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DEVELOPMENT OF INVENTORY MODELS FOR DETERIORATING ITEMS CONSIDERING UNIFORM, PRICE AND TIME-DEPENDENT DEMAND – A REVIEW

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Abstract

Generally, inventory control refers to the product or items stored for an infinite period for the future expected demand. Still, in reality, indefinite shelf life is not possible for deteriorating items. The quality of the products (like fruit and vegetables) get worse day by day hence after a specific period customer don't wish to buy these items for their consumptions. The decay in the quality of the product is known as deterioration. Different researchers like [1], [2], [3], [4], [5], [6] worked in the field of inventory modeling with a different approach to demand functions and assumptions. The deterioration is a common factor of loss to retailers; here, we report a comprehensive review of the uniform demand, price, and time-dependent demand functions of Inventory models for deteriorating items. We primarily focused on inventory models of different demand patterns like linear, ramp type, trapezoidal, etc., in our study. The Extensive list of references is provided, which will help the reader to delve into their topic of interest.

1. Introduction

Inventory is the stock of a finished product and raw material under the pipeline for the expected demand in the future. Inventory includes live stocks, machines, or materials. Inventory control and management are of utmost importance in any business and trade as it involves a huge amount of capital investment and is imperative in terms of profit maximization to any organization. In the case of stock products, a customer may prioritize another supplier in place of waiting for the order fulfillment. This may result in

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capital loss to the organization. Therefore, in order to avoid the unavailability of products, cost minimization, and profit maximization, organizations have to manage inventory.

Due to future expected demand, inventory of perishable items is carried, but due to time, the quality of stored items gets down as compared to fresh items like fruit, vegetables, meat, and seasonal products. This decrease in the quality of items, is known as deterioration. Deterioration refers to damage, spoilage, dryness, and decay of items. Consequently, we can't ignore the effect of deterioration on inventory modeling; hence inventory items can be divided into three categories.

1. Deterioration

2. Obsolesce

3. No obsolesce

Obsolesce refers to a change in the quality of items due to a change in time or change in technology. Like Mig Aircraft replaced by F12 in the Indian Army. Example: Mobile phones in the market are replaced by updated mobiles due to changes in time or changes in technology, old mobiles get replaced by updated technology. Deterioration is known as a change in quality, spoilage, drying of the product like fruits, vegetables, and blood. The products which have a fixed lifetime is (e.g., fruits) are known as perishable items. On the other hand, if shelf life is not fixed, these products are known as no obsolesce deteriorating products. Some products have an infinite shelf life, so these would fall into the category of obsolesce deterioration.

1.1. Challenges in deterioration

The various kinds of items are included in deterioration, and every item has its unique identity. Few items are under immediate deterioration, like milk. Vegetables and fruits have different kinds of life. Therefore, the deterioration of such products needs to be treated differently. The product's shelf life varies; for example, the shelf life of electronic items and the shelf life of perishable items are different. The shelf life of medicine and fruits differs, so we have to adopt a different strategy before adopting the deterioration rate. It has been seen that some items get change after deterioration (e.g., radioactive products). Sometimes fashion changes, new technology arrives, sometimes deterioration either on time- or price-dependent. These kinds of challenges were faced at the time of the introduction of deterioration.

Our study focuses on Uniform demand, Price dependent demand, and time-dependent demand of the inventory model.

2. Inventory Models Considering Uniform Demand

Optimum policy for deteriorating items was presented by [7], then [8] developed an inventory model for deteriorating items with the assumption of exponential deterioration. The EOQ model was presented for deterministic demand where shortage was not allowed further; [9] introduced Weibull distribution for deteriorating items without shortage. The First-time shortage was allowed by [10]. Then, [11] presented an inventory model for a single deterioration with two different warehouses concept. The basic concept was carrying the cost of excess inventory is better than owning a warehouse to carry more inventory because if let down the cost of deterioration as a consequence organization gets more profit by this approach. Then [12] introduced the 'EOQ' model for optimal value considering constant demand without shortage.

