CHAPTER 1
CHAPTER I
INTRODUCTION

1.1 INVENTORY MANAGEMENT THEORY

The origin of INVENTORY MANAGEMENT begins with the management of household items relating to food, groceries, clothes etc. under the restrictions of the finance, available space or social circumstances. Thus the inventory management helps to cope up with the existing situation regarding the problems related to the routine stock control for such items.

Ford Harris and R. H. Wilson were the pioneers for building up the Inventory Management Theory. They developed the first mathematical model which is very commonly known as ECONOMIC ORDER QUANTITY (EOQ) MODEL or WILSON'S LOT SIZE MODEL.

The problem of inventory management is always crucial for every organisation, entrepreneur and service agencies like government and non-government organisations as well as the development agencies.
The major reasons for establishing any inventory management system can be stated very briefly as under:

1. To run business efficiently
2. To provide an adequate service to the customers
3. To purchase adequate quantity of commodity to get the advantage of sales promotional schemes and discounts
4. To provide safeguard for variation occurred in procurement of commodity or material known as delivery time lag (lead time) allowing for a flexibility in the production process
5. To expand business and to increase profitability by maintaining the reputation of the firm
6. For prompt accessibility of product or service within a given time frame
7. To minimise the cost associated with the inventory system etc..

**Procurement System** is a part of **Inventory Management System**. The terminology which are frequently used in the inventory management system are as under:

**Lead Time** : The time lag that occurs between the placement of an order and its receipt is known as Lead Time.
**Procurement or Order Quantity**: For the procurement of a commodity, the quantity of commodity for which an order is placed is known as Procurement or otherwise Order Quantity.

**Re-Order Level**: The inventory level at which the order for the procurement of commodity is placed is known as Re-Order Level.

**Safety or Buffer Stock**: Generally in the procurement system or inventory system having variable lead time or variable demand, decision is taken to stock certain minimum number of units, so that stock out situation can be avoided. This stock is known as Safety or otherwise Buffer stock.

**Perishability**: Perishability of a commodity may be defined as the decay, damage, spoilage, breakage, quality deterioration etc. Due to perishability, the commodity can not be used further for the predetermined productive activity.

**COST ASSOCIATED WITH THE SYSTEM**

The major intention of inventory theory is to help management in formulating the action strategy in such a way that it minimises the cost associated with the system. The various costs associated with the system are known as procurement cost, inventory holding cost, shortage cost or stock out cost and the loss occurred due to perished units.
PROCUREMENT COST:
Procurement cost comprises of set-up cost and variable cost. This may be explained by set-up cost which is a fixed cost of an order which is independent of procurement quantity and includes the cost due to paper work, transportation cost and other overhead expenses, while variable cost includes the cost of labour, cost of unit purchased and some other costs which are proportional to the number of units purchased.

HOLDING COST:
The inventory holding cost comprises of actual cost and opportunity cost. As purchasing is an inherent activity of any manufacturing or retailing organisation and it has impact on warehouse requirement, actual cost includes the cost of insurance, taxes, breakage, warehouse rent, electricity charges, administrative expenses, etc.. The opportunity cost incurred is due to the capital locked up in inventory rather than having it invested elsewhere which is equivalent to the maximum rate of return that could be obtained from the alternate mode of investment. Therefore the opportunity cost is proportional to the total investment made in the inventory. Hence the opportunity cost and partially actual cost will be proportional to the average number of units in inventory.
To calculate the inventory holding cost with accuracy is a difficult task. However, inventory holding cost incurred is proportional to the average amount in inventory held at any given point of time.

SHORTAGE COST:
This cost occur when system is out of stock. There are two possibilities which arise when system is out of stock. In first situation, order is kept pending and it is to be executed when the goods have arrived. This situation is known as backorder policy approach and in second situation, demand is lost due to the lack of onhand items which is known as lost sale or otherwise lost procurement policy approach.

The shortage cost comprises of costs of lost sales, loss of goodwill, special administrative expenses which might have occurred due to the shortage of goods. Besides this, it also includes the cost occurred due to unproductive resources viz. idle machinery, idle manpower and partially due to the electricity consumption that is required for the shortage situation.

LOSS OCCURRED DUE TO PERISHED UNITS:
This cost is calculated on the basis of how many units are perished in the system during entire time cycle. Certainly this cost is introduced for the perishable nature of
commodity only and for the non-perishable commodity, this cost turns out as zero.

