Chapter 2 Review of Literature

2.1 Introduction

Lots of literature have been published in inventory control by considering different environmental conditions, but the inventory control models for perishable products are still not discussed much enough. The aim of this chapter is to present a complete and updated picture of inventory theory related to inventory models for perishable items. Review of literature and survey of the developed inventory models are being treated for consideration. Although, there is an abundance of the literature of general inventory systems, however, an attempt has been made to cover some of them related to the problem.

2.2 Inventory Models with Trade Credits

Trade credit is commonly used by business organizations as a source of short-term financing. By using the trade credits facilities, we can increase our total annual profit and also, this credit is extended by one trader to another for the purchase of goods and services. First model based on trade credits was developed by Goyal [10]. When the supplier announces credit period in settling the account, so in case if the account is settled within the allowable delay period, in this situation, no interest charges are payable from the amount. If the account is not settled by the end of the permissible delay period, the supplier will obviously charge higher interest. Goyal’s model is extended by Shah et al. [14] by allowing shortages. Also in Goyal’s model, the sales revenue was not discussed. Chapman and Ward [15] have studied Goyal’s model by including the trade credits and calculate the interest which is earned from the sales revenue on the stock remaining for a subsequent settlement period but in this model, the condition of offering one time delay in payments was not discussed. Davis and Gaither [16] developed inventory control model for firms that have offered a one time permissible delay in payment. For optimal economic order quantity model, the convexity of the total annual variable cost function under conditions of permissible delay in payments was established by Dallenbach [17] and Chung [18]. Arcelus and Srinivasan [19] represented their models by studied delay of payments for extra ordinary purchases which is more realistic situation.
Abad and Jaggi [20] considered the seller-buyer channel and developed an economic inventory control model, in which the end unit price which is charged by the seller and the credit period length, offered by the seller to the buyer both, influence the final demand for the product was considered. They considered policy variables for the seller. The case of no credit was used as a benchmark in analysis. This model provides algorithm for determining the seller’s and the buyer’s policies under non cooperative as well as cooperative relationships. In the non-cooperative, they determined the seller’s optimal unit price and the credit period length. In the situation where, immediately payment for the item must be made and when quantity which is ordered is less than the quantity at which a permissible delay in payments is permitted, also, where the delay in payments based on the ordered quantity, an economic order quantity model under conditions of permissible delay in payments is determined by Chung et al. [21]. Otherwise, the fixed credit period is allowed. The inventory control problem under the order size, dependent delay in payments and the retailer’s optimal price was dealt by Shinn and Hwang [22]. The length of the credit period is a function of the retailer’s order size is assumed. Also the demand rate is a function of the selling price which is more realistic as compare to [21].

By considering the difference between unit selling price and unit cost to derive closed-form solution to the offer of the trade credit, Teng and Chang [23] concluded that the economic replenishment, interval and order quantity increases marginally under the permissible credit period and they gave algorithm for a retailer to determine optimal selling price and lot size simultaneously, when the permissible delay in payments offers and the difference between the selling price and the purchase cost was considered. Carlson and Rousseau [24] examined economic ordered quantity under date terms supplier credit where carrying cost partitioned into financial cost and variable holding costs. When a distinction between these types of holding costs is made, but in this study, partially permissible delay in payments for retailer was not discussed, in case when the order quantity is smaller than a predetermined quantity, an offer is offered by the supplier to the retailer for partially permissible delay in payments, retailer’s replenishment decisions in the economic production quantity model was developed by Huang [25] in two levels of trade credit policy. Teng et al. [26] derived retailer’s optimal ordering policies with trade credit financing. Robb and Silver [6, 27] derived optimal policy under date-terms supplier credit with probabilistic demand and lead-time. Ouyang et al. [28] established an economic ordered quantity model (EOQ) with limited storage
capacity, in which the supplier provides cash discount and permissible delay in payments for the retailer. Most of the inventory replenishment policies under trade credit are developed under the assumption of instantaneous receipt of the goods in an inventory system and the supplier also offer a cash discount to encourage the retailer to pay for his purchases at the earliest. An inventory model with non-instantaneous receipt under trade credit, in which the supplier provides not only a permissible delay in payments but also a cash discount to the retailer developed by Ouyang et al. [29]. Recently, Soni et al. [30] presented optimal ordering policies for exponentially deteriorating items under credit period, with non-instantaneous receipt under trade credit and cash discount. Huang and Hsu [31] studied the retailer’s optimal replenishment policy when the retailer’s unit selling price is not lower than the unit purchasing price.

