CHAPTER - II

Literature Review
2.1 LITERATURE REVIEW AND SURVEY OF INVENTORY MODELS

Review of literature and survey of the developed inventory models are being treated for consideration in this chapter. Although there is an abundance of the literature of general inventory models, however an attempt has been made to cover some of them which are related to our problems. The aim of this chapter is to present a complete and update picture of inventory theory related to the problems of the thesis. The review of the related literature is an essential aspect of a research work.

2.1.1 Survey of Inventory Models with Inflation

In the classical inventory it is assumed that all the costs associated with the inventory system remain constant over time. Since most decision makers think that the inflation does not have a significant influence on the inventory policy and most of the inventory models developed so far does not include inflation and time value of money as parameters of the system. But, due to large scale of inflation the monetary situation in almost of the countries has changed to an extent during the last thirty years. Nowadays inflation has become a permanent feature in the inventory system. Inflation enters in the picture of inventory only because it may have an impact on the present value of the future inventory cost.
Thus the inflation plays a vital role in the inventory system and production management though the decision makers may face difficulties in arriving at answers related to decision making. At present, it is impossible to ignore the effects of inflation and it is necessary to consider the effects of inflation on the inventory system.

**Buzacott (1975)** developed the first EOQ (Economic Order Quantity) model taking inflationary effects into account. In this model, a uniform inflation was assumed for all the associated costs and an expression for the EOQ was derived by minimizing the average annual cost. **Misra (1975-a, 1979)** investigated inventory systems under the effects of inflation. **Bierman and Thomas (1977)** suggested the inventory decision policy under inflationary conditions.

Economic analysis of dynamic inventory models with non-stationary costs and demand was presented by **Hariga (1994)**. The effect of inflation was also considered in this analysis. An economic order quantity inventory model for deteriorating items was developed by **Bose et al. (1995)**. Authors developed inventory model with linear trend in demand allowing inventory shortages and backlogging. The effects of inflation and time-value of money were incorporated into the model. The inventory policy was discussed over a finite time-horizon with several reorder points. It was assumed that the goods in the inventory deteriorate.
over time at a constant rate. The results were discussed with a numerical example and sensitivity analysis of the optimal solution with respect to the parameters of the system was carried out. Several particular cases of the model were discussed in brief.

Effects of inflation and time-value of money on an inventory model was discussed by Hariga (1995) with linearly increasing demand rate and shortages. Hariga and Ben-Daya (1996) then discussed the inventory replenishment problem over a fixed planning horizon for items with linearly time-varying demand under inflationary conditions. Ray and Chaudhuri (1997) developed a finite time-horizon deterministic economic order quantity inventory model with shortages, where the demand rate at any instant depends on the on-hand inventory at that instant. The effects of inflation and time value of money were taken into account. A generalized dynamic programming model for inventory items with Weibull distributed deterioration was proposed by Chen (1998). The demand was assumed to be time-proportional, and the effects of inflation and time-value of money were taken into consideration. Shortages were allowed and partially backordered. The effects of inflation and time-value of money on an economic order quantity model have been discussed by Moon and Lee (2000). Authors have considered the normal distribution as a product life cycle in addition to the exponential distribution. The
two-warehouse inventory models for deteriorating items with constant demand rate under inflation were developed by Yang (2004). The shortages were allowed and fully backlogged in the models. Some numerical examples for illustration were provided.

Chang (2004) proposed an inventory model under a situation in which the supplier has provided a permissible delay in payments to the purchaser if the ordering quantity is greater than or equal to a predetermined quantity. Shortage was not allowed and the effect of the inflation rate, deterioration rate and delay in payments were discussed as well. Models for ameliorating / deteriorating items with time-varying demand pattern over a finite planning horizon were proposed by Moon et al. (2005). The effects of inflation and time value of money were also taken into account. An inventory model for deteriorating items with stock-dependent consumption rate with shortages was produced by Hou (2006). Model was developed under the effects of inflation and time discounting over a finite planning horizon. The results were discussed with a numerical example and particular cases of the model were discussed in brief. Sensitivity analysis of the optimal solution with respect to the parameters of the system was carried out.

Jolai et al. (2006) presented an optimization framework to derive optimal production over a fixed planning horizon for items with a stock-
dependent demand rate under inflationary conditions. Deterioration rate was taken as two parameter Weibull distribution function of time. Shortages in inventory were allowed with a constant backlogging rate. Two-warehouse partial backlogging inventory models for deteriorating items were discussed by Yang (2006). The inflationary effect was considered in the models. Deterioration rates in both the warehouses were taken as constant. Some numerical examples for illustration were provided and sensitivity analysis on some parameters was made.

