An Inventory Model with Quantity Discount Offer Policy for Perishable Goods in the Two-Level Supply Chain

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Abstract—**The Literature highlights the existing challenges in the supply chain management of perishable goods including the reduction of product's value over time. Reduction in quality of products leads decrease in price of products. Consequently, this circumstance results in inefficient supply chain management. One possible solution for this problem is setting a supply change management strategy with proper discount policy in order to increase the total profit. Thus, in this paper, the two-level supply chain of perishable goods, was modeled by taking into account a percent discount. The result reveal that the percentage discount equal to 6% is the optimal value in order to achieve win-win agreement between suppliers and retailers.**

Keyword-Supply chain, perishable items, Discount policy, Profit

I.   Introduction and Literature Review

Nowadays, the management of the supply chain is one of the most important fields in the business environment. Every supply chain system includes costly factors such as information, product flows, and consumption-saving decision [1], [2]. Thus, proper management of these flows will be a key to success in the supply chain. In other words, the effective management of supply chain should include efficient system design [3], and flow of goods, information and financial resources in order to maximize the profitability of the entire supply chain [4]. In fact, one of the assumptions considered in old inventory models was that all items should maintain the physical characteristics when they are stored in the warehouse [5]. Nonetheless, mass storage of perishable goods in the warehouse, especially, once they begin to lose their quality results in continuous loss or performance deterioration, corrosion damage, waste and penalties for suppliers [6]. By considering these facts, controlling and maintenance of warehouse with perishable goods is a challenging problem for decision-makers. On the other hand, the supply chain of perishable products such as food or pharmaceutical is very important because the diversity of customers in this type of supply chain is more than other systems [7]. For instance, lack of inefficient pharmaceutical supply chain results in remarkable waste of expired medication [8]. Therefore, delivering healthy goods, will increase competitiveness. A summary of conducted studies in recent years in relation to the supply chain management of perishable items is given in Table 1. Identification of characteristics related to destruction and corruptibility emerged as an interesting topic for the scholars since Pahl and his colleagues presented a model of the blood supply chain in warehouse [9]. Since then, researchers have been inspired to create and develop models for warehousing problems of perishable products in different demand levels, not only based on the items' life cycle but also with considering the type of demand which is the driving force of the entire storage system. One of the most comprehensive studies in terms of the production planning of perishable goods was conducted by Entrap [10]. Which is based on planning and scheduling systems (APS) to manage products with the short expiration date. Entrap explained how expiration date is inserted in APS common systems. He also defined special weaknesses of APS systems for perishable goods by a detailed study of the requirements and characteristics of supply chain for three different products. Based on three case studies, Entrap introduced some solutions in each APS systems that can be adopted with industry needs of new materials.

TABLE I. The summary of recent studies of perishable good supply chain modeling

row	Researcher Name	Year	Terms of problem-solving							Solution method
			Minimize the costs	Maintenance Cost	Shortage price	Price shortages caused by corruption	Time-dependent demand	Perishable goods	Stairway fine in the delay in delivery	
1	Shaabanietal. [11]	2016	▓	▓				▓		The simulation algorithm based on Population genetics CPLEX, software
2	Memariet al. [12]	2015	▓	▓						Matlab software
3	Mishra et al. [13]	2013	▓	▓			▓			Graphics solutions
4	Ghiamiet al. [14]	2016		▓	▓		▓			Numerical
5	Feng et al. [15]	2015		▓	▓	▓	▓			Numerical Simulation and Sensitivity Analysis
6	Yang et al. [16]	2015		▓	▓	▓	▓			mathematical modeling
7	Rahdar et al. [17]	2014	▓	▓		▓				Mathematical models and numerical solution
8	Chung et al. [18]	2013					▓			Mathematical model
9	Berk et al. [19]	2008	▓	▓						Numerical
10	Kouki et al. [20]	2013	▓	▓			▓	▓		Simulation and exact solution
11	Rossi et al. [21]	2010	▓			▓				Constraint Programming
12	Rau et al. [22]	2003	▓					▓		The economic production
13	Govindan et al. [23]	2014					▓	▓		Meta-heuristic algorithm