Deterioration and trade credit or decay is defined as a physical phenomena which hinders an item from being used for its original purpose such as (i) spoilage, as in perishable food stuffs, fruits and vegetables; (ii) physical depletion, as in pilferage or evaporation of volatile liquids such as gasoline, perfumes, alcohol; (iii) decay as in radioactive substances, degradation, as in electronic components or loss of potency as in photographic films, pharmaceutical drugs, fertilizers etc. For perishable goods such as dairy products, bakery items, vegetables, fruits etc, it is observed that the age of inventory has a negative impact on consumer confidence for reasons such as (i) proximity to expiry dates, (ii) detrimental effects on the quality of the product, (iii) general conception that an item lying unsold for a long time may be of inferior quality. Not only manufacturing goods but also services may deteriorate, for example, flight seats, hotel rooms, theatre seats and curtains etc. Refer to review articles by Raafat [32], Shah and Shah [33], Shah [34], Aggarwal and Jaggi [35] and Chung [36] developed lot-size models when units in inventory deteriorate at a constant rate and the supplier also offers credit period M for settling the accounts for the purchase quantity. The optimal order quantity is obtained by minimizing the total cost of the inventory system. Jamal et al. [12] extended Shah’s [34] model by allowing shortages and permissible delay in payments.

Under permissible delay in payments, the optimal payment time obtained by Ouyang et al. [37] where units in an inventory are subjected to deterioration. Chang and Dye [38] derived mathematical model of an inventory system for deteriorating items with partial back-logging, when supplier offers fixed credit period to settle the account. With a effect of deterioration under permissible trade credit,
Liao [39] derived a production model for an inventory control system with finite production rate. He made restrictive assumption of a relaxed permissible delay at the end of the credit period. It is assumed that the retailer will make a partial payment on total purchasing cost to the supplier and pay off the remaining balance by loan from the bank. The existence of a unique optimal cycle time to minimize the total variable cost per unit time is established. The bounds for the optimal cycle time are obtained. Chung and Liao [40] extended Hwang and Shinn’s [22] and Khouja and Mehrez [41], exponentially deteriorating items under permissible delay in payments model, by assuming that the delay in payments depends on the quantity ordered.

To present real-life situations, Chung and Huang [42] developed a retailer’s replenishment model by assuming that the retailer also adopts the trade credit policy to stimulate his/her customer demand. For deteriorating items, they proposed a two-warehouse inventory control model with a permissible delay in payments. Lokhandwala et al. [43] extended Davis and Gaither’s [16] model with constant rate of deterioration to determine optimal order quantities for firms where the seller offered a one time opportunity to delay payment for an order of a commodity but inflation rate was not discussed. Chang [44] studied effect of inflation rate in above model. Shah and Trivedi [45] analyzed an economic ordered quantity model for deteriorating items, when the supply is random and supplier allows a fixed credit period for settling the accounts. During the time when account is not settled, it is assumed that the cost of unit sold is deposited in an interest bearing accounts and the profit margin is used to meet the operational expenses of the system but present value of the total cost incurred was not discussed in this model. A model to determine an optimal ordering policy for deteriorating items under inflation, permissible trade credit and allowable shortage was discussed by Chung and Dye [46]. The optimal order quantity and maximum allowable shortages are obtained by optimizing the present value of the total cost incurred. The effect of inflation rate and time discount is derived on the optimal order quantity and maximum allowable shortages.

