Chapter 1

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1.1 GENERAL:

The word "inventory" means a stock of some kind of physical commodity. The problem of the retailer, or the manufacturer, can be taken as a paradigm. In order to sell an item, he must maintain a stock of that item to satisfy the demand. As his stock reduces, he will order, or produce some quantity of the item so that he can continue to meet the demand for the item. It follows that inventory theory must deal with the logic which does or should underlie logical procedure. In words it might be:

Inventory theory deals with the determination of optimal procedures for procuring stocks of commodities to meet future demand. Thus, the chief characteristic of the inventory theory is: the stocking of anything, whether tangible or not to meet future demand. All inventories whether of tangible or intangible things, do have economic values. To incorporate this Hanssman(1961) suggested definition of inventory as:

An inventory an ideal resource of any kind, provided that such resource has economic value, and hence, Inventory theory deals with the determination of the optimal level of such an ideal resource.

The bare bones of the typical inventory problem has two main aspects: procurement of the commodity and the future demand. The procurement process has two kinds of differentiation. Either there is some time lag between the time when an order is placed and the time when the commodity in question actually received in inventory or there is no time lag between above stated actions. For the present thesis, the time lag is assumed to be zero.
The second aspect, i.e., the future demand can be divided into three categories. First, the future demand remains constant, which is a foremost assumption of the articles defined in this thesis. Second, the probability distribution of future demand is known. Such information is likely to be available if the item in question is one for which records of past demand is available, for example, inventory of tires for a taxicab fleet. This is also called an inventory problem under risk. Third, unawareness of the likelihood of various levels of future demand, for example, production of a new product which there is no existing market analogies. This case will be called an inventory problem under uncertainty.

In the thesis, repetitive kind of inventory decision process is studies. The demand is assumed to be constant over time. Thus, the resolution of any specific inventory problem requires the answers to two questions; viz; i) When or how often should the commodity be ordered?.

ii) How much of the commodity should be ordered on any particular order?

For first answer, there must be a cost associated with ordering too frequently. If this were not the case then the commodity would be ordered with the maximum possible frequency, perhaps a separate order for each item demanded and no analysis would be required. It is because of this cost which creates the inventory problem.

Second question can be answered as: If there were no cost associated with ordering
too much then some enormous quantity would automatically be ordered. Correspondingly, if there were no cost associated with ordering too little then no stock would be kept in inventory. If these costs did not exist there would be no inventory problem in terms of the amount of the commodity to be ordered. Hence, in every inventory problem, there are such costs and the first step of analysis must be to determine what the costs are and then, if possible, to measure them. The usual objective in inventory problems will be the minimization of the total costs which composed of the following relevant costs. The first major class of costs is the procurement costs. It is traditional to distinguish between procurement costs when outside suppliers are involved, the ordering cost and the same kind of cost when the commodity is self supplied, the set-up cost. These costs play an important role in the analytical formulation of the inventory problem. The ordering cost includes all those cost components which result from the processing of an order. In order to send out an order it is necessary to review the given item and determine how much must be ordered.

The second class of the costs will be of the costs of carrying inventory. The amount of money invested in the inventory could be utilized, elsewhere to earn some kind of return. Since it is tied up in inventory it is not available and this fact requires that a cost be assigned to reflect lost earning power. The cost of the money in inventory might be measured by the interest rate paid. The space required to store the inventory of the given item has a storage cost associated with it. This depends on whether there is an alternative use for the space in question. It there is not then the space is a fixed cost for the decision concerning inventory. Many kinds of commodities and
items deteriorate in value during storage. This can result from actual deterioration, obsolescence or even pilferage. This loss in value represents a deterioration cost. In classical inventory problem, the total cost is sum of all above stated costs and there is a single supplier which satisfies the demand.

