2.1 SURVEY OF INVENTORY MODELS WITH SUPPLY CHAIN

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 and 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 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.

Current literature has dealt with collaborative approach of integrated models. 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. They consider a dynamic programming approach to finding the optimal inventory policy for a system consisting of several facilities in series. In this model each facility is an echelon or stage. The retailer is referred to as the lowest stage, while the original (raw material) supplier is referred to as the highest stage. Goods flow from the original supplier to the retailer, i.e. from upstream to downstream. In this model, demand is stochastic and can be experienced at any of the stages. They define the echelon stock for a stage as the amount of inventory on-hand plus on-order at that stage, minus any backlogs, plus the amount on-hand plus on-order, minus any backlogs, at all downstream stages. Holding and shortage costs are assumed to be assessed on the echelon stock level at each stage.
Clark and Scarf (1962) consider a similar model, but with a fixed order cost at each facility. In this case, they find that the problem cannot be broken down into a series of single stage problems. They do, however, use this technique to find bounds on the cost function for the optimal solution.

Sherbrooke (1968) considered an ordering policy of two-echelon model for warehouse and retailer. It is assumed that stockouts at the retailers are completely backlogged.

Later, Cohen and Lee (1988) put forward a model for determining material requirement for all materials at every stage in the supply chain. This paper presents a comprehensive model framework for linking decisions and performance throughout the material-production-distribution supply chain. The purpose of the model is to support analysis of alternative manufacturing material/service strategies. A series of linked, approximate sub-models and a heuristic optimization procedure are introduced. A prototype software implementation is also discussed.

Pake and Cohen (1993) extended the above study to consider for stochastic sub systems to explore the supply chain system.

Goyal (1995) proposed an alternative shipment policy in which the quantity of products delivered to the purchaser is not identical at every replenishment. At each delivery, the vendor supplies the entire available
inventory to the purchaser. This strategy results in an increase in the inventory level of the purchaser of shipments.

Hill (1997) removed the restriction of identical shipments and allows delivering all available vendor inventories to the buyer. Their models showed that ‘deliver what is produced’ is better than ‘identical delivery quantity’. However, Viswanathan (1998) discussed that none of the strategies explained by Goyal (1995) and Hill (1997) obtains the best results for all possible problem parameters.

Chang and Dye (1999) presented an EOQ model for deteriorating items with partial backlogging. They also assumed that the demand rate was a time-continuous function. They commented that in some inventory situations, the backlogging rate should be dependent on the length of the waiting time for the next replenishment. Some of the previous research permits backordering but considers separately the inventory situation of the vendor and the purchaser. Others consider jointly the total annual cost of both the vendor and purchaser in order to find the optimal order quantity of the product, but do not allow stockouts.

Hill (1999) and Goyal and Nebebe (2000) kept working on integrated vendor buyer (IVB) systems to obtain a better optimal solution while
considering alternative policies and considered a problem of determining economic production from a vendor to a buyer.

A two-echelon inventory model with lost sales was suggested by Andersson and Melchiors (2001). A two reorder level inventory system with renewal demands and partial backlogging was suggested by Longo and Arivarignan (2002).

Seo (2000) developed an optimal reorder policy for a two-echelon distribution system with one central warehouse and multiple retailers. A multi-echelon inventory model for a deteriorating item 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 computer code is developed to derive the optimal solution. A numerical example is given to illustrate the model. This paper shows that the integrated approach strategy results in the lowest joint total cost as compared with the independent decision approaches.

Rau et al. (2003) explored an inventory model for deteriorating items with a shortage occurring at the supplier involving a supply chain between the producer and buyer. A numerical example is used to illustrate the model and demonstrate that integrated decisions are more cost-effective compared
with independent decisions from the supplier, producer or buyer. A sensitivity analysis is given to explore the effect from a supplier shortage.

Many researchers have studied how the buying company manages its relationship with suppliers (i.e. buyer–supplier relationship). Extending this genre of study, researchers have recently shown interest in investigating how the buying company manages relationships between the suppliers (i.e. supplier–supplier relationship). In other words, just as the relationship with the suppliers does, the relationships between suppliers have strategic implications for the buyer. **Wu and Choi (2004)** presented in this study eight cases that describe supplier–supplier relationship dynamics. Using theory building through case studies, we identify five archetypes of supplier–supplier relationships. Each type of relationship is a unique configuration of the relational characteristics. We also present working propositions that associate the antecedent conditions that lead to these archetypes and eventual performance implications. A deteriorating item inventory model in a supply chain was proposed by **Wu and Wee (2005)**. Shortages in inventory were allowed and fully backlogged.

