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Retailers modeling approach for determining order quantity and issuing policy of perishable products.

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Abstract:- In present scenario, retailers of perishable products are facing the challenges of deciding order quantity and issuing policy in order to fulfill customer demands. This paper proposes an integrated modeling approach that allows easy and quick exploration and selection of the best ordering and issuing policy from among various available alternatives regarding perishable products at the retailer end. Using this approach, on the basis of available inventory retailers can take decisions regarding placing of orders, and allocation of products with respect to shelf life to customers. The modeling algorithm is based on dynamic programming approach, and is developed using the programming platform of MATLAB software.

Keywords- Dynamic programming, Perishable, Inventory management, Retailer, Food supply chain, Modeling.

I. INTRODUCTION

In the present market scenario, the role of the retailer in supply chains is very vital in controlling and regulating the market. The retailer performs the job of communicating the information from customer to manufacturer/wholesaler with regards to sales forecast, customer complaints, inventory turnover etc. Thus in general, the linkage with customer is possible only through the retailer.

Due to increasing competition, and ever-changing customer needs induced through globalization, tremendous pressure is being exerted on retailers to maintain proper inventory of products and to satisfy customers with customized products. This has complicated the situation at the retailers' end leading to high inventories and poor customer service [1]. Present market conditions dictate the need for retailers to change the way they manage their inventories. Placing the right order quantity with respect to demand is highly essential for the retailers in order to control inventory. Thus deciding the right order quantity and maintaining the right level of inventory are the key issues that need to be addressed in order to have efficient retailer supply chain networks.

Till date many researchers have contributed in the area of perishable food supply chains with objectives of developing optimal order quantity policies and inventory management policies by considering different scenarios related to demand patterns, issuing policies, selling prices, and review periods of inventory (e.g. [3]-[5]).Research on pricing and inventory policies has been pursued by economists, marketing scientists, and operations researchers from a wide range of perspectives ([2], [6]-[8]).

Substantial research has been done in the area of modeling to improve the retailer performance in food supply chain management ([9]-[11]).

The review of literature indicated a strong orientation towards identification of methodologies for formulating policies for inventory management, optimal order quantity estimation, pricing, issuing, and retailer management from the viewpoint of maximizing the profit of perishable products. In most of the cases it was observed that modeling was done to tackle only one given problem area. However, under the present market conditions were staying competitive is the key to success, it is highly desirable to develop new approaches that provide a comprehensive solution to all the problems of retailers. Hence, the proposed research work attempts to develop an integrated modeling framework (based on dynamic programming approach) to address several issues faced by the retailers of perishable products such as deciding on the amount of ordering quantity required per period and choosing the right issuing policy on the basis of remaining shelf life.

The rest of the paper is organized as follows: Section 2 presents the proposed approach in a systematic way. After a basic introduction of the models that constitute the overall framework, the assumptions made as well as the notations used are clearly outlined. Then the formulation of the models is taken up in detail. Section 3concludes the paper with some inferences and proposed future research directions.

II. MODEL APPROACH

2.1 Model Introduction

The proposed model is basically concentrate on retailer dealing with single perishable product, the demand of the product at the retailer end is assumed to deterministic and the objective of the modeling is to solve a multi-period ordering problem for a product having fixed life perishability, in a way that maximizes the long-term cumulative profit. The generalized problem formulation is done using a dynamic programme approach. The algorithm is developed using the programming platform of MATLAB software. The whole model is based on the initial inventory level available with the retailer. It is proposed that the retailer can take the decision of placing the order at any level of initial inventory.

The overall framework is formulated by integrating two separate models:

Model I. Optimum order quantity model for deterministic demand

The basic objectives of this model are to:

- Determine the optimum initial order quantity for any desired length of planning horizon as well as for any level of initial inventory.
- Determine the optimum ordering quantity for each period of the selected length of horizon on the basis of initial inventory.

To achieve the above mentioned objectives, this model is divided into two stages (stage 1 and stage 2) which have been discussed in detail in section 2.3.

