CHAPTER 1

INTRODUCTION
1.1 LITERATURE SURVEY:

Operations research being an applied branch, I decided to work in this area with the idea of doing some socially useful work. I came across the reading of opinion of Churchman(1957). I quote it

"More operations research has been directed towards inventory control than towards any other problem area in business and industry."

By his above mentioned opinion I was excited to the extent that I decided to carry out my research work in 'Inventory Control'. The outcome of my toiling efforts in the persuasion of my objective is in the form of this Ph.D. thesis wherein I modestly try to elucidate my findings after giving briefly historical development of the work done in the area/problem of interest.

'Inventory can be considered as an accumulation of physical commodity which can be used to satisfy some future demand for that commodity' says Johnson and Montgomery (1974). The main and foremost reason of maintaining inventory level is to shorten the gap between demand and supply for the commodity under consideration. Any inventory system consists of an input process and output process. The input process refers to supply either by means of production or purchase while the output process refers to demand due to which depletion of inventory occurs. Thus, supply is a replenishment process whereas demand is a depletion process. Ladaney and Sternlieb(1974) have considered an EOQ model for infinite replenishment rate under the influence of the marketing policies. They explicitly relate demand to price and price to cost, and discussed the effect of price variation on demand with the objective of profit maximization. The pricing policies considered were subject to the fixed markup
and known price dependent demand, assuming that the demand curve has constant demand elasticity. Fluctuations in the order quantity are designed to trigger the necessary price changes to satisfy the given demand. Brahmbhatt and Jaiswal(1981) extended this model by including variable markup rate which is considered as a function of the decision variables. Schrader and Krishnan(1976) used an objective as return on investment while Morse and Schneider(1979) used residual income as optimizing criteria in the design of inventory policy. There are several studies on these lines viz. Subramannyam and Kumarswamy (1981), Agrawal and Aylawadi (1988), Jani (1978) Shah and Jha (1991) etc. However, these models considered demand and price to be deterministic and constant.

Wayland(1958) has shown how economic order quantities and decision making based upon the break-even chart analysis are inter related. Kotler(1971) has shown that there is an interaction between the marketing policies and economic order quantities. He determined the optimal price which gave maximum revenue, independent of the ordering quantities, and then derived the economic order quantity treating price and the demand as fixed entries.

The modified EOQ model developed by Arcelus and Srinivasan(1987) argued that the assumption that an inventory management system designed to satisfy a known demand level at a given price is not compatible with the treatment of inventories as an investment. They relaxed the assumption of constant demand and price. They took demand as a function of price, price as a markup on unit cost and unit cost as either constant or subject to number of units purchased. They had decision variable as order quantity and markup rate with maximization of profit(PR), of return on investment(ROI), of residual income(RI) as possible optimizing objectives.
Here, Profit (PR) is defined as the difference between gross revenue and total inventory cost. Return on investment (ROI) is defined as the ratio of profit to the average investment in inventory during the cycle. Residual income (RI) is defined as the difference between net profit and capital charge. Profit, the best known and most widely used index suffers with a major drawback that it is not related to the size of the investment needed to generate the said profit. The measure, Profit, can be used by the managers who do not have the authority to set investment levels for their units. The return on investment, ROI, the ratio of profit to investment relates the magnitude of the profit earned to the corresponding capital requirements, is a more appropriate measure of performance. The use of ROI encourages a more efficient use of assets, since managers are then motivated to invest only if a fair return can be earned rather than as long as a marginal profit increase can be realized. ROI does suffer from the shortcomings. For example, it may encourage managers to raise the ROI level by decreasing or at the best not increasing the capital base. This can be done by lowering the value of the denominator, rather than by increasing the numerator. ROI may also encourage managers to reject investments whose return exceeds firm’s cost of capital, but decrease the unit’s over all ROI. To avoid these problem, Kaplan(1982) advocate the use of residual income as an optimizing criteria. As an absolute measure, RI avoids ROI’s scaling problems. More importantly, it allows for the inclusion risk premiums in the calculations through the assignment of different opportunity costs and subsequently of different capital charges to different investments. However, RI is plagued by the same size problem as PR. Large investment units tend to earn a higher RI then small ones do, even if the latter are more efficient in managing resources.