It is an essential requirement to manage the inventory efficiently for each organisation as well as entrepreneur as procurement, demand and supply of goods can not be predicted with certainty. Keeping more inventory than its actual requirement will increase the holding cost and a large amount of capital remains tied up in inventory, while too low inventory results into higher risk of the stockout situations as well as frequent placement of orders to satisfy the demand. This highlights the need to do compromise in the determination of inventory level in such a way that it minimises the associated cost or maximises the gain associated with the system.

In the inventory management theory, question arises for information regarding the future demand pattern. Future demand pattern can be classified into three categories. In the first category, one may know exactly what the future demand will be. In the second category, one may know the probability distribution of future demand and in the third category, one may be entirely ignorant of the likelihood of various levels of future demand. These three categories of demand are known as inventory problem under certainty,
inventory problem under risk and inventory problem under uncertainty respectively.

The process of procurement always has some typical phenomena. The time lag that occurs between the placement of an order and its receipt is one of this phenomena. Generally lead time is considered either as a constant or in some cases it has a well defined probability distribution. Another phenomena is that some procurement decisions are subsequent actions of initial decisions only. In most of the industrial houses, procurement problem involves repeated procurement of raw commodity and hence it falls under continuing process of procurement decision. Thus in the continuing process, the outcome of the first decision has an immediate effect on the subsequent decision.
1.2 OBJECTIVES FOR THE DEVELOPMENT OF PROCUREMENT SYSTEM

From the manufacturer's point of view, customers order may not arrive uniformly over given time point or manufacturer may appoint the sole selling distributors for the product that he has manufactured. Manufacturer need not worry about the stock of the furnished product in both the cases, as plant capacity is fixed, it is not possible to manufacture an amount exceeding this limit nor he can reduce the production time for the furnished product. Thus manufacturer has to manufacture the product continuously and it depends on his production target. According to his production requirement he has to manage the procurement of the raw material and hence determination of procurement quantity for raw material plays a crucial role in the production process.

It may become much more expensive to manage the huge stock of the perishable commodity, as more number of units are likely to be perished before the stock is fully exhausted. Management for small amount of stock may result into the inadequate inventory level due to the perishable nature of the commodity and hence in turn, it increases the setup as well as the shortage cost. Thus care should be taken to determine the procurement quantity which minimises the cost associated with the system.
Certain commodities, especially agricultural crops have typical characteristics. Beside these characteristics, perishability of agricultural crop also depends upon environmental factors, storage facility, mode of transport, holding time etc. Thus it is no longer valid to consider the single rate of perishability as well as the perishability after certain time period.

Hence in the development of the procurement system, rate of perishability can be considered as under:

Perishability occurs

1. During the transaction of the commodity (from the supplier warehouse to the production unit).
2. At the time when there is inventory onhand.

Procurement system is studied to enhance the effectiveness of the production process. The developed procurement system not only helps in the determination of the procurement of perishable commodity but it also helps in reduction of the cost, reduction of the wastage and hence there can be improvement in the utilisation rate as well as the quality of the product. Last but not the least, the development of procurement system helps in the effective coordination among various departments.
1.3 APPLICATION AREAS FOR THE DEVELOPED PROCUREMENT MODELS

Radioactive substances, Photographic films, Crockery and Glass wares, Pharmaceuticals and Chemicals, Horticultural and Agricultural products, Dairy products etc. can be considered as the perishable commodities.

Generally decay occurs in radioactive substances. For photographic film, spoilage may occur. Crockery, glass wares and other certain items suffer from breakages. Besides dairy products, horticultural and agricultural products are affected from the damaged as well as quality deterioration.

Thus application areas for the developed procurement models are corresponding to the various industries especially pertaining to dairy, fruits and vegetables processing industries, agroprocessing industries, pharmaceutical industries etc. as such industries continuously consume commodities most of which are perishable in nature.
1.4 SOME RECENT TECHNIQUES

To develop the object oriented model means a simplified representation of something which is a real one. Thus object oriented model is always, necessarily, a representation that is nearby the real situation. The development of object oriented model requires a set of coordinated decisions as to what aspects of the real system should be incorporated in the model, what aspects can be ignored, what assumptions can and should be made and so on. It is a kind of selection of the essential attributes of the real system and omission of the irrelevant ones.