Jaggi et al. (2007) presented the optimal inventory replenishment policy for deteriorating items under inflationary conditions using a discounted cash flow (DCF) approach over a finite time horizon. Shortages in inventory were allowed and completely backlogged and demand rate was assumed to be a function of inflation. Optimal solution for the proposed model was derived and the comprehensive sensitivity analysis has also been performed to observe the effects of deterioration and inflation on the optimal inventory replenishment policies. Two stage inventory problem over finite time horizon under inflation and time value of money was discussed by Dey et al. (2008). Chern, Yang, Teng, and Papachristos, (2008) developed an inventory lot-size model for deteriorating items with partial backlogging and time value of money. Roy, Pal and Maiti, (2009) developed a production inventory model
with inflation and time value of money. Demand of the item was stock dependent and lifetime of the product was taken as random in nature with exponential distribution. Learning effect on production and setup cost was incorporated. In their study, model was formulated to maximize the expected profit during the whole planning horizon. Yang, Teng, and Chern, (2010) developed an economic order quantity model, in which shortages were allowed with partial backlogging. The effects of inflation and time value of money were taken into consideration.

2.1.2 Survey of Inventory Models for Deteriorating Items

In recent years, mathematical ideas have been used in different areas in real life problems, particularly for controlling inventory. One of the important concerns of the management is to decide when and how much to order or to manufacture so that the total cost associated with the inventory system should be minimum. This is somewhat more important, when the inventory under go decay or deterioration. Most of the researchers in inventory system were directed towards non-deteriorating products. However, there are certain substances, whose utility does not remain same with the passage of time. Deterioration of these items plays an important role and items cannot be stored for a long time. Deterioration of an item may be defined as decay, evaporation, obsolescence, loss of utility or marginal value of an item that results in
the decreasing usefulness of an inventory from the original condition. When the items of the commodity are kept in stock as an inventory for fulfilling the future demand, there may be the deterioration of items in the inventory system, which may occur due to one or many factors, i.e., storage conditions, weather conditions or due to humidity.

Commodities such as fruits, vegetables and foodstuffs suffer from depletion by direct spoilage while kept in store. Highly volatile liquids such as alcohol, gasoline etc. undergo physical depletion over time through the process of evaporation. Electronic goods, photographic film, grains, chemicals, pharmaceuticals etc. deteriorate through a gradual loss of potential or utility with the passage of time. Thus, deterioration of physical goods in stock is very realistic feature. As a result, while determining the optimal inventory policy of that type of products, the loss due to deterioration cannot be ignored. In the literature of inventory theory, the deteriorating inventory models have been continually modified so as to accumulate more practical features of the real inventory systems.

The analysis of deteriorating inventory began with Ghare and Schrader (1963), who established the classical no-shortage inventory model with a constant rate of decay. However, it has been empirically observed that failure and life expectancy of many items can be expressed
in terms of Weibull distribution. This empirical observation has prompted researchers to represent the time to deterioration of a product by a Weibull distribution. Covert and Philip (1973) extended Ghare and Schraders’ (1963) model and obtain an economic order quantity model for a variable rate of deterioration by assuming a two-parameter Weibull distribution. Philip (1974) presented an EOQ model for items with Weibull distribution deterioration rate.