In general, the rate of deterioration increases with the age of (the longer) the items remaining unused, the higher the rate at which it loses its usability. Yang and Wee [47] developed a collaborative inventory system of a single vendor and single buyer to maximize the total profit of the whole system. However, the optimal solution for the whole system is not always acceptable to both parties. A negotiating factor was introduced to share profit between two players, according to their
contributions. Discounted-cash-flows (DCF) and trade credit are the average cost approach that has following two main drawbacks: (1) the time value of money is not explicitly taken into account. (2) There is no distinction between out-of-pocket holding costs and opportunity costs due to inventory investments. Carlson et al. [48] obtained economic order quantity (EOQ) under all units and incremental quantity discounts when purchase cost, ordering cost and inventory holding cost are all incurred on date-terms supplier credit. Payment dates for the three cost components need not be the same. Differences in the characteristics of day-terms and date-terms solutions to the quantity discount case are studied. Chung and Liao [49] extended Jaggi and Aggarwal’s [50] model under the assumption that the trade credit is linked to ordering quantity using DCF – approach.

Salameh et al. [51] examined the continuous review inventory model under permissible delays in payments, i.e. a retailer can pay for the goods immediately upon the receipt of the order or delay the payment till the next replenishment order, where supplier will charge interest over the delayed period. They assumed demand to be constant over the time and the lead – time to be random variable. The optimal ordering quantity and reorder level are obtained by maximizing the vendor’s total expected profit per time unit when retailer is offered trade credit and discount policy in this section, has two incentives, i.e. price discount and trade credit are compared. Arcelus and Srinivasan [52] discussed the effect of payment by dividing the holding cost into the costs of physically holding the units in inventory and of the funds tied up in them.

Arcelus et al. [53] analyzed the advantages and disadvantages of two scenarios, discount in unit purchase price made under the assumption of a price dependent demand, in this study the ability of the retailer to pass on some of the savings to the customer’s price included. For constant rate of deterioration, Arcelus et al. [54] extended Arcelus et al. [53] model. For exponentially deteriorating items and non-instantaneous receipt, an economic ordered quantity (EOQ) model for two-level trade credit discussed by Liao [55]. For supply chain system, an economic ordered quantity (EOQ) model under trade credit policy for deterioration items was presented by Liao and Chung [56] but in this study stochastic inventory model was not discussed.

By considering stochastic inventory with trade credit, Gupta and Wang [57] developed an economic ordered quantity model. For deteriorating items with two-level trade credit, inventory model under stock-dependent demand was studied by Min et al. [58] and Soni et al. [30]. Inventory control models
for conditionally permissible delay in payment for a two-warehouse inventory situation for deteriorating items was presented by Liang and Zhou [59] but in this model, retailer partial trade credit policy was not discussed. In supply chain, an economic production quantity (EPQ) model for partial trade credit policy under exponentially deteriorating items was presented by Mahata [60]. Limited storage capacity in the supply chain system, an optimal retailer's ordering policies with trade credit financing was studied by Yen et al. [61]. The optimal retailer's ordering policy under two levels of trade credit with partial payment financing to its customers was developed by Yen et al. [62].

In supply chain system, an economic order quantity model with two warehouses and trade credit for deteriorating items was developed by Liao et al. [63] but conditionally permissible delay in payment was not explained. Under conditionally permissible delay in payment for a two-warehouse inventory model for deteriorating items and linear demand, an economic ordered quantity model was presented by Singh and Hadibandhu [64], also Singh and Sharma [65] studied an optimal trade-credit policy with stock dependent demand for perishable items deeming imperfect production.

2.3 Inventory Models with Inflation

Most of the inventory models developed so far, do not include inflation and time value of money as parameters of the system. 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.