Model II. Retailer issuing policy and cost analysis model

The basic objectives of this model are to:

- Provide an Analysis of the order quantity received on the basis of given lead time and to determine the hands-on inventory at the end of each period.
- Provide detailed data regarding remaining shelf life of perishable products for any given issuing policy.
- Provide a detailed analysis of cost as well as the net profit earned by the retailer in each period of the selected planning horizon.

2.2 Model Notations and Assumptions

Notations:

1) $d_n =$ Demand for the product in period *n.*

2) $q_n(i) =$ Order quantity with respect to initial inventory ‘i’ for period ‘*n’*.

3) $q_{\max}$ = Maximum ordering quantity.
4) i_n = Balance inventory at the end of period *n*.
5) i_{ho} = Hands-on inventory.
6) $i_{\max}$ = Maximum inventory limit.
7) $c(\cdot)$ = Cost function.
8) $f_n(i)$ = Minimum policy cost when entering inventory is at level 'i' with 'n' more periods to go.
9) $C_n(t)$ = Cost at time 't', of the unit that was received in the n^{th} period.
10) h_{cost} = Inventory holding cost per unit.
11) OC_n = Ordering cost of the unit that was received in the n^{th} period.
12) F = Fixed ordering cost.
13) V = Variable ordering cost.
14) SL = Initial shelf life of fresh product.
15) $SL(n)$ = Remaining shelf life of the unit received in the n^{th} period.
16) $SL(t)$ = Remaining shelf life of the unit at time 't'.
17) l_t = Lead time required by the wholesaler to replenish the order quantity.
18) $f_A[SL(t)]$ = Allocation function with respect to shelf life (SL) of product in period (t).
19) $FIFO$ = First in first out issuing policy
20) $LIFO$ = Last in first out issuing policy

Assumptions:
1) The demand is deterministic. In other words, a constant demand of d_n units per period is considered.
2) The product has a deterministic lifetime of *N* periods. However, throughout its life, the utility of the product is assumed to be constant.
3) Products are discarded if the shelf life of the product is exhausted.
4) It is assumed that due to some constraints, the retailer can not exceed a limiting ordering quantity of $q_{\max}$ in any period.
5) It is assumed that due to space limitations, the retailer can not keep an inventory level more than $i_{\max}$.
6) Hands-on inventory is always less than $i_{\max}$.
7) Whenever an order is placed by the retailer, it is always made available at the end of the lead time. In other words, it is assumed that stock out never occurs at the wholesaler /distributor end.
8) New order replenishments by the wholesaler / distributor have maximum shelf life.
9) Inventory level is zero at the end of period *n*, i.e.: $i_n = 0$ (1)

2.3. Model Formulation

Model I (Optimal order quantity Model): This model consists of two stages. The basic objective of the first stage is to decide the optimum initial ordering quantity and optimum cost for any length of horizon and for any level of inventory when the demand is assumed to be deterministic. Dynamic programming approach has been used for developing the optimum order quantity model. This optimization approach is carried out by splitting the given problem into a sequence of stages in such a way that an optimal solution is obtained by progressively solving the stages [12]. In the second stage, optimum order quantity for each period at a given level of initial inventory for the assumed time horizon is determined.

Stage 1: The proposed approach is used for deciding ordering quantity for given length of horizon when the demand of the product is deterministic. For analyzing the model we will assume value of maximum ordering quantity $(q_{\max})$ and maximum initial inventory available with the retailer is $(i_{\max})$. In order to determine the minimum cost for different level of horizon, the detail procedure is as follows:

Step 1: For period $(n=1)$,calculate the ordering quantity $q_n(i)$ and the associated cost $f_n(i)$ (where initial inventory 'i' varies from 0 to $i_{\max}$).

$$q_1(i) = (d_n - i) \quad (2)$$

$$f_1(i) = c(d_n - i) \quad (3)$$

Step 2: Calculate the optimal ordering quantity $q_n(i)$ and minimum cost $f_n(i)$ (where initial inventory, 'i' varies from 0 to $i_{\max}$ and order quantity 'q' varies from 0 to $q_{\max}$) for period $(n=2)$.

