Analysis of Deteriorating Inventory Work (2016-2019)

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Abstract. In the present review paper, we are presenting comprehensive information about the advances and recent researches made in the field of inventory supply chain for deteriorating items. This paper studied some characteristics which are playing important role in management area of deteriorating inventory supply chains. We have categorize our reviewed papers according to the keywords like demand rate, deterioration rate, two warehouses dispatching policy, green supply chain, permissible delay in payments and some strategies like vendor managed inventory (VMI), Stackelberg Game, sale, discount, effects of dynamic pricing of deteriorating items on income and deterioration, unexpected deterioration identification etc. The research work which is tabulated in this paper offer clear information about the inventory supply chain of deteriorating items. We have also provided future research directions in this area.

Keywords: Inventory supply chain, Deterioration, Demand, Carbon emission, Warehouse dispatching policy, Vendor managed inventory

1. Introduction

Perishable or deteriorating products are very common in practical world but managing these items is not simply normal. At business level, running ISC for deteriorating products is challenging and quite risky because the usefulness of the deteriorating products decreases with time throughout the process of storage and transportation through spoilage, damage, or decay.

“Deterioration is a process through which items lose its utility or marginal value due to expiring date or any other reasons like damage, spoilage, obsolescence, pilferage, invalid devaluation, deviation of its normal and expected performance etc.” Reduction of usefulness and substantial characteristics like color, consistency, odor, appearances etc. of a substance due to defective packaging or nonstandard storage conditions is also a kind of decay. Some items get deteriorate because of fashion, new technology and alternatives available in the market. According to above knowledge deterioration can be divided into two categories - Natural deterioration and Random deterioration. Natural deterioration includes the products that become decay or damage with time and lose its utility naturally whereas random deterioration includes the products that lose their utility or total economic value due to new arrival of technology, change of season and the opening of alternatives.

Ghare and Schrader (1963) were first to worked on deteriorating items. After that many researchers worked on different aspects of deteriorating items like Covert and Philip (1973), Raafat (1991), Nahmias (2011), Janssen et al. [2016] etc. In presenting review paper, we have studied papers between 2016-2019 dealing with deteriorating items by considering different parameters like demand, rate of deterioration,
permissible delay in payments, two warehouse dispatching policy, green supply chain, some strategies like vendor managed inventory (VMI), Stackelberg game (SG), sale, discount, effects of dynamic pricing, unidentified deterioration etc. which are effecting deteriorating ISC.

2. Objective of Research
This paper aims to provide comprehensive information and gaps on some recent research practices related to inventory management of deteriorating items. It will help readers to understand the recent advances and research in this field and provide more clear vision of research directions in this field.

3. Need of deteriorating inventory strategy
In a competitive world of business, managing the supply chain for deteriorating products is tough and challenging due to short life cycle of products therefore it is requirement of business enterprises to have knowledge of deteriorating inventory strategies like price discount, order discount, credit policy, dispatching policy, optimal order, replenishment plan, promotional effort strategies such as product advertisement and schedule of the special sale plan with a finite planning horizon etc. for survival in market. Many researchers worked in this area for providing a comprehensive analysis and method to derive above mention strategies and support business organizations with the theme “A well-designed inventory system is way to success of any business organization”

4. Methodology
The flow chart given below is presenting the review process.

Figure 1. Process of research work of deteriorating inventory supply chain.
5. Parameters Effecting Deteriorating Inventory Study

In business organization inventory management is not dependent only on one factor but it is multi variable dependent management where change in one parameter will change others. Some of these are demand rate, deterioration rate, payment policies, carbon emission and its regulation, warehouse dispatching policies, VMI policy and SG approach etc. Here, we have discussed about these parameters.