Pierskalla and Roach (1972) suggested optimal issuing policies for perishable inventory. Misra (1975-b) presented a production lot size model for an inventory system with deteriorating items with variable rate of deterioration while rate of production was finite. An order level inventory model for a system with constant rate of deterioration was presented by Shah and Jaiswal (1977). Aggarwal (1978) and Aggarwal and Jaggi (1989) presented inventory ordering policies for deteriorating items. Goyal (1986) and Gupta and Vrat (1986) suggested inventory models with variable rates of demand. Dave (1986) presented an order level inventory model for deteriorating items. Model was continuous in units but allowed discrete opportunities for replenishment. In this model, demand kept on changing from time unit to time unit and occurs instantaneously at the beginning of each time unit. Deterioration rate was assumed to be constant and lead-time was zero.
A deterministic inventory system with stock dependent demand rate was formulated by Baker and Urban (1988). An inventory model concerning a single item was suggested by Mandal and Phaujdar (1989) for deteriorating items with a variable rate of deterioration. Model was developed with stock-dependent consumption rate and uniform production rate. Shortage was allowed and the excess demand was backlogged as well. The rate of deterioration was assumed first as constant and then variable. Dutta and Pal (1990) presented a note on an inventory level dependent demand rate. Inventory model for deteriorating items with stock dependent demand rate was proposed by Pal et al. (1993). Inventory models for perishable items with stock dependent selling rate were suggested by Padmanabhan and Vrat (1995). The selling rate was assumed to be a function of current inventory level and rate of deterioration was taken to be constant with complete, partial backlogging and without backlogging. Balkhi and Benkherouf (1996) presented a production lot size model for deteriorating items and arbitrary production and demand rates. In this model demand and production were allowed to vary with time in an arbitrary way and shortages were allowed. The rate of deterioration was taken as constant and the method was illustrated with the help of numerical example.
Mandal and Maiti (1997) presented an inventory model for damageable items with fully backlogged shortages for both linear and non-linear damage and demand functions. The authors considered production rate as finite and solved the model with profit maximization criteria together with sensitive analysis. An economic order quantity model for perishable products with nonlinear holding cost was proposed by Giri and Chaudhuri (1998). The demand rate was taken as function of on-hand inventory.

An EOQ inventory model with ramp-type demand rate for items with Weibull deterioration was formulated by Wu et al. (1999).

An order level inventory model for deteriorating items was proposed by Gupta and Agarwal (2000). The demand was taken as a linear function of time and production rate was taken as demand dependent. A production inventory model for deteriorating items with exponential declining demand was discussed by Kumar and Sharma (2000). Time horizon was fixed and the production rate at any instant was taken as the linear combination of on-hand inventory and demand. Aggarwal and Jain (2001) presented an inventory model for exponentially increasing demand rate with time. The items were deteriorating at a constant rate and shortages were allowed. The authors solved the model by two methods. The first method was efficient for
getting accurate results, although, lengthy and complicated while the second method was faster than the first method and thus easy to apply.

Goyal and Giri (2001-a) presented a review of the advances of deteriorating inventory literature since early 1990s. The models available in the relevant literature have been suitably classified by shelf-life characteristic of the inventoried goods. A single-vendor and multiple-buyers production-inventory policy for a deteriorating item was formulated by Yang and Wee (2002). Production and demand rates were taken to be constant. A mathematical model incorporating the costs of both the vender and the buyers was developed.

An order level inventory model for deteriorating items with an exponential increasing demand was proposed by Sharma and Singh (2003). An order-level inventory problem for a deteriorating item with time dependent quadratic demand was presented by Khanra and Chaudhuri (2003). The inventory was assumed to deteriorate at a constant rate and shortages were not allowed. A production-inventory model for a deteriorating item over a finite planning horizon was presented by Sana et al. (2004). Deterioration rate was taken as constant fraction of the on-hand inventory. The demand was taken to be linear time-varying function. An economic production quantity model for deteriorating items was discussed by Teng and Chang (2005). Demand
rate was taken as dependent on the display stock level and the selling price per unit. A deteriorating multi-item inventory model with limited storage capacity was suggested by Mandal et al. (2006). The demand rate for the items was finite and deterioration rate was taken to be constant. The replenishment rate was taken as constant. The problem was supported by numerical examples. A note on the inventory models for deteriorating items with ramp type demand was developed by Deng et al. (2007). They have proposed an extended inventory model with ramp type demand rate and its optimal feasible solution. Liao (2008) considered an EOQ model with non-instantaneous receipt and exponentially deteriorating items under two-level trade credit. Chung (2009) explored a complete proof on the solution procedure for non-instantaneous deteriorating items with permissible delay in payment.

2.1.3 Survey of Inventory Models with Permissible Delay in Payments

There have been a lot of discussions in the existing literature for the possible extension of the basic economic order quantity model to a number of situations where its assumptions are not valid up to now. A business either manufactures the products it sells or it purchases the products to sell from other businesses. In either case, an increase in inventory usually involves a corresponding increase in accounts payable.
Raw materials used in the production process are purchased on credit, and many other manufacturing costs are not paid for immediately. Products from other businesses are bought on credit. Instead of making immediate cash payment when inventory is increased, a business delays payment, perhaps by a month or so.