For individual values of inventory 'i', calculate minimum cost $f_n(i)$ for every combination of 'i' and 'q' using recursion equation (4) [13].

$$f_n(i) = \min_q (c(q) + h_{cost}(i+q-d_n) + f_{n-1}(i+q-d_n)) \quad (4)$$

$$\text{Where, } c(q) = F + V * q(i) \quad (5)$$

Here, F and V are the fixed and variable costs associated with the ordering cost respectively.

$$\text{When } q_n \le 0 \text{, we have } c(q_n) = 0 \quad (6)$$

Note that $(i+q-d_n) < 0$ and $(i+q-d_n) \ge i_{\max}$ represent infeasible combinations.

Step3: Calculate optimum order quantity $q_n(i)$ and optimum policy cost $f_n(i)$ using the same procedure as explained in step2 for periods $n = 3, 4, ...,$ upto N (i.e. upto the end of the selected horizon).

The results of stage 1 provide the initial optimal order quantity and the corresponding optimum policy cost for various levels of initial inventory.

Stage 2: For calculating the order quantity for each individual period, the detailed procedure is as follows:

1. Find the value of the initial order quantity $q_n(i)$, for given values of (i) and (n) using the result obtained from stage 1.

$$\text{Let, } q_n(i) = x \quad (7)$$

2. Calculate the balance hands-on inventory (y) at the end of the period using equation (8).

$$y = (i + x - d_n) \quad (8)$$

3. Determine $q_{n-1}(y)$ from the result obtained in stage 1. Note here that y becomes the initial inventory for period $(n-1)$.
4. Repeat steps 2 and 3 for calculating the order quantity for all remaining periods (i.e. till the count of n reaches 0).

Model II- Issuing policy and cost analysis model: The basic objective of this model is to help decide on an issuing policy (based on the shelf life of the product) that will earn maximum profit for the retailer in each period for given level of inventory.

Once the order quantity for a given length of horizon with respect to initial inventory is known, the inference procedure for analyzing the order quantity, issuing policy, at the end of horizon is given by equations (9),(10),(11),(12),and (13) .

$$i_{ho} = (i + q_n) \tag{9}$$

$$i_n = (i + q_n - d_n) \tag{10}$$

$$f_A\left[SL(t)\right]_{FIFO} = \min_{i_{ho}}\left[\sum_{j=1}^{d_n} SL_j(t)\right] \tag{11}$$

$$f_A\left[SL(t)\right]_{LIFO} = \max_{i_{ho}}\left[\sum_{j=1}^{d_n} SL_j(t)\right] \tag{12}$$

$$i_{bal} = i_{ho} - d_n \tag{13}$$

The net profit earned takes into consideration an optional sales promotion scheme under which, perishable products having lesser remaining shelf life are cheaper than the fresher one.

The result of model 2 is the detailed analysis of ordering quantities and the issuing policy with respect to shelf life. It also gives the cost analysis for the respective period for the retailer.

The integrated framework proposed in the present paper helps the retailer to decide on the length of horizon, level of initial inventory, and the quantity of order to be placed so as to maximize the overall profit.

III. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

The proposed integrated framework provides a comprehensive solution to many issues confronted by the retailers of perishable products in the form of:

- Determining optimum order quantity for retailer at any level of initial inventory.
- Eliminating the need to estimate the reorder quantities.
- Deciding on the best policy for issuing the products to customers so as to maximize profits.
- Determining the selling price of product with respect to shelf life for every period of the horizon.

The proposed integrated framework allows retailers to decide on the optimum ordering quantity for the complete planning horizon at the beginning of any given period itself. This approach is also useful for wholesalers/distributors in maintaining inventories in accordance with the demand placed by retailers.

Following are some suggested future research directions:

- Currently, the proposed model takes into consideration only a single perishable product. However it can be easily extended to deal with multiple products for a single retailer.
- Since the proposed framework allows easy access to the knowledge of the age of all available products in each period, opportunities for the development of appropriate promotional schemes using different price reduction factors can be explored.
- The proposed integrated model can be extended to include multi-period ordering polices for various stochastic demand scenarios, and also to investigate the nature of the profit function for various stochastic demands.

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