In the classical inventory, it is assumed that all the costs associated with the inventory system remains constant over time. Since most decision makers think that the inflation does not have significant influence on the inventory policy. But due to large scale of inflation, the monetary situation in almost all the countries has changed to an extent during the last thirty years. 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, we can say that in inventory control models, it is impossible to ignore the effects of inflation and it is necessary for the inventory system to consider the effects of inflation.

The concept of inflation in inventory modeling first time was included by Buzacott [11]. The author
showed that the effect of inflation results in cost increase. The effect of inflation was considered in the main cost components, and the optimal order quantity expression was developed. He developed deterministic inventory models under inflation for two cases, first when the price is subject to the same inflation rate as costs and in the second case, when the price is dependent on ordering policy assuming constant rate of inflation. Between 1975 to 1985, many researchers have been addressing the inflationary effect on an inventory policy. Ray and Chaudhuri [66] presented an economic ordered quantity (EOQ) model under inflation and time discounting allowing shortages, Here, inventory decision policy under inflationary conditions was not discussed. Bierman and Thomas [67] suggested the inventory decision policy under inflationary conditions.

Hariga [68] studied the time value of money on the replenishment policies and the effects of inflation of items with time, continuous non-stationary demand over a finite planning horizon. He developed dynamic programming models for three commonly used replenishment policies in the inventory lot-sizing literature with time varying demand and shortages. The effect of inflation was also considered in this analysis. An economic order quantity (EOQ) inventory model for deteriorating items was developed by Bose et al. [69]. Chen [70] proposed a generalized dynamic programming model for inventory items with Weibull distribution deterioration. Shortages were allowed and partially backordered in this model. The time value of money was not discussed. Moon and Lee [7] discussed the effects of inflation and time-value of money. With exponentially increasing demand for deteriorating items, Mehta and Shah [71] developed an inventory model under shortages, inflation and time discounting.

For deteriorating items with constant demand rate under inflation, Yang [72] developed the two-warehouse inventory control models but time value of money was not discussed. The shortages were allowed and fully backlogged in the models. Models for ameliorating deteriorating items with time-varying demand pattern over a finite planning horizon were proposed by Moon et al. [73]. With stock-dependent consumption rate and shortages, an inventory model for deteriorating items was produced by Hou [74]. 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. In optimal solution, the sensitivity analysis under different parameters of the system was carried out. Jolai et al. [75] 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 parameters in Weibull distribution function of time. Shortages in inventory were allowed with a constant backlogging rate. Jaggi et al. [8] presented the optimal inventory replenishment policy for deteriorating items under the conditions of inflationary by using a discounted cash flow (DCF) approach over a finite time horizon. Shortages in inventory were allowed for 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. With finite time horizon, Dey et al. [76] discussed two stage inventory problems under inflation and time value of money.

For finite production rate, an inventory control model under uncertain inflationary conditions for deteriorating items with shortages and inflation-dependent demand rate was presented by Mirzazadeh et al. [77] but in this study money inflation was not discussed. With money inflation, Uthayakumar and Geetha [78] discussed replenishment policy for single item inventory model. Under the conditions of inflationary, linear trend in demand and shortages, Jaggi and Verma [79] developed a two-warehouse inventory model for deteriorating items. Sarkar et al. [80] expanded this model by presented a finite replenishment model with increasing demand under inflation. An inventory model with time dependent demand for deteriorating products with inflation, lost sales and stock discussed by Sharma and Singh [81], With inflation and time value of money, Sarkar et al. [82] presented an imperfect production process for time varying demand.

Under shortages, an inventory model for deteriorating items, quadratic demand pattern under influence of inflation is discussed by Misra et al. [83], With three-parameters Weibull distribution deterioration under inflation, Yang [84] studied a partial backlogging inventory models for two-warehouses. For Weibull deterioration rate and inflation with volume agility, Singh et al. [85] presented an economic ordered quantity model with variable demand rate. For deteriorating items, Yang and Chang [86] studied a two-warehouse inventory model under inflation and partial backlogging with permissible delay in payment but time dependent demand under the effect of reliability and inflation was not discussed.