5.1 Demand

Demand means “size of order”. It is an important and first main feature which cannot be ignored in an ISC as it plays the role of the driving force for the whole inventory system. Demand is basically of two types, Deterministic and Stochastic. Demand in which size of order is known at commencement of supply chain is known as deterministic demand whereas in stochastic demand order size is uncertain. The firms dealing with stochastic demand are facing many challenges like management of inventories, dealing with shortages, customers satisfaction etc. In this review paper, we have studied different types of demands like time dependent, stock dependent, price dependent, ramp type, credit dependent, order dependent, discount dependent, preservation and quality dependent, multi-variable demand, advertising and preservation level dependent, promotional effect dependent and uncertain demand. Some of recent work by considering different demand are Aliyu and Sani [2018], Banerjee and Agrawal [2017], Bouslah et al.[2016], Chakraborty et al.[2018], Claassen et al.[2016], Dehghani et al.[2019], Deng et al.[2019], Duan et al.[2018], Gong et al.[2019], Grillo et al.[2017], Hsieh and Dye[2017], Kouki et al.[2016], Li et al.[2019], Li et al.[2016], Li et al.[2017], Lin et al.[2019], Lin and Wang[2018], Liu et al.[2019], Liuxin et al.[2018], Mahmoodi [2019], Minner and Transchel[2017], Onal[2016], Panda et al.[2017], Pando et al.[2018], Pauls-Worm et al.[2016], Raut et al.[2019], Rivera-Gómez et al.[2016], Sen[2016], Tai et al.[2016], Tai et al.[2019], Tashakkor et al.[2018], Timajchi et al.[2019], Tiwari et al.[2018], Tiwari et al.[2018], Wong et al.[2017], Wu et al.[2017], Xu et al.[2017] etc.

Credit-price dependent demand has not been considered by any researcher for deteriorating items. Recently Johari [2018] studied it for bi-level credit coordination. A work by Adenso-Díaz [2017] consider price and age dependent demand and develop a model for reducing loss due to spoilage of food and other perishable products. Tao et al. [2019] consider Advertising and preservation level dependent demand.

5.2 Deterioration

Deterioration can be classified in two categories (a) Instantaneous deterioration - It occurs due reduction in natural attributes of products as soon as they stocked in inventory. These products undergo decay process while kept in warehouses. (b) Non-instantaneous- Non-instantaneous deterioration is not immediate, but it takes a fixed period of time which is known as expiration date. Non- instantaneous deterioration was first introduce by Wu et al.[2006]. Some of recent work in this area are Afshar-Najafi [2016], Aliyu & Sani[2018], Bai.et al.[2016], Banerjee & Agrawal[2017], Duan et al.[2018], Dye and Yang[2016], Dye [2019], Feng.et al.[2017], Ghiami and Beullens[2016], Gong et al.[2019], Huber et al. [2017], Jing and Mu[2019], Li et al.[2019], Li et al.[2017], Liu et al.[2018], Maihami et al.[2019], Muriana et al.[2016], Onal et al.[2016], Panda et al.[2017], Panda et al.[2017], Pando et al.[2018], Rabbani et al.[2016], Rozhkov, and Ivanov[2018], Sazvar et al.[2016], Sazvar et al.[2016], Tiwari et al.[2016], Tiwari et al.[2018], Wu et al.[2016], Xu et al.[2017], Yang et al.[2019], Zhang et al.[2016].etc. Afshar-Najafi [2016] studied the influence of sale announcement on perishable products and developed models for finding optimum quantity and optimum time for perishable product’s sale.
5.3 Two warehouse dispatching policy

Two warehouse dispatching policy is also an important factor which affects inventory control of deteriorating items. In peak seasons enterprises purchase extra stock for future use but do not have extra space to store it because of financial reasons. In this situation, if the order size exceeds the warehouse storage limit, the retailer needs to hire extra storage facilities, which is known as a rented warehouse (RW). Recently, many enterprises use rented warehouse facilities to enhance productivity and profitability in business organizations. For example, some organizations manufacture their products in rented space and then deliver them to their own warehouse (OW). Researchers have shown interest in this field and developed many effective policies.

After purchasing extra stock in peak seasons and storing it in OW and OR, the next problem arises in front of the organization that which inventory should be used first. In this situation, an effective dispatching strategy can only work for deteriorating products that can fulfill market demand as well as minimize total cost and maximize profit. Many researchers worked with different dispatching policies, which can be classified as follows.