To derive the conclusions from the developed model, it is important to rationalise, analyse and conceptualise all the components of the deductive process. The model conclusions are then translated into practice cautiously with regards to the possible discrepancies that may arise between the model and its application environment.

Some techniques which are utilised for the inventory management are as under

1. ABC/VED Analysis
2. Mathematical Models
3. Simulation Techniques
4. Just-In-Time Concepts
5. Total Quality Management
ABC/VED ANALYSIS

Sometimes it is desirable to classify the groups of items subject to their consumption or otherwise demand pattern along with the associated price. After classifying them, strategic planning has to be made for the procurement of goods which optimises their utilisation rate. Generally, in such circumstances ABC/VED classification techniques are widely utilised. Usually such kind of situation is prevailing in the batch processing house, general stores etc..

ABC classification:

In this technique, more stress is given to the rates of consumption and thus it works out in terms of their monetary values. Then its classification is done accordingly.

Generally, the items which are important and need high attention are to be classified as A group items, the items which are less important and also need less attention are classified as C group items and rests of the items are classified as B group items.
The General thumb rule for classification of items is as under:

<table>
<thead>
<tr>
<th>Group</th>
<th>Consumption Rate</th>
<th>Monetary value (in percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>70</td>
<td>10</td>
</tr>
</tbody>
</table>

General rules for procurement policy during a cycle are as under:

1. A group items should be ordered frequently.
2. C group items should be ordered once or twice.
3. B group items should be ordered less as compared to A group items and more as compared to B group items.

**VED Analysis:**

In this system of classification, stress is given to the production process.

**VED stands for:**

V: Vital items without which production can stop.
E: Essential items without which temporarily loss of production may occur.
D: Desirable items which are necessary but they do not cause any immediate loss in production.
General thumb rules to maintain safety stock are as under:

(1) Safety stock for vital items should be kept in adequate quantity so that production loss should not occur.

(2) Less quantity of safety stock is required for the essential items as it only makes temporary loss in the stockout situations.

(3) There is no necessity to maintain safety stock for desirable items and items are procured as and when they required.

MATHEMATICAL MODELS

The mathematical models have been classified under two broad categories which are known as deterministic as well as probabilistic inventory models respectively.

In reality, one or the other assumptions made for the procurement of commodity in classical inventory management theory are violated. In the light of this, various mathematical models under restrictive situations and conditions have been developed by several researchers for maintaining the inventory under the existing circumstances. The concepts and theoretical models developed by them are extremely useful. In developing these models, different types of mathematical and statistical techniques can be used.
There is a wide opportunity for the application of the mathematical programming techniques in the inventory management system. The application of mathematical programming techniques should be explored for the inventory management areas.

Fuzzy modeling has been established as an efficient and potentially significant tool for modeling subjective opinion of individuals. In real decision making approach, imprecise human opinion and behaviour are responsible for complexities. Fuzzy decision making under multiple conflict objectives explore the applicability of constrained optimization to seek robustness.

Many real life situations involve multiple criteria which are non-commensurable and conflicting in nature. Fuzzy programming provides flexibility in the decision and added subjective managerial consideration and priorities in the decision making approach.

**SIMULATION TECHNIQUES**

Sometimes advanced mathematical approaches might turn out to be inadequate and only alternative left out is to adopt simulation technique, as this technique has the flexibility to represent model with unique features. Simulation technique
gives indication of the situation if a particular phenomena is a part of the system. This indication helps the decision maker in the strategic planning for the production process.

JUST-IN-TIME CONCEPTS
In prevailing competitive environment in the business field, stress is given to keep or maintain inventory level as small as possible. Just-In-Time concept is an integrated approach for the Material Requirement Planning (MRP) for the production process. The development of KANBAN system for MRP is very much popular. In recent times, Just-In-Time concept becomes much more popular as it ensures smooth flow of business and reduces the amount of working capital drastically by way of reduction in the onhand inventories.

Just-In-Time concept attempts to manufacture products whenever they are required. Thus in JIT environment production is made in smaller batch quantities which in turn increases the number of batches.

The success of MRP has induced the distribution planners to consider some opportunities to gain similar benefits in the distribution activity through the application of the Material Requirement Planning (MRP) concept. This has led to the
development of Distribution Requirement Planning (DRP) concept which is like a mirror image of MRP concept since it identifies the requirement for finished product at the point of demand and then produces aggregated time phased requirement scheduled for each echelon in the distribution system.