One of the main conclusions to be drawn from the above discussion is that no short-term performance measure clearly dominates the others. All three have some
theoretical advantages and disadvantages and there is no consensus in the literature as to which measure is more appropriate.

Another stringent assumption of the conventional EOQ model is that the payment for the units received is to be made immediately after the receipt of the order. In practice, the supplier gives some credit period to the retailer to settle the accounts. This amount is giving a kind of incentives in the form of supplying goods as an interest free loan to the buyer. The buyer, in turn, can make the use of this incentive and earn some interest by keeping the amount in an interest earning account. With this idea, Goyal (1985) developed a simple EOQ model with deterministic demand when delay in payments is permissible. The same model was reinvestigated by Chand and Word (1987). Mandal and Phaujdar (1989) extended the results of Goyal (1985) by allowing shortages. Shah (1991) studied this problem when quantity received was uncertain. Using the first two moments of the distribution of the quantity received, Shah (1993) derived modified results of Goyal (1985) by introducing probabilistic order level system when delay in payments is permissible. Shah (1997) extended the model when there is a positive lead time. Shah et al (1997) developed a model when demand increases with time and delay in payments is permissible. The aspect of admissible delay in payments has been extended to the case of two levels of storage by Shah and Shah (1992) which co-relates the idea of Goyal (1985) and that of Hartely (1976).

Thirdly, in classical EOQ formula, it is assumed that all the costs associated with the inventory system remain constant over time. Most of the inventory models developed so far do not include inflation and time value of money as crucial parameters of the system. Probably, low inflation in the economy of western countries during seventies may be the root of this approach in inventory modelling. Today, inflation has become a permanent feature of the economy throughout the world. Buzacott (1975)
developed the first EOQ model taking inflationary effects into account. In his model, a uniform inflation rate is assumed for all associated costs and an expression for the EOQ is derived by minimizing the average annual cost. It is shown that (a) if changes in the price do not depend on the timings of reorder, the inventory charge is low and independent of the inflation rate. (b) if no 'double ticketing' is allowed and the company uses a constant percentage of markup, carrying charge is high and depends on the inflation rate and markup. (c) if the company is allowed a fixed monetary marginal then the EOQ model holds.

Misra (1975) developed an economic order quantity model by taking inflationary effects on inventory systems into account. In this model, a uniform inflation rate for all the costs is assumed and an expression for the EOQ is derived by minimizing the average annual cost. Biermann and Thomas (1977) studied an inventory model considering both inflationary trends and time discounting. They assumed a single inflation rate for all cost factors. They suggested the use of a search procedure to find the EOQ. A similar cost function was derived by Misra and Wortham (1977) and they derived approximation to the EOQ. Misra (1979) analyzed a model incorporating the time value of money and different inflation rates for various costs associated with an inventory system. He concluded that though the optimal order quantities calculated with and without time discounting and inflation are quite different, the corresponding total costs per unit time were very close to that of the EOQ model. Chandra and Bahner (1985) extended the model of Misra (1975) by allowing shortages in inventory and incorporating the finite replenishment instead of the infinite rate of replenishment. Datta and Pal (1991) studied a finite time horizon (T, S,)-policy following the approach of Misra (1975) with linear time dependent demand.
rate, allowing shortages and taking into account the effects of inflation and time-value of money.

In classical inventory models, the ordering cost being constant plays a little role in the determination of the EOQ. However, the time-value of money and inflation invalidates the assumption of constant ordering cost. In realistic situation, there should be a separate inflation rate for each of its cost components (Hadley and Whitin (1963), Van Hees and Monhemius (1972)). The cost components may be divided into two classes. The costs those increase at the inflation rate prevailing within the company are brought under class-I. The costs increasing at the inflation rate of the general economy fall under class-II. Two separate inflation rates Viz : the internal (company) inflation rate and the external (general economy) inflation rate are considered. These two inflation rates can be estimated by simple averaging or weighted averaging, the individual inflation rates of costs in each class. The ordering cost increases at the internal inflation rate and the unit purchase cost at the external inflation rate. The inventory holding cost consists of the opportunity cost and costs including insurance, taxes and the cost of storage. The capital invested in inventory depends on the unit cost which increases at the external inflation rate. The classification of costs vary, depending on the particular features of the inventory system.