Capacity planning is one of the key decisions in the production of perishable items [24], [25]. Studies carried out in this field have been focused more on agricultural products. Based[26] described the current challenges in production planning with special attention to long-term capacity investments, uncertain return and uncertain demand. He created a two-step problem as follows; the first step includes determination of capacity investment and the second step includes determination of the production quantity. Jones et al, [27]analyzed the problem of planning production that has a secondary increase in production after the initial output, which caused the uncertain returns. Jones et.al [28] analyzed the real-life capacity management problem. The profiling of demand of perishable items may be random and inconsistent due to promotional activities of the retailers, weather condition, short product life cycle, and seasonality of production [29], [21]. This inconsistency creates demand volatility in a specific period and variation in the type of uncertainty in sequential periods. Mena et.al [30] implied that demand volatility due to weather and advertisement are the main reasons in food wastes. As a result of complexity of demand volatility, the quantitative models for the inventory systems of perishable production have been created [31]. Moreover, environmental factors such as severe weather condition, lack of financing may delay manufacturing or distribution of perishable product [32], [33]. Thus, the value of items is diminished over time. To prevent loss, which is derived by value reduction of perishable items, it is assumed that the determination of a discount policy might help to design more efficient supply chain system. The discount offered by suppliers for high number of products endeavours to encourage buyers to order more products. Shin and Benton [34] offered a discount model for the supply chain including one supplier and one buyer. This model is provided as a risk analysis for the buyer that aims to increase the profit of buyer and supplier without any major changes in the economic lot sizes. The main objective of this paper is a supply chain management of perishable items using a mathematical model that can be employed as a proper tool in the management of perishable products that can improve decision making process in supply chain. The current study endeavours to provide some modifications to improve the efficiency and sustainability of supply chains of perishable items by considering the optimized lead time and discount policy. Finally, it will be endeavoured to achieve a constant desired demand which can maximize the profit for supplier and the retailer. Moreover, the impact of issuing

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policy to the retailer including First in First out (FIFO) and Last in First out (LIFO) policies will be determined on profitability of supply chain value.

II.   Mathematical model

A.   Assumptions

For the mathematical model in this study, the following assumptions are considered:

- The retailors order rate is used as a proxy for real customer demand.

- The equal lead time for both supplier and retailer is assumed [35].

- It is assumed that the items have a certain and fixed life time.

- The items will be considered as waste of the system after the end of life time, if the items are not consumed.

- It is assumed that no reduction occurred in the value of the materials during the life time.

- It is assumed that the lead time for replacement and transferring of raw material for each supplier is α

- Another assumption is that the sorting and packaging activities to be performed quickly in the supply stage.

-The corrupted items will be replaced in the next replacement as follows: the old items of warehouse will be inspected. If their useful life has passed and there is no possibility to satisfy the order, then the cost of shortage caused by corruption will be added to the total cost. Each component in the supply chain must follow this policy for determination of the quantity of daily orders.

B.   Model

1)   The policies for issuing FIFO and LIFO

According to FIFO policies, seller's priority is to offer older product to buyers. If the order quantity is less than the inventory, then seller will satisfy the order by providing older items according to equation 1.

$$S_{n,t} = \sum_{sl=1}^{sl\ max} B_{n,t,sl} \quad (1)$$

If the order quantity ($Q_{n+1,t-1}$)is less than inventory ($I_{n,t}$), the items which their remaining life are equal to 1,will bethrown away by considering waste handling cost. Equation 2 is representative of waste handling cost calculation.

$$W_{n,t} = B_{n,t,sh=1} - S_{n,t} \quad (2)$$

On the other hand, insufficient inventory results in a sales reduction. Equation 3 is representative of sale loss.

$$L_{n,t} = Q_{n+1,t-1} - I_{n,t} \quad (3)$$

According to LIFO policy, the newest items are offered to the customer. In issuing LIFO policy, if the order quantity is less than inventory ($I_{n,t} > Q_{n+1,t-1}$), the seller will provide the order by choosing the products from the inventory by considering the process of decrease in the remaining useful life.

$$S_{n,t} = \sum_{sl\ max}^{sl=1} B_{n,t,sl} \quad (4)$$

Equation 5 is representative of thelossesin LIFO policies.

$$W_{n,t} = \min (B_{n,t,sh=1}, \ L_{n,t} - S_{n,t}) \quad (5)$$

The lost sales for LIFO policy follows equation 3 likewise FIFO policy.

