the supplier and the buyer.

In Chapter VIII, we summarise the important conclusions of the study and suggest several areas of interest for future research.

To maintain the continuity of thought and to improve the clarity of presentation the additional materials which are required to understand the details have been presented in the form of Appendices.

Finally, all the previous works referred in the body of the thesis have been listed at the end of the thesis.