In today’s business transactions, it is more and more common to see that the customers are allowed some grace period before they settle the account with the supplier. This gives a very advantage to the customers due to the fact that they do not have to pay the supplier immediately after receiving the product, but instead, they can delay their payment until the end of the allowed period. The customer pays no interest during the fixed period they have to settle the account, but if the payment is delayed beyond that period, interest will be charged. The permissible delay in payments brings some advantages to the buyer, as he would try to earn some interest for the payment received during this period. When a supplier allows a fixed time for settling the account, he is actually giving a loan to the buyer without interest during this period. Therefore, it is economical to delay in the settlement of accounts to the last moment of the permissible delay in payments.

Inventory policy with trade credit financing was formulated by Haley and Higgins (1973). The effect of payment rules on ordering and
stock holding in purchasing was suggested by Kingsman (1983). Different inventory policies with trade credit was developed by Chapman et al. (1984) and Chapman and Ward (1988). Goyal (1985) was the first to develop the economic order quantity under conditions of permissible delay in payments. Author has assumed that the unit selling price and the purchase price are equal. In practice, the unit selling price should be greater than the unit purchasing price. Aggarwal and Jaggi (1995) developed ordering policies of deteriorating items under permissible delay in payments. The demand and deterioration were consumed as constant. Retailer’s pricing and lot sizing policy for exponentially deteriorating products under the condition of permissible delay in payments was discussed by Hwang and Shinn (1997). Jamal et al. (2000) presented optimal payment time for a retailer under permitted delay of payment by the wholesaler. The wholesaler allowed a permissible credit period to pay the dues without paying any interest for the retailer. In the study, a retailer model was considered with a constant rate of deterioration. An inventory model for initial-stock-dependent consumption rate was suggested by Liao et al. (2000). Shortages were not allowed. The effects of inflation rate, deterioration rate, initial stock-dependent consumption rate and delay in payments were discussed.
Chang and Dye (2001) developed an inventory model for deteriorating items with partial backlogging and permissible delay in payments. Chung et al. (2002) have discussed the inventory decision for EOQ inventory model under permissible delay in payments. An EOQ model for deteriorating items with credit policy was discussed by Chang et al. (2003). Lot sizing decision policy was presented by Chung and Liao (2004). In this policy trade credit was depending on the ordering quantity. Teng et al. (2005) presented an optimal pricing and ordering policy under permissible delay in payments. Deterioration rate was taken as constant and shortages were not allowed in the study. The optimal ordering policy in a DCF analysis for deteriorating items was suggested by Chung and Liao (2006). In this policy trade credit was also depending on the ordering quantity.

Huang (2007) developed optimal retailer’s decisions under two levels of trade credit policy within the economic production quantity (EPQ) framework. Author has assumed that the supplier would offer the retailer a delay period and the retailer also adopted the trade credit policy to stimulate his/her customer demand to develop the retailer’s replenishment model. Replenishment rate was taken as finite. Sana and Chaudhuri (2008) formulated the retailer’s profit maximizing strategy. Increasing deterministic demands were discussed in the environment of
permissible delay in payment and discount offer to the retailer. An inventory model under two levels of trade credit policy was proposed by Jaggi et al. (2008) with credit-linked demand.

2.1.4 Survey of Supply Chain Inventory Models

One of the most important topics in the study of the management of contemporary manufacturing and distribution is supply chain management (SCM). Inventory management is an essential process for all parties engaged in supply chain activities, from the procurement of raw materials through to the delivery of finished goods. The effective execution of this process has a major influence on both the financial and operational performance of an organization.

While many may argue that inventories are undesirable and should be eliminated from the supply chain, the fact remains that organizations require inventory in order to operate effective and to ensure the smooth operation of their day-to-day business. Notwithstanding the critical importance of inventories, companies have to keep in mind that inventories can also cause adverse effects and often disguise other underlying issues in the supply chain. Managing inventory can be both a complicated and critical process given the conflicting business objectives that can occur with in an organization and across multiple enterprises.
Supply chain management can be defined as “Supply chain management is the coordination of production, inventory, location and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served.”

The term “supply chain management” arose in the late 1980s and came into widespread use in the 1990s. Prior to that time, business used terms such as “logistics” and “operations management” instead.

There is a difference between the concept of supply chain management and traditional concept of logistics. Logistics typically refers to activities that occur with in the boundaries of a single organization and supply chains refer to networks of companies that work together and coordinate their actions to deliver a product to market. Also, traditional logistics focuses its attention on activities such as procurement, distribution, maintenance and inventory management. Supply chain management acknowledges all the traditional logistics and also includes activities such as marketing, new product development, finance and customer service.