A study reported by [13] introduced the inventory model for perishable items, where the deterioration rate was exponential, holding cost and purchasing cost included with this model. [2] Introduced an inventory model for constant demand for deteriorating items with a finite replenishment rate. [14] Presented an inventory model of two warehouse approaches with different deterioration rates. Replenishment rate was allowed with a shortage. On the parallel side of research, [15] presented an inventory model for the time-dependent deterioration rate without shortage allowed. Further, [16] extended the work of [13] they considered lead time in shortage period as a consequence if, shortage took a long time then occurring low cost. In this way, the shortage period has reduced the long period into a cycle. [17] Developed a new idea of permissible delay allowed when a purchaser ordered in bulk quantity. This allowed controlling the inflation effect on inventory because a delayed payment was invested for extra earning to retailers. Further, [18] introduced the inflation and shortage approach in two warehouses for inventory control of deteriorating items. This model considered shortage started in a cycle and it will be finished when no shortages are there. Thus, this model has proved the higher cost of the previous warehouse as compared to the presented models. Therefore, the presented model was cheaper as compared to the previous model in the condition of inflation. [19] Presented an inventory control model to maximize earning function to optimal replenishment policy for constant demand of deteriorating items. In the previous studies, researchers focused on minimizing cost in the inventory model to find optimal replenishment policy, and maximization in earning was ignored. Further, [20] introduced partial backlogging to compare between two warehouses to cost minimization. In this model, he extended his work of [18]. Then [21] modified the model of [14] with worked on FIFO policy to control inventory in two warehouses approach, but [21] introduced the LIFO method to control inventory for two warehouses. Interestingly, the LIFO method is not applied in practical life because fresh items of perishable goods get preference. In this way, the study says the FIFO model's cost is less than the LIFO method. And holding cost of the rented warehouse is less as compared to its own warehouse. [22] Presented an inventory model with an approach to obtain maximum profit per unit of item. In this model, the assumption of two warehouses was adopted. The own and rented warehouse concept, introducing when the supplier gets more order quantity than the capacity of own warehouse. The deterioration rate was different for both warehouses. Shortage allowed in the main warehouse and backlog demand is dependent on empty space in the warehouse. [23] Extended the work of [21] and proved that [21] was wrong he suggested a new type of calculation for deteriorating items. [21] Worked on two warehouses. They extended the model of [14] but proved it wrong by [23].

[24] Builds on [12] work by developing an inventory control model for degrading items with an allowable payment delay. The selling price per unit is higher than this model’s purchasing price per unit. The assumption of interest earned should be more than the interest charge adopted in their study. In this study, the delay in payment is allowed up to a decided time limit; as a consequence, purchasing power of retailers increases, and he may purchase more items; as a consequence, retailers accomplish orders in bulk quantity which convert into the form of extra sale. This approach enhances

the profit of suppliers and retailers due to extra sales, allowed by the permissible delay in payment. [25] Developed two warehouses inventory model approaches for perishable items. Sometimes the production of an item is seasonal only (e.g., wheat). The capacity of the self-warehouse is very restricted, so we have to take another warehouse on a rent basis for excess storage. Their warehouse's deterioration rate is more than the rented warehouse due to a better preservative technique. The shortage is allowed with complete backlogging. The deterioration rate was constant for uniform demand. Later, [26] presented the inventory model with the assumption of two warehouses-one for own warehouse and the second which was taken on rent. The permissible delay in payment was allowed in own warehouse. Shortage with partial backlogging was allowed in uniform demand.