TOTAL QUALITY MANAGEMENT

Now a days, TQM becomes an emerging concept for the business environment. TQM concept includes the qualitative improvement in all aspects, viz: work environment, quality of product, quality of service, cost of product, etc. All the factors are considered as an integrated system rather than individual one.

Total Quality Management is a way of managing the effectiveness, flexibilities and competitiveness in the business environment. Working strategy in TQM concept is quite different. As a part of working strategy, various qualitative circles are formed through participatory management approach to improve willingness and enthusiasm among the staff members. Preventive measures are taken for the reduction in qualitative defects through research and developmental project, training and workshop for the users etc.
1.5 LITERATURE SURVEY

Various probabilistic and deterministic inventory models have been discussed by Hadley & Whittin [1963], Naddor [1966], Swarup [1969], Tersine [1994] etc. Inventory management through ABC/VED classification techniques is also discussed by many authors.

Silver [1981] has reviewed the work carried out on inventory management and its implementation process in various organisations. In his research paper, he has highlighted the gap which exists between theoretical development and practical situations and made various constructive suggestions to bridge the gap.

Sharma and Sadiwala [1997] have reviewed the work carried out on multiple inventory system and they have highlighted the areas for further research relating to this field of application.

The existence of randomness in lead time creates problems in determination of the procurement quantity eventhough demand is known. The variation in lead time also influences the variation in demand during lead time period. Hence in such situation, it may not be possible to decide demand pattern exactly. In such a situation, general practice of keeping
buffer stock equivalent to the demand during average lead time period is observed in most of the cases.

Das [1975] has studied (Q, R) inventory system with random lead time and discussed the relative sensitivity of the decision variables along with its performance measure to average lead time. An up-to-date review of the work carried out considering the case of variable lead time was done by Bramson [1962]. Sphicas [1982] has discussed the inventory system considering general distribution for lead time.

As perishability plays a crucial role in the determination of procurement quantity, it received attention by several researchers to make an attempt for the determination of the optimum procurement quantity under the various restrictive situations.

Hadley and Whittin [1963] have discussed the inventory models for items deteriorated at the end of the storage period. Specifically they have considered the problem of News-Boy as well as the problem of Fashion Goods Industries.

Ghare and Schrader [1963] have developed the inventory model by considering Negative Binomial distribution for
deterioration of items. Covert and Philip [1973] have developed the inventory model for deteriorating items by considering two parametric weibull distribution for deteriorating time. These parameters are known as scale and shape parameters respectively. Philip [1974] had generalised the model further by considering three parametric weibull distribution for the deterioration of commodity.

Shah [1976] has generalised Covert and Philip [1963] model by considering general distribution for deterioration, which was further modified by Agrawal [1979] by introducing correction term in the average number of units held at a given time point.

An up-to-date review on the perishable commodity has been done by Nahmias [1982] and Raafat [1991]. The attempts made by them have a great importance as they cover extensive literature survey in the field of perishable commodity. In his research paper, Raafat has highlighted the need of inventory model for the perishable commodity at the time of announcement made for the temporary price discount.

Clark and Rowe [1960] have discussed the various policies related to inventory system. They have explained the EOQ formula for the demand during lead time period. Besides this,
for the given inventory system, they have also discussed various complexities which may arise.

Kaplan [1970] has discussed dynamic inventory model with stochastic lead time, while Liberatore [1979] has also discussed the inventory system with stochastic lead time and established relationship with the EOQ model.

Kalpakam and Sapna [1996] have discussed the \((s, S)\) perishable inventory system for arbitrary distributed lead time when demands occur according to poisson process. Su et al [1996] have discussed inventory system for perishable items considering exponential decay along with stock dependent consumption rate.

Market of a product can be influenced substantially by the frequency of advertisements. In light of this, Budhbbatti and Jani [1986 and 1988] and Shah and Jani [1988] have discussed the inventory system alongwith price mark-up and cost of damaged goods. Song and Zipkin [1993] have developed the inventory model under fluctuating demand environment as so many products are sensitive to the various economic conditions prevailing in the market.
Dave & Jaiswal [1980] have discussed the inventory system for the perishable commodity having constant deterioration rate. Ouyang et. al. [1996] have discussed the inventory system by taking both lead time as well as the order quantity as a decision variable. For this inventory system, lead time was decomposed into components each having different crashing cost for reduction.