In the wider view of supply chain thinking, these additional activities are now seen as part of the work needed to fulfill customer requests. Supply chain management views the supply chain and the
organizations in it as a single entity. It brings a systems approach to understanding and managing the different activities needed to coordinate the flow of products and services to best serve the ultimate customer. This systems approach provides the framework in which to best respond in business requirements that otherwise would seem to be in conflict with each other.

Taken individually, different supply chain requirements often have conflicting needs. For instance, the requirement of maintaining high levels of customer service calls for maintaining high levels of inventory, but then the requirement to operate efficiently calls for reducing inventory levels. It is only when these requirements are seen together as part of a large picture that ways can be found to effectively balance their different demands.

Effective supply chain management requires simultaneous improvements in both customer service levels and the internal operating efficiencies of the companies in the supply chain. Customer service at its most basic level means consistently high order fill rates, high on-time delivery rates and a very low rate of products returned by customers for whatever reason. Internal efficiency for organizations in a supply chain means that these organizations get an attractive rate of return on their investments in inventory and other assets.
The effective management of supply channel inventories is perhaps the most fundamental objective of supply chain management. Manufacturers procure raw material and process them into finished goods, and sell the finished goods to distributors, then to retailer and/or customer. When an item moves through more than one stage before reaching the final customer, it forms a “multi-echelon” inventory system. A large amount of researches on multi-echelon inventory control has appeared in the literature during the last decades.

Clark and Scarf (1960) were the first to study the two-echelon inventory model. They proved the optimality of a base stock policy for the pure serial inventory system and developed an efficient decomposing method to compute the optimal base stock ordering policy. Sherbrooke (1968) considered an ordering policy of two-echelon model for warehouse and retailer. It is assumed that stock-outs at the retailers are completely backlogged. Van der Heijden et al. (1997) presented stock allocation policies in general single-item and N-echelon distribution systems, where it is allowed to hold stock at all levels in the network. Diks and De Kok (1998) determined a cost optimal replenishment policy for a divergent multi-echelon inventory system. A joint replenishment policy for multi-echelon inventory control was proposed by Axsater and Zhang (1999).
was developed by Rau et al. (2003). An optimal joint total cost has been derived from an integrated perspective among the supplier, the producer and the buyer. A deteriorating item inventory model in a supply chain was proposed by Wu and Wee (2005). Shortages in inventory were allowed and fully backlogged. Two-echelon inventory model with lost sales was proposed by Hill et al. (2007). A two level supply chain in which production interruptions for restoring of the quality of the production process coordinated by Ahmed et al.(2008). Wong et al. (2009) proposed a two-echelon supply chain with a single supplier serving multiple retailers in vendor-managed inventory (VMI) partnership.

2.1.5 Survey of Partial Backlogging Inventory Models

An important issue in the inventory theory is related to how to deal with the unfulfilled demands which occur during shortages or stock outs. In most of the developed models researchers assumed that the shortages are either completely backlogged or completely lost. The first case, known as backordered or backlogging case, represent a situation where the unfulfilled demand is completely back ordered. In the second case, also known as lost sale case, we assume that the unfulfilled demand is completely lost.
Furthermore, when the shortages occur, some customers are willing to wait for backorder and others would turn to buy from other sellers. In many cases customers are conditioned to a shipping delay and may be willing to wait for a short time in order to get their first choice. For instance, for fashionable commodities and high-tech products with short product life cycle, the willingness of a customer to wait for backlogging is diminishing with the length of the waiting time. Thus, the length of the waiting time for the next replenishment would determine whether the backlogging would be accepted or not. In many real life situations, during a shortage period, the longer the waiting time is, the smaller is the backlogging rate would be. Therefore, for realistic business situations the backlogging rate should be variable and dependent on the waiting time for the next replenishment. Many researchers have modified inventory policies by considering the “time proportional partial backlogging rate”.

Some researchers have developed inventory models in which the proportion of customers who would like to accept backlogging is the reciprocal of a linear function of the waiting time up to the arrival of next lot. Some researches have been done in which backlogging rate is taken as exponential decreasing function of time. The inventory involving backlogging and lost sales is called mixture inventory. Mixture inventory means mixture of backorders and lost sales. Therefore, in the third case, it
is assumed that a fixed fraction of the unfulfilled demand during the stock out stage is back ordered while the remaining fraction is lost. Thus, concept of partial backlogging should not be ignored in inventory models of shortage.