3. Inventory Models Considering Price-dependent Demand

The price of items and demand by retailers are correlated with each other. If the price is low, retailers influence excess lot size and vice versa. [27] Worked on replenishment and pricing policy on inventory control for perishable items. When demand was exponentially declined with respect to price, they considered a constant rate of deterioration with partial backlogging. Further, [28] extended his model with considerable variation in the deterioration rate. [29] Worked on the lot size of the inventory for perishable items for a price dependent on allowing shortage and partial backlogging. Then [30] extended his own inventory model [28], allowing quantity discount and partial backlogging. His previous study was based on cost minimization then adopted a new approach with profit maximization. [31] Focused on price dependent inventory control model for the lot size demand by retailers for constant deterioration with backlog demand. The sale price was also fixed in this model. It was the first time when backlog rate was considered before that study; the backlog rate was not considered in previous studies. [32] Worked on the study of [30], worked on price-dependent inventory model with constant deterioration, but [32] focused on the concave function of the sale price for profit maximization. In this model, the waiting time of the next replenishment was reduced. In this way, inventory took better control, and in consequence, more profit was earned by the organization. [33] A presented price-dependent inventory model for perishable items is considered in this model. The deterioration rate was exponential, which increased over time. Shortage and partial backlogging were allowed in this study. Secondly, [33] makes another model for impatient customers. They might shift to another supplier if they were not getting items at the appropriate time. In this case, the supplier arranges items from other production units if getting at a reasonable rate. [34] Developed an inventory control model for deterministic demand dependent on the sale price for deteriorating items. In this study, he worked on optimal pricing policy and optimal lot size at the same time. He introduced the concept of permissible delay to retailers. The credit period of delay in payment was dependent on a lot size of order by retailers bulk order quantity gets more time to credit settlement [18] developed an inventory control model of deterministic demand on price dependent for deteriorating items. In this study, he considered optimal policy for price and order as an integrated profit of buyer and seller. If the seller was getting more profit, he attracts the buyers by the discount rate given to them. In this way, he considers two partie's approaches (buyer and seller) for the same profit. In this way, more profit is attracted by more sales. [35] Developed the inventory model to determine lot size of inventory for perishable items with price and inventory dependent on a shortage. The shortage capacity of items was minimal by this assumption. [36] Developed an 'EOQ' model for retailers to decide optimal selling price and replenishment, allowing partial backlogging. The profit function is concave with respect to P. A comparison has been shown in [37]. In this model, they compare between lot size deterministic and pricing of the model. In this study, he extends the model of [33] by including shortage cost and a sale lost cost, then compares with the model of [38], [39] considered a dynamic pricing issue in this study to show the effect of advertising on buyers and trade credit effect of the manufacturer. The motive of the study was to determine the optimum price value for retailers. [40] Developed an inventory model for perishable items dependent on price and time under-inflation on a finite horizon of time. The study's goal was to figure out how to calculate the lot size and sale price for profit maximization of the organization. Shortage and partial backlogging were allowed in this study. Further, [41] presented an inventory model with a shortage as partial backlogging. The motive of the research was to find an optimal value for sale and determine the order of quantity for profit maximization. [42] Discussed the extreme competition in the market because suppliers provide concession or discounts to retailers in the form of permissible delay in payment which attracted more demand as per their need. This bulk purchasing needs a storage facility that attracted inventory modelling. The capacity of our own warehouse was very limited, so we need to take another warehouse on a rent basis. The holding cost per unit was more in a rented warehouse as compared to the own warehouse. This model aimed to compute the minimization of the total average cost. Further, [43] developed the inventory model for perishable items. Three types of demand rate were considered via a linear demand depending on time, price, then constant. Before this study, only a single demand rate was considered. Shortages with Development of Inventory Models for Deteriorating Items considering partial backlogging were allowed for a constant deterioration rate.