Goyal and Gupta [1990] have discussed the simple procedure to determine the optimum order quantity when temporary price discount is offered on bulk quantity purchase for the items. Goyal et al. [1991] have reviewed the work done on the inventory system for the perishable commodity when special incentive price is offered.

With the help of difference equations, Shiue [1990] has discussed the procurement system of perishable commodity for bulk quantity discount. This procurement system allows for the partial backlogging involving lost sales policy approach. In the developed country like India, there are large number of landless agricultural labourers as well as small and marginal farmers. This segment of people are bound to sell a portion of agricultural crops after cultivation takes place. Hence this segment of people can not store in adequate quantity of food grain to meet their requirement.
To understand such a situation, Bhunia and Maiti [1991] have developed inventory model by considering time dependent demand pattern.

The various items, like glass items, ceramic items, crockery items etc. get damaged during the storage period due to accumulated stress of piled stock. Mandal and Maiti [1991] have developed inventory model for such type of items by considering the stock-dependent demand pattern.

Xu and Wang [1990] have developed a \((T_i, S_i)\) inventory policy for the deteriorating items with deterministic demand. For the development of model, dynamic programming approach is utilised to determine optimum procurement quantity.

Goswami and Chaudhuri [1992] have developed the inventory model considering bulk release pattern with linear trend in demand. Pakkala and Achary [1992] have developed the inventory model with two warehousing facilities for the perishable commodity having different deterioration rates at both the warehouses and continuous release of the commodity. Again in 1994, they have developed the inventory model for bulk order release pattern.
Johansen and Thorstenson [1996] have discussed (r,q) inventory system with poisson demand under exponentially distributed lead time. For the development of the model, interest related holding cost has been taken into consideration and decision making strategy has been formulated accordingly.
1.6 SCOPE OF WORK

Chapter 1 describes the brief introduction and summary of the inventory system as well as the objective for this study. A brief review of literature pertaining to this study is also discussed in this chapter.

In chapter 2, the development of the procurement model with lead time following truncated normal distribution under backorder policy approach is given.

Chapter 3 discusses the development of the procurement model having lead time as a truncated normal variate with lost sales policy approach.

It may also be worthwhile to determine Amount Spent Per Unit Consumed (ASPU) rather than the aggregate amount spent on maintaining inventory (TIC). This ASPU (proposed) approach can become more beneficial for the perishable commodity as compared to TIC approach.

In Chapter 4, procurement quantity is determined through ASPU approach and application to POWER PLANT is also highlighted.
Chapter 5 describes the procurement system having lost sales policy approach as well as the procurement system having backorder policy approach considering the aspect of functional behaviour of price. For the determination of procurement quantity, Mathematical Programming Technique is utilised.

In the business world, sales promotional scheme becomes one of the strategies to raise its market share. In such a situation, the determination of the procurement quantity for perishable commodity becomes one of the major concerns. An attempt is made to determine the optimum procurement quantities at two levels for the perishable commodity.

Chapter 6 describes the procurement system for perishable commodity with backorder policy approach in the sales promotional environment. Procurement quantities are determined through Mathematical Programming Technique.

Chapter 7 describes the procurement system for perishable commodity with lost sales policy approach in the sales promotional environment. Procurement quantities are determined through Mathematical Programming Technique.
Agricultural crop has typical characteristics and its price varies during different time segments of the given cycle time. This situation highlights the necessity for determination of the optimum procurement levels during the given time segments. A procurement system pertaining to such agroprocessing unit is described in chapter 8. For the developed procurement system, a linear programming technique is applied to determine the procurement quantities.

Some of the value added products of agroprocessing industries have a fixed life time. For such a processing unit, processing has to be done as per the existing requirement only, otherwise it results into the loss which is equivalent to the cost of perished units.

With the help of Simulation Technique, an attempt is made to answer two relevant questions for such production process house which manages inventory in an effective way.

The above decision making approach suggests to take decisions as under:

(1) Up to which level stock should be piled up?
(2) At what level of value added product, the production process should be restarted?

This decision making approach is briefly explained in Chapter 9.
1.7 FUTURE SCOPE OF WORK

The developed procurement system can be extended for the multi-item procurement model. Besides this, the developed model can be synchronised in the Just-In-Time environment using KANBAN concept under Material Requirement Planning approach.

Some of the selected references pertaining to the study under taken by me are given at the end of this thesis.