By considering the effect of reliability and inflation, Sarkar et al. [87] presented an EMQ model with
price and time dependent demand but in this model, trapezoidal demand under inflation was not discussed. Also, Dem et al. [88] discussed a volume flexible inventory model with trapezoidal demand under inflation.

### 2.4 Inventory Models with Partial Backlogging

The inventory involving backlogging and lost sales is called mixture inventory. Zangwill [5] developed an inventory model for multi period production, scheduling with backlogging. Inventory models for backorders and lost sales were formulated by Montogomery et al. [89].

Rosenberg [90] presented a lot-size model with partial backlogging. Inventory models with partial backorders were proposed by Park [91]. For an inventory system, Mak [92] proposed optimal production-inventory control policies. With partial backordering, Wee [93] developed economic production lot size model for deteriorating items but dynamic pricing and lot-sizing for perishable items was not discussed. Abad [94] formulated a generalized model for perishable items with dynamic pricing and lot-sizing. Shortage was allowed and the demand was partially backlogged. Limited time free back-orders economic ordered quantity model was formulated by Abboud and Sfairy [95].

Deteriorating inventory model with pricing and partial backordering with quantity discount was developed by Wee [96]. Demand was assumed to decrease with the increment in price for the product in this study. Shortages were allowed and partially backlogged. For deteriorating items, an EOQ Model with time varying demand and partial backlogging; a note was given by Wang [97]. Optimal price and order size inventory policy for a reseller under partial backlogging was proposed by Abad [98]. Shortage was allowed with partial backordering and lost sale but in this model, a two reorder level inventory system was not discussed.

A two reorder level inventory system with renewal demands and partial backlogging was suggested by Longo and Arivarignan [4]. Ouyang and Chang [13] presented stochastic continuous review inventory model with variable lead time and partial backorders to capture the reality of uncertain backorders. With time-varying demand, an economic ordered quantity model with partial backlogging for deteriorating items was suggested by Teng et al. [99]. For a general time-varying demand, lot-size-dependent replenishment cost, Zhou et al. [100] developed an inventory lot-sizing
model with waiting-time-dependent backlogging and also, some convenient mathematical properties of the cost function were identified, with which an effective numerical solution procedure was developed for determining the optimal replenishment policy.

An economic ordered quantity model with time varying deterioration and linear time varying demand over finite time horizon was proposed by Ghosh and Chaudhuri [101]. In this model, shortages in inventory were allowed and partially backlogged with waiting time dependent backlogging rate. An analytic solution of the model was discussed and it was illustrated with the help of a numerical example. An economic manufacturing quantity problem for an unreliable manufacturing system was presented by Giri and Yun [102], where machine was subject to random failure and at most two failures can occur in a production cycle. The shortages, if occur due to longer repair time, were backlogged partially by resuming the production run after machine repair. Some characteristics of the model with exponential failure and exponential/constant repair times were studied.

Computation algorithm for inventory model with a service level constraint and lead time demand was discussed by Lee et al. [103]. The backorder rate was dependent on the length of lead time through the amount of shortages. Authors have developed two computational algorithms to find the optimal order quantity and the optimal lead time. The two numerical examples were also given to illustrate the results.

A deterministic inventory model for deteriorating items was developed by Dye et al. [104] where price dependent demand was considered. In this study, the demand and deterioration rates were continuous and differentiable function of price and time respectively. Shortages 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.

Teng et al. [105] extended Abad [106] 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. Authors established a modeling approach as in Goyal and Giri [107] model, to the same pricing and lot sizing problem and then proved that both the models provide the same profit if all the parameters are constant. If any single parameter is varied with time then performances of both models are varied. They have obtained some theoretical results that show the conditions under which one model has
more net profit per unit time than the other.