**Jaber** and **Osman (2006)** achieving effective coordination among suppliers and retailers has become a pertinent research issue in supply chain management. This paper proposes a centralized model where players in a
two-level (supplier-retailer) supply chain coordinate their orders to minimize their local costs and that of the chain. Analytical and experimental results are presented and discussed to demonstrate the effectiveness of the proposed model.

**Haq and Kanna (2006)** focused an approach for the improvement of supply chain distribution inventory management is the optimization of the inventory level adopted by various supply chain entities. This paper presents an approach of optimizing the inventory level for a two-echelon supply chain by considering the distribution costs and various production related costs in meeting the customer demand.

A cooperative inventory policy between supplier and buyer is proposed by **Lin and Lin (2007)**. Unlike other studies, they consider the case of deteriorating items and permit the completed back-order in the problem. The sensitivity analysis for a cooperation policy between supplier and buyer also are explored.

**Singh et al. (2007)** developed a supply chain for deteriorating items with stock dependent demand rate under inflationary environment. Two-echelon inventory model with lost sales was proposed by **Hill et al.(2007)**.

Inventory record errors within a supply chain can lead to problems that cause low customer satisfaction and high operational costs. **Buyurgan et al.**
Ahmed et al. (2008) presented a simulation model of a two-echelon inventory system consisting of a retailer, a distribution center, and a supplier that includes multiple item types and the use of cycle counting as the corrective action. An extensive set of cycle-counting configurations were examined while observing the trade-off between fill rates, accuracy, and system costs in order to investigate the best possible configuration of cycle counting for two set of experiments that examine high-demand–low-cost and low-demand–high-cost items. The results indicate that the correct application of cycle counting will increase record accuracy and provide significant amount of savings for the entire supply chain.

Ahmed et al. (2008) have recently coordinated a two level supply chain in which they considered production interruptions for restoring of the quality of the production process. Mathematical models are developed with numerical results discussed.

Wong et al. (2009) coordinating supply chains is an effective way to improve channel performance. This paper details how a sales rebate contract helps achieve supply chain coordination which allows decentralized decisions of chain members to perform a centralized decision for the whole system. A model in the context of a two-echelon supply chain with a single supplier serving multiple retailers in vendor-managed inventory (VMI) partnership is
proposed. VMI facilitates the application of the sales rebate contract since information sharing in VMI partnership allows the supplier to obtain actual sales data in a timely manner and determine the rebate for retailers. Retailers are considered in two scenarios, independent retailers with a demand function sensitive only to their own price and competing retailers with a demand function depending on all retailers’ prices. The proposed model demonstrates that the supplier gains more profit with competing retailers than without as competition among the retailers lowers the prices and thus stimulates demand. Jha and Shanker (2009) considered a two-echelon supply chain inventory problem consisting of a single-vendor and a single-buyer. In the system under study, a vendor produced a product in a batch production environment and supplied it to a buyer facing a stochastic demand, which was assumed to be normally distributed. Also, buyer’s lead time was controllable which can be shortened at an added cost and all shortages were backordered. Kang and Kim (2010) considered a two-level supply chain in which a supplier served a group of retailers in a given geographic region and determined a replenishment plan for each retailer by using the information on demands of final customers and inventory levels of the retailers.
2.2 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 undergoes decay or deterioration. Most of the researchers in inventory system were directed towards non-deteriorating products. However, there are certain substances, whose utility do 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, grain, 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. Pierskalla and Roach (1972) suggested optimal issuing policies for perishable inventory. Covert and Philip (1973) extended Ghare and Schrader (1963) model and obtain an economic order quantity model for a variable rate of deterioration by assuming a two-parameter Weibull

Misra (1975) 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). Dave and Patel (1981) suggested an inventory model for deteriorating items with time proportional demand.

Roy Chowdhury and Chaudhuri (1983) formulated an order level inventory model for deteriorating items with finite rate of replenishment. Hollier and Mak (1983) developed inventory replenishment policies for deteriorating item with demand rate decreases negative exponentially and constant rate of deterioration. The authors developed two models, in the first model it was assumed that replenishment orders were placed at an equal interval. The system operates for a period of time, which was finite and known. In the second model, the replenishment time was also variable and taken as decision variable. The replenishment policy based on the second model leads to a lower total cost.