1.2 LITERATURE SURVEY:

In recent years, yield randomness has become an important research topic in the inventory area. Silver (1976) extended the economic order quantity formulation to include the case where the quantity received from the supplier does not necessarily match the quantity requisitioned. They derived optimal order quantity dependent upon the mean and standard deviation of the amount received. The same model was extended by Shah and Shah (1992,1993) for deteriorating items. Yano and Lee (1995) reviewed the literature on quantitatively oriented approaches for determining lot-size when procurement yields are random. Raafat (1991) presented a up-to-date survey of published inventory literature for deteriorating inventory models. He surveyed those papers that consider the effect of deterioration as a function of the on-hand level of inventory.

In all the above stated models, the minimization of the total cost was the objective. Wayland (1958) discussed the relation between economic order quantities and decision making based upon the break-even-chart analysis and concluded that
they are inter-related. Kotler (1971) showed the interaction between the marketing policies and economic order quantities. He determined the optimal price which will give maximum revenue, independent of the ordering quantities and then derived the economic order quantity treating the price and the demand as fixed quantities.

Ladaney and Sternlieb (1974) considered an EOQ model for infinite replenishment-rate under the influence of the marketing policies. Two alternative types of quantity discounts were considered. The pricing policies considered were subject to the fixed markup of pricing and the varying but known price dependent deterministic demand, assuming that the demand curve has constant demand elasticity. Fluctuations in the ordered quantity are designed to trigger the necessary price changes to meet the given demand. Brahmbhatt and Jaiswal (1981) extended these models by including variable markup rate which is considered as a function of selling price, one of the decision variable. Schroder and Krishnan (1976) considered the return of investment as objective function while Morse and Schneider (1979) considered the residual income as objective function in designing of inventory policy. All these models considered demand and price to be deterministic.

Arcelus and Srinivasan (1987) developed a modified EOQ model assuming that an inventory management system designed to satisfy a known demand at a given price is not compatible with the treatment of inventories as an asset. The assumption of the constant demand and the constant price is relaxed and considered the demand as a function of selling price of unit, the selling price as a markup on unit cost and
the unit cost as either constant or dependent on number of units purchased. The decision variables are the ordered quantity and the markup. Net profit (NP) is defined as the difference between gross revenue and total inventory costs. Return on investment (ROI) is defined as the ratio of the profit and the average investment in inventory during the cycle. Residual income (RI) is defined as the difference between the net profit and the capital charge. NP, ROI and RI are considered as the possible objective functions. Considering NP, the most widely used index suffers from a major drawback that NP is not related to the size of the investment needed to generate the said profit. The measure NP, can be used by the managers who do not have the authority to set the investment levels for their units. ROI, the ratio of the profit to the investment relates the magnitude of the profit earned to the corresponding capital requirements. This is a more appropriate measure of performance. But this may encourage managers to raise the ROI level by decreasing the capital base rather than by increasing the profit. It may also encourage managers to reject investments whose return exceeds firm’s cost of capital but decreases the units of overall ROI. To avoid these problems, Kaplan (1982) advocated the use of residual income as an objective function. Gor and Shah (1994,1997,1998) extended Arcelus and Srinivasan (1987)’s model for deteriorating items and random yield. In all the papers mentioned above, the crucial assumption is that there is a single supplier.

Recently, Gerchak and Parlar (1990) have modelled the tradeoffs involving two suppliers in the EOQ context. They have compared the costs of using two independent suppliers with different yield distributions to the cost associated with a single
source with lower ordering cost and they have found the conditions under which diversification is optimal.

In portfolio theory, it is well-know that risk averse investors should diversify their investments. Levy and Sarnat (1984). In portfolio selection problems, the concave expected utility function of the risk-averse investor is maximized subject to budget constraints.

In the present thesis, we will show, the objective function to be minimized (or maximized) is convex (or concave) for a wide range of parameter values and this would suggest that a similar pattern of diversification might emerge. Using two suppliers may result in reduced overall yield variability, an analysis of the resulting diversification issues suggests that it could be beneficial to order smaller quantities from two suppliers, rather than one large order from a single supplier. The prices charged by two suppliers and the unit holding costs incurred for items purchased from the two sources are different. The lead time is assumed to be zero. The total cost expression is derived as a function of the order quantities from each supplier. The optimal order quantities and the minimum value of the cost function are found explicitly in terms of the problem parameters. These results are used to compare the cost of diversification with the cost of using a single supplier.