Chern et al. [108] formulated an inventory lot-size model for deteriorating items under partial backlogging. In this model, authors have taken time value of money into consideration. The demand was assumed as fluctuating function of time and the backlogging rate of unsatisfied demand was a decreasing function of the waiting time. Thangam and Uthayakumar [109] presented a two-level supply chain model with partial backordering and approximated poisson demand. Skouri et al. [110] studied an inventory models for ramp type demand rate with partial backlogging and Weibull deterioration rate and Hu et al. [111] presented an inventory model with partial backordering and unit backorder cost linearly increasing with the waiting time.

For deteriorating items under inflation, Yang et al. [112] developed an economic order quantity model with stock-dependent demand rate with partial backlogging and shortages are permitted, but in this model, imperfect quality items with partial backlogging was not discussed. Agrawal and Rajput [113] developed modelling of an inventory system is dependent on selling price, stock and time dependent demand rate with partial backlogging. Economic order quantity model of imperfect quality items with partial backlogging ware presented by Roy et al. [114].

For time and price dependent demand, non-instantaneous deteriorating items with partial backlogging Maihami and Isa [115] discussed an inventory control model for joint pricing. Singh and Tomer [116] developed a deteriorating inventory model with time varying linear demand and partial backlogging. Huang et al. [117] presented dynamic pricing for fashion goods with partial backlogging and Acharya and Debata [118] presented an inventory model with time dependent demand for deteriorating items under partial backlogging.

### 2.5 Inventory Models for Deteriorating Items

The deterioration of physical goods in stock is very realistic feature, commodities such as fruits, vegetables and foodstuffs suffer from depletion by direct spoilage, while kept in store. The items like 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. Due to deterioration, inventory system faces the problem of shortages and loss of good will or loss of profit.
The analysis of deteriorating inventory began with Ghare and Schrader [9], who established the classical no-shortage inventory model, where a constant rate of decay was taken. 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 Weibull distribution. A production lot size inventory model for deteriorating items under arbitrary production and demand rate were presented by Balkhi and Benkherouf [119].

Ghare and Schrader model is extended by Covert and Philip [120] to obtain an economic order quantity model for a variable rate of deterioration by assuming a two-parameters Weibull distribution. Also, Philip [121] presented an economic ordered quantity model for items with Weibull distribution deterioration rate but in this model optimal issuing policies was not discussed. Pierskalla and Roach [122] presented a model based on optimal issuing policies for perishable inventory. In above models, finite rate of production was not discussed. Misra [123] presented a production lot size inventory control model for an inventory system with deteriorating items with variable rate of deterioration while rate of production was finite. An order level inventory model with constant rate of deterioration was presented by Shah and Jaiswal [124].


A deterministic inventory system with stock dependent demand rate was formulated by Baker and Urban [129]. In this model, power demand pattern was not discussed. Dutta and Pal [130] 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. Some particular cases for demand pattern have also been discussed in the model. An inventory model concerning a single item was suggested by Mandal and Phaujdar [131], 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 first assumed as constant and then variable.

Dutta and Pal [132] presented a note on an inventory level dependent demand rate. An economic ordered quantity model with a linear trend in demand for deteriorating items was formulated by Goswami and Chaudhuri [133]. Inventory model for deteriorating items, where the demand is dependent upon stock level was proposed by Pal et al. [134]. In that model, perishable items were not discussed. Inventory models for perishable items with stock dependent selling rate were suggested by Padmanabhan and Vrat [135]. In this model authors have assumed that selling rate is a function of current inventory level and constant rate of deterioration with complete, partial backlogging and without backlogging. For damageable items, Mandal and Maiti [136] presented an inventory model for both linear and non-linear damage and demand functions, where shortages are assumed fully backlogged. In this model, authors considered production rate as finite and solved the model with profit maximization techniques and sensitive analysis is also carried out.