4. Inventory Models Considering time-dependent Demand

The demand is not constant forever due to the time period; it has to change like fashion, the taste of goods, etc. New technology arrived new products, so demand for old product reduced due to arrival of a new product and technology in the market. For example, the new version of mobile phones reduced the demand for the current model of mobile phones because a unique feature of mobile phones attracts customers more; hence their preference gets changed as new technology has arrived. [44] First time introduced the inventory control model for constant deterioration rate where demand was considered a negatively exponential function of time. The replenishment time of inventory is divided into equal intervals of replenishment. In this study, they find an optimal replenishment policy for both cases. [45] Presented the inventory with the assumption of constant deterioration and shortage. [46] Worked on an optimum replenishment policy. Further, [47] Economic production quantity model 'EPQ' was developed for deteriorating items with a shortage as partial backlogged. This study was helpful to the minimization of the total cost. [48] Extended the model of [44] by assuming an exponential demand, either increasing or decreasing demand. [27] Developed an inventory model with consideration demand rate was exponentially decreased in a fixed time of horizon. The shortage allowed between the first and final periods of inventory. [49] Developed the optimal replenishment policy for perishable items where the deterioration rate was time-varying. [50] Worked on Weibull deterioration which was better than previous models because changes in replenishment intervals arrived cost minimization of inventory. [51] Represent the inventory model with time-dependent, shortage allowed, and partial backlogging varied as an exponential increase in time. [52] presented a comparison study of [13] for deteriorating items between complete and partial backlog. [53] Considered the linear and exponential demand function in their study. [54] Explained optimal replenishment policy with a shortage allowed as partial backlogging for perishable items and fill the research gap [51]. [55] Presented a time-dependent inventory control model that revised the deterioration rate to see the inflation effect. In this way, the effect of inflation may be controlled by applying this model. Optimal replenishment was fixed, and demand function was time-dependent. Further, [56] worked on exponential demand with partial backlog shortage. The aim of the study was cost minimization. [57] Presented the inventory model for perishable items with an assumption of shortage and inflation. In this study, shortages start from the beginning and end till the cycle length. Further partial backlogging was allowed. The deterioration rate was price and time dependent. [58] Presented an inventory model for comparison between two warehouses. One of them should consider own warehouse and other was taken on rent. The deterioration rate was different for both warehouses, but both warehouses were time-dependent. Later, [59] presented a comparison between two warehouses of inventory control for time-dependent deterioration. [58] Presented a time-dependent inventory model, where deterioration rate was constant and start afterlife vanish of items. [60] Worked on permissible delay concept with shortage till next replenishment. [61] Presented an inventory model where demand rate was time proportional considered. The partial backlog shortage was allowed. The motive of the study was the minimization of holding costs. On the other hand, [61] worked on inventory control modeling on time-dependent demand without shortage. Before this study, the demand rate was assumed constant, but it is not possible in practical life, so [62] proposed an inventory model towards optimal quantity. [63] Proposed an inventory model whose demand rate depended on holding cost and selling price. A single warehouse assumption was considered in this model, with shortage allowed. The aim of the study was to minimization of cost by using the deterioration concept. Further, [64] presented the inventory model on time-dependent with an assumption of two warehouses. This model worked when production quantity or order quantity was higher, so we needed to store this extra quantity in a rented warehouse. The study tells us the holding cost of inventory of rented warehouse is more than own warehouse due to extra preservative technique in rented warehouse. The deterioration rate was constant and took the same rate of deterioration in both warehouses. Generally, researchers choose either price-dependent or time-dependent demand, but [65] presented a price and time-dependent inventory model for constant deterioration for trapezoidal demand further [66] extended the model with the time-dependent deterioration concept. [67] Worked on a permissible delay concept for ramp-type demand. Latest [68] introduced a preservative technology concept for ramp type demand which is price and time-dependent.

5. Conclusion and Future Research

[2] Discussed different types of inventory models in their study 25 years ago. Still, many of the demand functions are based on their research, like linear, exponential, ramp-type, and trapezoidal demand, etc. We discuss inventory models for perishable items for uniform, price, time, price, and time-dependent demand functions. We concluded literature review work till now in our study. There are a lot of topics available like permissible delay, advance payment, trade credit, etc., as broach in the inventory control community. [69] Already discussed inventory models with assumptions of the stochastic demand function. Yet, no emerging work has not been seen in inventory modeling from the last decade. If the researcher focused on the stochastic approach, it would be good for the research community because real-life problems may be discussed very closely through the stochastic approach. We more discussed deterministic demand on a monthly or weekly basis (Macro period). Still, in real life, demand may change to-three times in a day, like a retail grocery inventory. So in the future, micro-level inventory models may be discussed towards deteriorating items in inventory. Consumers prefer fresh items like fruit and vegetables for their consumption. Sometimes shelf life of deteriorating items is comparatively more like an example of the expiry date on the medicine. So, FIFO and LIFO policies will also be helpful in future inventory modeling. So future researchers may develop inventory models as per future aspects and requirements.

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