**Zangwill (1966)** developed a production multi-period production scheduling model with backlogging. Inventory models with a mixture of backorders and lost sales were formulated by Montgomery et al. (1972). Rosenberg (1979) presented the analysis of a lot-size model with partial backlogging. Mak (1987) proposed optimal production-inventory control policies for an inventory system. Shortages in inventory were allowed and partially backlogged.

Economic production lot size model for deteriorating items with partial backordering was suggested by Wee (1993). Abad (1996) formulated a generalized model of dynamic pricing and lot-sizing for perishable items. Shortage was allowed and the demand was partially backlogged. The effects of lost sales on composite lot sizing were discussed by Sharma and Sadiwala (1997).

Deteriorating inventory model with quantity discount, pricing and partial backordering was developed by Wee (1999). In this study, demand was assumed to decrease with the increment in price for the product. The
Numerical example was also given to illustrate the model. Optimal price and order size inventory policy for a reseller under partial backlogging was proposed by Abad (2000-a). The problem of determining the lot size for a perishable good under finite production was formulated by Abad (2000-b). Shortage in inventory was allowed with partial backordering and lost sale. Author has taken a problem of determining the production lot size of a perishable product that decays at an exponential rate. Wu (2000) developed inventory model for items with Weibull distribution deterioration rate, time dependent demand and partial backlogging.

An EOQ inventory model for items with Weibull distribution deterioration rate and ramp type demand was formulated by Wu (2001). Shortages in inventory were allowed and assumed to be partially backlogged. Ouyang and Chang (2002) presented stochastic continuous review inventory model with variable lead time and partial backorders to capture the reality of uncertain backorders. An EOQ model for deteriorating items with time-varying demand and partial backlogging was suggested by Teng et al. (2003). Papachristos and Skouri (2003) considered a model where the demand rate was a convex decreasing function of the selling price and backlogging rate was a time dependent function. The time of deterioration of the item was distributed as two parameter Weibull distribution function of time.
A general time-varying demand inventory lot-sizing model with waiting-time-dependent backlogging and a lot-size-dependent replenishment cost was developed by Zhou et al. (2004).

An EOQ model with time varying deterioration and linear time varying demand over finite time horizon was proposed by Ghosh and Chaudhuri (2005). Shortages in inventory were allowed and partially backlogged with waiting time dependent backlogging rate. Ouyang et al. (2005) discussed an EOQ inventory mathematical model for deteriorating items with exponentially decreasing demand. The shortages were allowed and partially backordered. The backlogging rate was variable and dependent on the waiting time for the next replenishment.

Pal et al. (2006) have developed an inventory model for single deteriorating item by considering the impact of marketing strategies such as pricing and advertising as well as the displayed stock level on the demand rate of the system. Shortages were allowed and the backlogging rate was dependent on the duration of waiting time up to the arrival of next lot. An economic production lot size model for deteriorating items with stock-dependent demand was produced by Jolai et al. (2006) under the effects of inflation. Shortages were allowed and partially backlogged.
A deterministic inventory model for deteriorating items with price dependent demand was developed by Dye et al. (2007-a). The demand and deterioration rates were continuous and differentiable function of price and time, respectively. Shortages for unsatisfied demand were allowed and backlogging rate was taken as negative exponential function of the waiting time. Numerical example was also used to study the problem numerically. Dye et al. (2007-b) presented a deterministic inventory model for deteriorating items with two warehouses. The deterioration rate in both the warehouses was taken as different. Shortages in OW were allowed and the backlogging demand rate was dependent on the duration of stockout. Authors have used numerical example to illustrate the model and conclude the paper with suggestions for possible future research.

An inventory lot-size model for deteriorating items with partial backlogging was formulated by Chern et al. (2008). Authors have taken time value of money in to consideration. The demand was assumed to fluctuating function of time and the backlogging rate of unsatisfied demand was a decreasing function of the waiting time. The effects of inflation and time value of money were also considered in the model. Thangam and Uthayakumar (2008) presented a two-level supply chain model with partial backordering and approximated Poisson demand.
Skouri et al. (2009) developed an inventory model with general ramp type demand rate, time dependent (Weibull) deterioration rate and partial backlogging of unsatisfied demand.
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