(i) LIFO means ‘last-in-first-out’ dispatching policy, as the name suggests; inventory first kept in OW but it will be out last, whereas inventory kept in RW but will be used first. Recently, Chakraborty et al. [2018] used LIFO policy in their work.

(ii) FIFO means ‘first-in-first-out’, under a FIFO policy, inventory first fills in OW and is used first from OW. We can say that the oldest inventory will be used first. Recently, FIFO is considered by Yu [2019] in his research work.

(iii) Mixed FIFO and LIFO policy, under this policy, inventory is used by both FIFO and LIFO policies depending on buyer’s requirements and choice. Some buyers prefer fresh products, whereas some prefer old products from the store. Recently, Janssen et al. [2018], Minner and Transchel [2016] use Mixed FIFO and LIFO policy.

(iv) Modify last-in-first-out means ‘MLIFO’. There are some enterprises that are manufacturing their inventory at some hired place due to limited capacity of their OW. After manufacturing, the products dispatch to OW first and then to buyers. The products which get deteriorate during storage in the OW are replenished with fresh ones. Thus, the inventories of OW are used first, followed by the inventory in the RW. Lee [2016] and Tiwari et al. [2018] used MLIFO policy in their work.

(v) Modify first-in-first-out (MFIFO) policy. Xu et al. [2017], first to use MFIFO policy for deteriorating items with constant demand and finite time horizon.

(vi) Allocation-in-fraction-out “AIFO” policy, other than above-mentioned dispatching policies, a new policy AIFO is introduced by Alamri and Syntetos [2018]. In this dispatching policy, the products at RW and OW consume together at the same ratio, which indicates depletion of both inventories at the same time period. Location of warehouse is one more factor in which researchers took interest. Enterprises must work for the best location for their inventory hubs (warehouse) according to the product’s requirement. For example, establishing warehouses in an inner-city area easily satisfy customer’s demands but maximize land cost and other operating expenses. Location of warehouse in outer-city area minimizes warehouse set-up cost but maximizes operating expenses like transportation, labor charges, and troubles easy reaction towards market situations. Gendron et al. [2016], Lin and Wang [2018] worked in this area.

At a practical point of view, FIFO policy is more profitable than LIFO policy because in this competitive world of business, rented warehouse charges are very less and they provide better stocking facilities for deteriorating items like cold warehouses, better space, etc. Many businesses use FIFO policy in their supply chain.

Most of the existing models above, not considering transportation time during (delivery) shipment of inventory. The theory of not considering shipment time during delivery of inventory is working only when the supply chain is completely limited in a small area but the shipment time cannot be ignored when business
is in widen area. Traffic problem is also one of the reason in which the shipment time should be calculated. Therefore more research work can be possible by considering transportation time during shipment.

5.4 Green supply chain
In recent years policy makers and organizations throughout the world facing the challenge of green supply chain (GSC). Global alertness on carbon emission and ecological fortification persuaded many researchers, industrialist, policy makers and enterprises to build up green supply chain policies with the basic motto of business to maximize profit. Production process, transportation, preservation methods in warehouse and deteriorating inventory are main factors which are responsible for carbon emission. Government as well as policymakers around the world set various regulation policies for achieving the target of GSC for social welfare as well as maximize profitability of firms. It is expected that firms should follow these regulations while maintaining their profitability. In this regard, firms can manage carbon emissions across their supply chain by regulations policies sets by the government like carbon cap, carbon tax, carbon trade, and carbon offset. Many researchers worked to show the effect of use of these regulation policies in a supply chain. The main objective of the GSC is maximizing social welfare and profitability of firm.

Recent Hariga et al.[2017], Sarkar et al.[2016], [2017], [2018], Ledari et al.[2018], Wu et al.[2018], Ahmed et al.[2018], Das and Jharkharia,[2018], Jabbour et al.[2018], Damert et al. [2018] all worked considering carbon footprints and regulation policy. Some researchers like Damert et al. [2018] collected some data of different organizations and tested that how and what factors responsible for environmental related problems and how to create external pressures on a supplier’s decision to practice on carbon reduction supply chain management policies.