Goyal (1986), 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.

Dutta and Pal (1988) investigated an order level inventory model with power demand pattern with a special form of Weibull function for deterioration rate, considering deterministic demand as well as probabilistic demand. A deterministic inventory system with stock dependent demand rate was formulated by Baker and Urban (1988). Aggarwal and Jaggi (1989) presented inventory ordering policies for deteriorating items.

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. An EOQ model for deteriorating items with a linear trend in demand was formulated by Goswami and

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. Hill (1995) formulated inventory policies for deteriorating items with time varying demand.

An inventory model with exponential demand and constant rate of deterioration was proposed by Kishan and Mishra (1995). Shortages were allowed in the model. Wee (1995-a) and Wee (1995-b) presented inventory policies for deteriorating items with declining market. 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.

Giri et al. (1996) discussed an inventory model with an inventory-level-dependent demand rate followed by a constant demand rate for items
deteriorating at a constant rate. The sensitivity of the decision variables to change in the parameter values was examined and the effects of these changes on the optimal policy were discussed in brief. 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. Giri and Chaudhuri (1998) developed an economic order quantity model for perishable products with nonlinear holding cost and the demand rate was taken as function of on-hand inventory.

Su et al. (1999) formulated a deterministic production inventory model for deteriorating items with an exponential declining demand over a fix time horizon. The production rate at any instant depends on demand at that time. The item deteriorates at a constant rate and shortages were allowed in the model. Wu et al. (1999) developed an EOQ inventory model with ramp-type demand rate for items with Weibull deterioration.

Giri et al. (2000) presented a note on a lot sizing heuristic for deteriorating items with time varying demand and shortages. 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 generalized production lot size inventory model for deteriorating items over a finite planning horizon was considered by Balkhi (2001). The demand, production and deterioration rate were assumed to be known and continuous functions of time. Shortages were allowed and completely backlogged.

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. Chung and Lin (2001) proposed the discounted cash flow approach to investigate inventory replenishment problem for deteriorating items taking account of time value of money over a fixed planning horizon. The constant rate of deterioration was applied to on-hand inventory. Two models were analyzed, in the first model shortage was not allowed and in the second model shortage was allowed and it was fully backlogged.

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 comment on Change and Dye (1999) was presented by Goyal and Giri (2001-b). In this comment an EOQ model for deteriorating items with time varying demand and partial backlogging was
proposed. A single-vender 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.

Goyal and Giri (2003) considered the production-inventory problem in which the demand, production and deterioration rates of a product were assumed to vary with time. Shortages of a cycle were allowed to be partially backlogged. Two models were developed for the problem by employing different modeling approaches over an infinite planning horizon. Solution procedures were derived for determining the optimal replenishment policies.

An order level inventory model for deteriorating items with an exponential increasing demand was proposed by Sharma and Singh (2003). Huang (2003) formulated the deterministic inventory models with shortage and defective units.

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 was not allowed. The model was solved analytically for an infinite time-horizon. Economic order quantity model with Weibull distribution
deterioration, shortage and ramp type demand was formulated by Giri et al. (2003).

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 order-level inventory model for a deteriorating item with Weibull distribution deterioration, time-quadratic demand and shortages was suggested by Ghosh and Chaudhuri (2004).

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. An order level inventory system for deteriorating items has been discussed by Manna and Chaudhuri (2006). The demand rate was taken as ramp type function of time and the finite production rate was proportional to the demand rate at any instant. The deterioration rate was time proportional and the unit production cost was inversely proportional to the demand rate. Results were illustrated with two numerical examples along with its sensitivity.
Order level inventory systems with ramp type demand rate for deteriorating items were discussed by Panda et al. (2007). 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. Sugapriya (2008) studied an EPQ model for non-instantaneous deteriorating item in which holding cost varies with time. It is a production problem of non-instantaneous deteriorating item in which production and demand rate are constant. Ouyang et al. (2008) deals with an inventory problem for non-instantaneous deteriorating items with stock-dependent demand when supplier offers an all-unit quantity discount. Manna et al. (2009) developed an EOQ model for non-instantaneous deteriorating items with demand rate as time-dependent. In the model, shortages are allowed and partially backlogged. The backlogging rate is variable and dependent on the waiting time for the next replenishment.