2)   The objective function

In the decentralized supply chain, each player in supply chain systems including retailers and suppliers attempt to maximize their own profits without collaborating with the other partners. The supplier earns benefit only through deal with retailer. Therefore, registering the order Q_2 by the retailer leads the supplier earn revenue, e.g., suppliers prefer to set a discount rate for retailers. The objective function of profit for providers and retailers, respectively is 6 and 7.

$$\max \sum_t \left[\left(P_1 \min (I_{1,t}, Q_2 . \delta_{2,t-1}) - \left[\delta_{1,t-LT_1}(OC_1 + P_0 Q_1) + H_1 \frac{I_{1,t}}{2} + WH_1 . W_{1,t} + LS_1 . L_{1,t} + \alpha P_1 . W_{2,t} \right] \right] \quad (6)$$

$$\max \sum_t \left[\left(P_2 \min (I_{2,t}, D_t) - \left[\delta_{2,t-LT_2} . (OC_2 + P_1 . Q_2) + H_2 . \frac{I_{2,t}}{2} + WH2 . W2, t + LS2 . L2, t - \alpha P_1 . W_{2,t} \right] \right] \quad (7)$$

Where:

$\alpha . P_1 . W_{2,t}$Discount that the supplier has considered for retailer.

$P_1 \min (I_{1,t} , Q_2 . \delta_{2,t-1})$The revenue of supplier.

$\delta_{1,t-LT_1} . (OC_1 + P_0 . Q_1)$Thetotal cost ofpurchasing and providing of order Q$_1$.

$H_1 . \frac{I_{1,t}}{2}$Themaintenance cost of items in stock at time t.

$WH_1 . W_1$The cost of waste disposal.

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$LS_1 . L_{1,t}$ The cost of losing sales for the supplier.

$P_2 . \min (I_{2,t}, D_t)$ The revenue of retailer.

$\delta_{2,t-LT_2} . (OC_2 + P_1 . Q_2)$ The total cost of the purchase and providing order equals to Q_2.

$H_2 . \frac{I_{2,t}}{2}$ The cost of maintenance items in stock at time t.

$WH_2 . W_{2,t}$ The disposal cost.

$LS_2 . L_{2,t}$ The cost of losing sales for the retailers.

C. Case study

All of the provided objective functions in the previous section, have calculated long-term profit to find optimal order quantity. Thus, to evaluate the performance of the proposed model, two parameters (the number of operating days and the discount percentage) were considered. In this case study, time period of 100 days and 10 series of customer demands are considered for calculating long-term profit. It was assumed that each series of customer's demand follow the normal distribution $N \sim (\mu, \sigma^2)$.

Table 2 illustrates numerical values which are chosen for the parameters in our objective functions. Table 3 shows numerical values of constraints.

TABLEII. Unit prices and Costs for the supplier and retailer's objective function

UNIT PRICE	UNIT COSTS		
$P_{0=}1$	Inventory holding cost	Supplier	1.005 (per day)
		Retailer	1.003 (per day)
	Waste handling cost	Supplier	1
		Retailer	1
$P_1=6$	Lost sales cost	Supplier	8
		Retailer	20
$P_{2=}10$	Ordering cost	Supplier	150
		Retailer	100

TABLEIII. Parameters for modelling

Inventory Capacity	Supplier	1000 units
	Retailer	700 units
Service level	Supplier	95%
	Retailer	95%
Lead-time	Supplier	2
	Retailer	1
Maximum remaining shelf time	7 days	
Customer Demand Distribution	$N \sim (100, 30^2)$	

III. Result

Before examining the impact of discounts or different issue policies, it is necessary to specify optimal order quantity for the supplier and the retailer in the decentralized supply chain. In Figure 1, averagelong-term profit in different quantity for retailer is shown., the average long-term profit of retailer and supplier are shown in different orders quantity on the basis of FIFO policy. As it is observed, the greatest amount of profitability for retailers occurs when the order quantity is 300 units. Interestingly, it can be clearly seen that the long-term profit of retailer remains constant after 350 units of orders which means that retailer can get no more benefit from selling more than 300 units since the revenue of retailer at price offers for deteriorated items will be equal to over inventory cost. On the other hand, figure 2 depicts that maximumlong-termprofit for supplier is 250 units within issuing policy of FIFO.