The existing literature discusses about maximization of Profit, Return on investment and Residual income as possible objective criteria or cost minimization when delay in payment is permissible or when inflation and time-discounting are allowed, under the basic assumption that unit cost of a unit remains constant and there is no deterioration of units in an inventory. Raafat (1991) and Shah and Shah (2000) gave an up-to date account of the theory of inventory models for deteriorating items.
In the present thesis, we relax these two assumptions. We allow unit price to increase (or decrease) and units may deteriorate in an inventory. Also, an attempt is made to decide optimum purchase quantity and optimum selling price.

The thesis is organized as follows:

1.2 SUMMARY OF THESIS:

In classical EOQ model, it is assumed that the quantity received matches with the quantity ordered, however, in practice, it happens that the quantity received differs from the quantity ordered due to variety of reasons viz, failure of electricity, worker's strike, unavailability of raw material, natural calamities like heavy rain, drought, earthquake. Silver (1976) has developed an EOQ model when quantity received is uncertain and is a random variable with specified mean and variance. In chapter 2, deterministic inventory model is developed under different marketing policies using the concept of variable markup of prices when quantity discounts are offered and quantity received is uncertain. In section 2.2, the model has been extended for deteriorating items. The effect of various parameters on optimum markup, procurement quantity, average expected profit, average expected return on investment and average expected residual income is studied. The dominance of objective functions has been illustrated with the help of graphs.

In chapter 3, an inventory model is developed, when vendor announces fixed price increase in unit cost from some future date, which considers the variable markup concept where actual discount for large purchase is available before price increase becomes effective. The effect of price increase on markup, procurement units and net profit has been analyzed in section 3.1. Section 3.2 deals with above mentioned
situation when units in inventory are subject to deteriorate at a constant rate. Section 3.3 deals with the development of an inventory model when vendor announces price discount in unit cost for short specified time. Now, when there is a temporary price discount, the system will pass on the benefit of lower purchase cost to the customers. Hence, in this case, we use the same value of markup parameter as in the usual purchase cost. Section 3.4 deals with deterioration of units when temporary price discounts in unit cost is offered.

Chapter 4 deals with single-item deterministic demand inventory control models in which effect of deterioration, discount in unit cost and availability of discount in unit cost on procurement quantity and total cost have been studied. It deals with a discount which is not always available. Let $P$ be the probability that a discount is available at a reorder time and hence, $(1-P)$ is the probability that the discount is not available at a reorder time. The decision is: "what quantity should be ordered when a discount is available and what should be order when a discount is not available?" The model is extended for deteriorating items in section 4.2 and section 4.3 discusses on planned shortages under aforesaid situation.

Chapter 5 undertakes the study of some real life situations for which an inventory model is developed when vendor announces fixed price increase in the unit cost from some future date, where actual discounting for large purchases is available.

Silver (1976) developed an EOQ model when the quantity received is uncertain which was extended by Karlo and Gohil (1952). Chapter 6 deals with extension of Kalro and Gohil's model by allowing shortages and deterioration of units in inventory.
The effect of changes in various parameters on the decision variables and total cost have been studied.

Chapter 7 critically studies an inventory system when delay in payments is permissible and when yield is random. In practice, the supplier offers some credit period for settlement of accounts to retailer, which is advantageous, in the sense that he can sell the product during that permissible credit period and earn some interest on the sales revenue during this permissible delay period. The model is formulated by introducing practical aspects regarding payment of a part payment required by the supplier prior to the complete settlement of the account. It is a common practice that a part of the purchase amount is to be paid sometimes during the period of the permissible delay in payment. The part to be paid and the time at which it is to be paid are mutually settled between the supplier and buyer at the time of purchase of goods.

In chapter 8, the effects of inflation and time-value of money on an economic order quantity model for deteriorating items is developed with a linear, negatively trended demand by allowing shortages. The model considers the internal (company) inflation rate and the external (general economy) inflation rate. It is assumed that the units in an inventory deteriorate over the time at a constant rate. The inventory policy is studied over a finite time horizon with several reorder points. The results are discussed with a numerical example and sensitivity analysis of the optimal solution with respect to the parameters of the system is carried out. Several particular cases are discussed at the end of the chapter.

The list of papers published and presented follows chapter 8.

Bibliography is given at the end.