The next section deals with outline of the thesis.
First chapter gives the background of the problems discussed in following chapters.

Chapter 2 deals with an EOQ model under the assumption that there exists two suppliers who ship amount ordered quantities and rate of replenishment is either infinite or finite. We analyze this problem for EOQ models under two different situations, viz:

Situation I: When orders are placed simultaneously to the two suppliers.
Situation II: When orders are placed one after the other to the two suppliers.

Analytic results for the optimal order quantities from the two suppliers and the minimum cost of an inventory system are obtained. The models are illustrated with a numerical example.

In chapter 3, an order level lot-size inventory model is developed by allowing shortages to occur. The model is analyzed for above stated situations. Analytic results for optimum order levels, the optimum order quantities and the minimum cost are obtained. Convexity of the objective function is discussed parametrically. A numerical example is given to study interdependence of parameters and its effect on decision variables and total cost.
In chapter 4, we develop an economic order quantity inventory model when units in inventory is subject to deterioration, there exists two sources who ship the ordered quantity. Since, they charge different unit prices and because of deterioration of items in inventory, diversification may be advantageous then using a single supplier. Effect of deterioration on optimum procurement quantities from both the suppliers and the minimum cost are studied by a hypothetical numerical example.

In chapter 5, it is assumed that there exists two suppliers who satisfy the order which is a random function of the amount replenished. The variance of a random yield is partially constant and partially depends on the quantity actually ordered. The optimal order quantities and minimum value of the cost function are found explicitly in terms of problem parameters. A comparison of the single source vs. diversification is studied with the help of hypothetical example.

The above stated model is extended for deteriorating items in an inventory. Effect of deterioration on decision variables and optimizing objective function is studied.

In chapter 6, the effect of diversification is studied on net profit and residual income. The effects of various parameters on decision variables, viz. optimal selling price, optimum procurement quantities from both the suppliers, and objective functions, viz. net profit and residual income are studied.
List of papers published/accepted and presented follows chapter 6. Thesis concludes with Bibliography.
LIST OF SYMBOLS
\[ C_1 = \text{Unit cost charged by supplier 1.} \]
\[ C_2 = \text{Unit cost charged by supplier 2.} \]
\[ Q_1 = \text{No. of units to be procured from supplier 1.} \]
\[ Q_2 = \text{No. of units to be procured from supplier 2.} \]
\[ Y_1 = \text{Random no. of units replenished from supplier 1.} \]
\[ Y_2 = \text{Random no. of units replenished from supplier 2.} \]
\[ b_1 = \text{Bias factor for supplier 1.} \]
\[ b_2 = \text{Bias factor for supplier 2.} \]
\[ \sigma^2_{01}, \sigma^2_1 = \text{constants for supplier 1.} \]
\[ \sigma^2_{02}, \sigma^2_2 = \text{constants for supplier 2.} \]
\[ Q_{1I} = \text{Optimum no. of units to be procured from supplier 1 for situation I.} \]
\[ Q_{2I} = \text{Optimum no. of units to be procured from supplier 2 for situation I.} \]
\[ Q_{1II} = \text{Optimum no. of units to be procured from supplier 1 for situation II.} \]
\[ Q_{2II} = \text{Optimum no. of units to be procured from supplier 2 for situation II.} \]
\[ NP_I = \text{Net profit of an inventory system per time unit in situation I.} \]
\[ NP_{II} = \text{Net profit of an inventory system per time unit in situation II.} \]
\[ RI_I = \text{Residual income of an inventory system per time unit in situation I.} \]
\[ RI_{II} = \text{Residual income of an inventory system per time unit in situation II.} \]
\[ I = \text{Inventory carrying charge fraction per unit per annum.} \]
\[ K = \text{Ordering cost per order.} \quad a = \text{Constant.} \]
\[ b = \text{Constant.} \]
\[ P = \text{Selling price of unit.} \]
\[ T = \text{Shortages cost per unit.} \]