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After obtaining the optimal order quantity for each of the components of the supply chain, the impact of discount policy on profitability for retailers, suppliers, and the entire supply chain is studied. The advantage of considering discounts is that, firstly, the retailers are more encouraged to order goods and earns more profit. Furthermore, by offering the discount, the supplier provokes the retailers to buy more products. Consequently, the total profit of supply chain will increase.
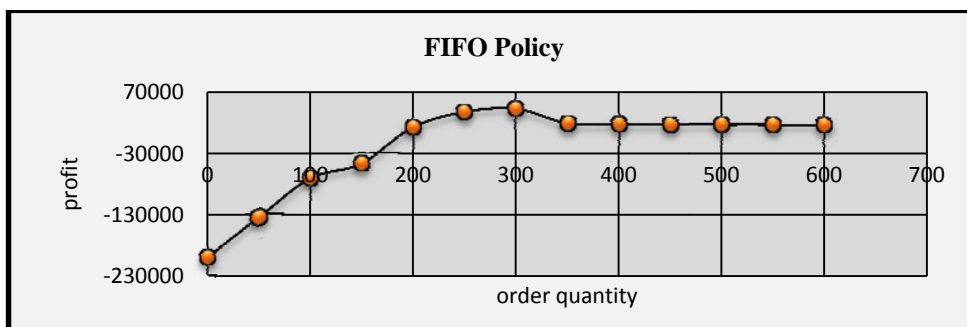
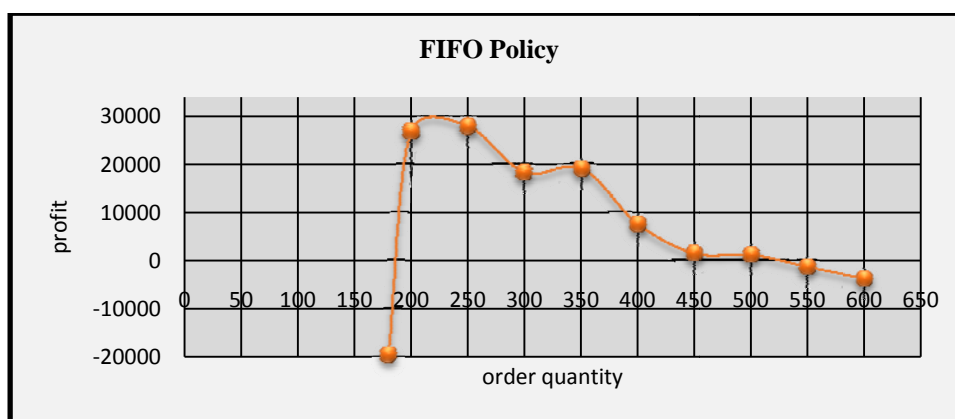Fig.1. Average long-term profit in different order quantity for retailer