An economic order quantity model for perishable products with nonlinear holding cost was proposed by Giri and Chaudhuri [137]. The demand rate was taken as function of on-hand inventory. Su et al. [138] formulated a deterministic production inventory model for deteriorating items under exponential declining demand over a fix time horizon, the production rate at any instant was taken as demand dependent at that time. For deteriorating items with time varying demand and shortages Giri et al. [139] presented a note on a lot sizing heuristic. Inventory control model for deteriorating items for an order level was proposed by Gupta and Aggarwal [140]. The demand was taken as a linear function of time and production rate was taken as demand dependent.

Aggarwal and Jain [141] presented an inventory model for exponentially increasing demand rate with time. The constant rate of deterioration was taken 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. Model for deteriorating items over a finite planning horizon was considered by Balkhi [142]. The demand, production and deterioration rate were assumed to be known and continuous functions of time. Shortages were allowed and completely backlogged.

For deteriorating item, a single-vendor and multiple-buyers production-inventory policy was
formulated by Yang and Wee [143]. Production and demand rates were taken to be constant. A mathematical model incorporating the costs of both the vendor and the buyers was developed. Goyal and Giri [144] 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.

A production-inventory model over a finite planning horizon for a deteriorating item was developed by Sana et al. [145]. In this model, 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 [23]. Demand rate in this model was taken as dependent on the display stock level and the selling price per unit. Authors have provided the necessary conditions to determine an optimal solution for maximization of profit for the economic production quantity model. Sensitivity analysis was applied on the parameter effects of the optimal price and the production run time.

A multi-item inventory model with limited storage capacity for deteriorating items was suggested by Mandal et al. [146]. The deterioration rate was taken to be constant and demand rate for the items was finite. The replenishment rate was taken as constant. The problem was supported by numerical examples. Order level inventory systems for deteriorating items with ramp type demand rate were discussed by Mandal and Pal [147] and Panda et al. [148]. A note on the inventory models with ramp type demand for deteriorating items was developed by Deng et al. [149]. They have proposed an extended inventory model with ramp type demand rate and its optimal feasible solution.

Also Balkhi and Tadj [150] presented a generalized economic order quantity model with time varying demand, deterioration, and costs but trapezoidal type demand was not discussed. Karmakar and Choudhury [151] discussed a review on inventory models for deteriorating items with shortages. Jie et al. [152] developed an EPQ model for deteriorating items with inventory-level-dependent demand and permissible delay in payments but vendor managed inventory supply chain was not discussed. Yu et al. [1] presented a vendor managed inventory supply chain with deteriorating raw materials and products. Sarkar and Chakrabarti [153] presented an economic production quantity model for
deteriorating items having Weibull distribution deterioration with exponential demand and production with shortages under permissible delay in payments but return on inventory investment maximization was not discussed. Cheng and Xiang [154] discussed deteriorating inventory model for an intermediary firm under return on inventory investment maximization and Mishra et al. [155] presented an inventory model for deteriorating items under time varying demand condition. Hariga [156] determined a single-item continuous review inventory problem with space restriction.

2.6 Research Gaps Identified

Based on the critical review of the literature, the following research gaps have been identified.

(i) The effect of partial backlogging on two storage model for time dependent deteriorating items with stock dependent demand.
(ii) Profit maximization production inventory models with time dependent demand and partial backlogging.
(iii) An inventory model for deteriorating products with inflation, lost sales and stock and time dependent demand.
(iv) An inventory model for decaying items, considering multivariate consumption rate with partial backlogging.
(v) Two-warehouse production policy for different demands under volume flexibility.
(vi) An EPQ model for deteriorating items with price sensitive demand and shortages in which production is demand dependent.
(vii) An EPQ model of deteriorating inventory with exponential demand rate and limited storage.
(viii) A generalized EPQ model for time dependent deteriorating items under inflation, exponentially increasing demand and partial backlogging.

Research will be carried out in some of the gaps identified above.