There are four regulations policies set by government for reducing carbon emission. These carbon regulation policies are set by government to motivate organizations for a GSC.

a. **Carbon Cap policy** In this regulation policy carbon cap or carbon emission due to supply chain should not be more than a limit point. This fixed limit is known as carbon cap and it is decided by the government. Mishra et al.[2019] studied recently this policy in their work.

b. **Carbon Tax policy** In this policy a tax is charged by the government if carbon emission due to supply chain is more than a limit point. Tax is directly related to carbon emission. Recently Daryanto et al.[2019], Shi et al. [2019], Tiwari et al.[2018] worked on it.

c. **Cap-and-Trade policy** Carbon cap-and-trade policy which is also known as trade or cap-and-price, established by Kyoto Protocol in an international treaty for encouraging the firms to emit less than their cap. If firms emits less than their cap then government accordingly reward them. Some recent works considered this policy are Bai et al [2019], Gong. et al.[2019], Wang et al.[2019] etc.

d. **Carbon Offset policy** Carbon offset is also known as cap-and-offset policy. According to this policy, the government charges a tax if the emission exceeds a point fixed by the government only. In this policy government gives facility to supply chain to purchase emission offsets from other parties to reduce carbon footprints. Huang et al. [2018] recently used this policy in their work.

5.5 Permissible delay in payments (Trade credit)
Organizations provide many types of gimmicks for the growth of their business enterprises. Permissible delay in payment or trade credit is one of such policies, which can attract customers and increase sells. Trade credit policy is very effective for the supply chain which dealing with deteriorating products. This policy not only increase sells but reduce loss due to deterioration. In this case, an organization gives a fixed credit period for payment of purchasing of products without any interest for a fixed period of time under few terms and conditions
One level trade credit – It is one way, only main supplier provide a fixed up-stream credit period to retailers but further retailer not providing any down-stream trade credit to customers. Mahata and De [2016], Pramanik et al. [2017], Benkherouf and Gildin [2017] all worked for one level trade credit. This policy is not very effective as real market point of view. Two level trade credit or bi-level trade credit- In this policy the supplier offers a credit period to the retailer and further retailer also offers a down-stream trade credit period to buyers. This credit period increases sales and revenue of business. Huang (2003) first to explore two level trade credit policy.

Credit period can be provided in two ways: (i) Full credit period - Fixed credit period for complete payment and no payment at the time of receiving inventory. Lin et al. [2019] and Otrodi et al.[2019] used this policy recently (ii) Partial credit period - Partial payment at the time of receiving inventory and partial after provided credit period. Recent work in this field are Diabat et al.[2017], Khanna et al.[2017], Pramanik et al.[2019], Shi et al. [2019], Tiwari et al.[2018], Tiwari et al.[2016], Tiwari et al.[2018] etc. After studied above publications we have observed that Pramanik et al. [2019], first who considered demand depends on inflation and time value of money with partial trade credit policy. Most of the works considered decentralized decision-making policy and only few papers considered integrated (centralized) policy like Johari et al. (2018). Sometimes, suppliers are giving permissible delay in payments if the amount of ordered inventory is more than a fixed limit. Such type of trade credit is known as order linked credit. Mishra et al. [2019] studied it.

5.6. Recent effective strategy for deteriorating items
Use of suitable strategy can maximize the profit, minimize total cost and improve customer-vendor relation or reliability in supply chain. Some of strategies used by different researchers for deteriorating ISC are vendor-managed inventory, stackelberg game, discount, sale and unexpected deterioration identification etc.

5.6.1. Vendor-Managed Inventory (VMI)
In traditional ISC size of order is decided by buyer only but in VMI strategy, only vendor is fully responsible for order size. Buyer gives all data of his requirement to vendor and according to that vendor decides the order size. By using this strategy buyer can reduce extra amount of stock and holding cost. VMI policy maximizes profit, reduce critical time or deterioration and improve collaboration between supply chain members. Yu, et al. (2012) studied first VMI strategy. According to past research of Gani and Sabarinathan (2013) VMI is useful only for reducing inventory levels and increasing the replenishment rates but presently it is used by many supply chains for the progress of business enterprises. In presenting review paper, the researches which considered VMI policy are Jiang et al.[ 2016], Shaabani, and Kamalabadi [2016], Bai et al.[2017], Kaasgari et al.[2017], Alamri, and Syntetos [2018], Lin et al.[2019], Gong et al.[2019]. As per our knowledge Bai et al. [2018] was first to use VMI in green supply chain.