Fig. 2. Average long-term profit in different order quantity for supplier

The effect of considering the discounts is shown in Figure 3. The discount percentage has an important role in margin profit allocation between supplier and retailer. Thus, both the supplier and the retailer will be able to achieve higher profit in the long-term. In addition, the total profit of supply chain system will be increased due to the higher order quantity. As it can be clearly seen, by increasing discount rate, the profit of supplier will decrease. In contrast, the profit of retailer has incremental process. In Fig. 3, the satisfactory intervals have been considered for discount amount by following logic. The higher discount rate imposes a heavy burden on the supplier. On the other hand, the lower values cannot encourage the retailer order more.Therefore, the appropriate discount rate interval should be defined in a way that both parties can be satisfied for participating in this deal. Moreover, satisfying discount percentage can result in long term relationship between supplier and retailer. Following, Fig.3 shows thatconsidering 2 percent discount maximizes the supplier's profit, while this rate is minimizing the long run profit obtained by the retailer. Thus,2 percent discount cannot be satisfying rate for each supply chain party. In this case, the supplier needs to raise the discount rate till retailer becomes satisfied. On the other hand, he has to take into account that the offered discount rate should cause the least profit reduction for him. It also seems that the percentage discount equal or higher than 6% would be desirable for the retailer. Hence, satisfactory discount rate interval is identified as 6% and higher. Nonetheless, 6% discount rate results in the least profit loss for supplier. Consequently,6% discount would be the best option that supplier can offer to the retailer.
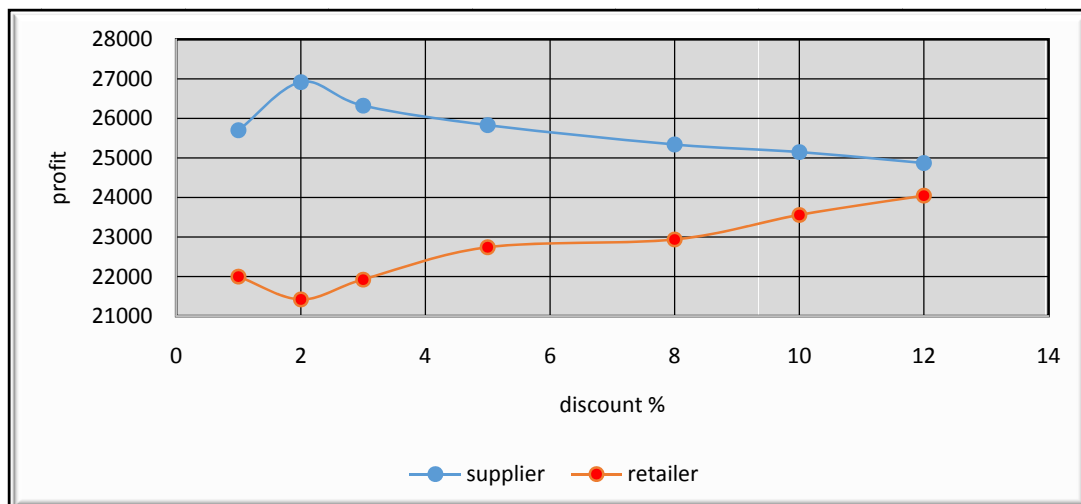
Fig. 3. Margin profit of supplier and retailer and discount percentage

IV. Conclusion

Perishable goods supply chain islong process, difficult because of short cycle of sales, complex in terms of added value achievement, and obtain high risk of uncertaindemand. The mentioned challenges are based on the nature of the product or the preferences of the target consumer. That is improving supply chain management of perishable goods are significantly helps different stakeholders related to deteriorating items to increase their long-term profit and maintain their long-term relationship.

On the other hand, the challenge for the management of perishable products is the fact that the value of product significantly reduced overtime. For many products, a decision related to supply chain strategy involves selecting between accountability and efficiency. The right choice depends on the way how product's value changes from manufacturing to customer delivery. Therefore, by inserting discount policy not only does the supply chain can encourage retailer to do more perishable items but also it results in more trade between retailers and suppliers which will prevent corruption of mentioned items. In this paper, two-level supply chain of perishable items include one supplier-retailer with discount rate was modelled. The result of the study shows that by increasing the discount percentage, the profit of supplier in long-term diminishes and the profit of retailer increases. Finally, the overall profit of supply chain in long-term will have incremental trend. The analysis also shows that the percentage discount for 6%, is the most optimal amount of discounts that can be offered by suppliers.

V. Future work

The finding of this study revealsa discount policy with optimized rate for supply chain of perishable goods. However, the nature of different perishable items is out of scope of this paper which can be considered in future. In other words, future research could be conducted to achieve an optimal discount policy for supply chain of perishable goods with consideration of different expiration date.

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