2.3 SURVEY OF INVENTORY MODELS WITH PARTIAL BACKLOGGING

Most of the inventory models unrealistically assume that during stock out either all demand is backlogged or all is lost. In reality, often some
customers are willing to wait until replenishment, especially if the wait will be short, while other are more impatient and go elsewhere. Researchers have often studied the EOQs and EPQs with this theory in mind and came forth with certain interesting facts.

Zangwill (1966) developed a 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).

An Inventory models for perishable items with stock dependent selling rate were established by Padmanabhan and Vrat (1995). The rate of deterioration was taken to be constant with complete, partial backlogging and without backlogging. A comparison of two replenishment strategies for the lost sales inventory model was presented by Donselaar et al. (1996).

Wu (2000) developed inventory model for items with Weibull distribution deterioration rate, time dependent demand and partial backlogging.

Chang and Dye (2001) explored an inventory model for deteriorating items with partial backlogging and also considered the policy of permissible delay in payments. 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. An inventory replenishment policy for deteriorating items with shortages and partial backlogging over a finite planning horizon was developed by Wang (2002). Author has defined time-varying demand and an appropriate time dependent partial backlogging rate.

A single-item production-inventory system over an infinite time horizon with increasing demand and finite production rate was discussed by Giri et al. (2005). The demand during the stock-out period was partially captive with a known fraction. The proposed model was also shown to be suitable for a prescribed time horizon. Dye and Ouyang (2005) proposed an EOQ model for perishable items under stock dependent selling rate and time dependent partial backlogging. Pal et al. (2006) 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 optimal replenishment policy for non-instantaneous deteriorating items with stock-dependent demand and partial backlogging was proposed by Wu et al. (2006). The necessary and sufficient conditions of the existence and uniqueness of the optimal solution were shown.

Teng et al. (2007) extended Abad (2003) pricing and lot-sizing model by adding not only the shortage cost for backlogged items but also the cost of lost goodwill due to lost sales into the objective. The demand was assumed to fluctuating function of time and the backlogging rate of unsatisfied demand was a decreasing function of the waiting time. Thangam and Uthayakumar
(2008) presented a two-level supply chain model with partial backordering and approximated Poisson demand.

2.4 SURVEY OF INVENTORY MODELS WITH INFLATION

Generally, in the classical inventory model it is assumed that all the costs associated with the inventory system remains constant over time. 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 the large scale of inflation the monetary situation in almost of the countries has changed to an extent during the last thirty years. Now-a-days 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.

Buzacott (1975) was the first author to include the concept of inflation in inventory modeling. He showed that the effect of inflation results in cost increase. After the pioneer work of Buzacott (1975), it is found that inflation plays a vital role in the inventory system and production management though the decision makers may face difficulties in arriving at answers related decision making.
At present, it is impossible to ignore the effects of inflation. From (1975) to (1985) many researchers have been addressing the inflationary effect on an inventory policy. Misra (1975) investigated inventory systems under the effects of inflation. Ray and Chaudhuri (1977) presented an EOQ model under inflation and time discounting allowing shortages. Misra (1979) simultaneously considered both the inflation and time-value of money for internal as well as external inflation rate, and analyzed the influence of interest rate and inflation rate on replenishment strategy. Chandra and Bahner (1985) extended the result in Misra to allow for shortages.

Vrat and Padmanabhan (1990) proposed an inventory model for stock dependent consumption rate items under inflationary environment. Bose et al. (1995) then developed an EOQ model for deteriorating items with linear time-dependent demand rate and shortages under inflation and time discounting. 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. Liao et al. (2000) studied the effects of inflation and time value of
money on a deteriorating inventory when the supplier allowed permitted delay in payments, with a constant demand rate.

The discounted cash flow approach to investigate inventory replenishment problem for deteriorating items taking account of time value of money over a fixed planning horizon was proposed by Chung and Lin (2001). The constant rate of deterioration was applied to on-hand inventory. 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 optimal inventory replenishment policy of deteriorating items under inflationary conditions using a discounted cash flow (DCF) approach over a finite planning horizon was considered by Jaggi et al. (2006), the demand rate was assumed to be a function of inflation; shortages were allowed and completely backlogged. 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.
Dye et al. (2007) proposed a deterministic inventory model for deteriorating items with price-dependent demand. Two stage inventory problems over finite time horizon under inflation and time value of money was discussed by Dye et al. (2008).