5.6.2. Stackelberg game (SG)
It is a planning (strategy) game in which a leader (Government) develops a strategy and followers (policy maker) work sequentially to this commitment. For achieving the target of green supply chain in business enterprises government sets regulations policies for emission reduction and business enterprises should follow these policies for green supply chain along with their basic objective of profitability. In this strategy government’s motto is to reduce emission for social welfare and that of the business enterprises is to minimize total expenses and maximize their profit. Some of recent works in this field are Sarkar et al.[2016], Huang et al.[2016], Hafezalkotob [2017],Hong et al.[2017], Tiwari et al.[2018], Tai et al.[2019] and Halat and Hafezalkotob [2019] etc.

5.6.3. Effects of dynamic pricing of deteriorating items on revenue and deterioration
Sales and discounts are impressive tools for managing deteriorating inventory and attracting buyers before reaching their expiry date. Recent researches in this area are Bai et al. [2016], Chen et al. [2016], Dye and Yang [2016], Onal et al. [2016], Rabbani et al. [2016], Sen [2016], Zhang et al. [2016], Adenso-Díaz [2017], Bai et al. [2017], Banerjee and Agrawal [2017], Chakraborty et al. [2018], Duan et al. [2018], Dye [2019], Feng et al. [2017], Hsieh and Dye [2017], Khan et al. [2017], Khanna et al. [2017], Li et al. [2017], Panda et al. [2017], Lin and Wang [2018], Liuxin et al. [2018], Tiwari et al. [2018], Gong et al. [2019], Li et al. [2019], Mahmoodi [2019], Mishra et al. [2019], Otrodi et al. [2019], Pramanik et al. [2019], Shi et al. [2019], Wang et al. [2019].

5.6.4. Unexpected deterioration identification

It is possible for deteriorating inventory to decay before its expiry date due to bad transportation conditions, inevitable weather conditions, sudden storage power shutdowns etc. This kind of unexpected deterioration cannot be recognized because the product is still fresh according to mentioned date on it. Vendor and customer both are unfamiliar with this deterioration but there is a tool to solve these kinds of problems which can identify the unexpected deterioration of product quality. Time-temperature-indicators (TTIs) combined with radio frequency identification (RFID) can track real quality of product and recognize the sudden deterioration. Some recent works used the effect of this tool in their researches like Gaukler et al. [2017], Herbon and ceder [2018].

There are some policies related to replenishment of inventory like macro-periodic control and micro-periodic control. Under macro-periodic control policy restock of inventory takes place once in a cycle length. Janssen et al. [2018] worked on a new inventory restock policy through micro-periodic control of inventory. According to micro-periodic control policy, inventory can be controlled on every day bases means “restock of grocery stores can be done multi time in a day”. This policy is very useful for deteriorating products as it decreases lose due to wastage. The buyers can order the inventory as many times a day as they required. Micro-periodic control replenishment policy could be extended with more research work along with more parameters.

6. Conclusion and future research direction

In presenting review paper, study and compilation of recent publications existed for deteriorating items has been taken place. In recent few years research work on deteriorating ISC has increased greatly with more real business world strategies. We have divided our study according to the parameters which are affecting supply chain of deteriorating items as demand rate, deterioration rate, permissible delay in payments, green supply chain, dispatching policy and recent strategies like VMI, SG approach, discount, sale and unexpected deterioration identification etc. Presenting review paper indicates recent changes in ISC for deteriorating products.

More research work can be done in this area by taking uncertain demand, credit period policy, dispatching policies, green supply chain, micro-periodic policy etc. Documentation of publications must be carry on in the future, as it gives information about present research activities and future research direction in this field.

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