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A genetic algorithm approach for multi-product multi-period continuous review inventory models

Ilkay Saracoglu [a,*], Seyda Topaloglu [b], Timur Keskinturk [c]

[a] Graduate School of Natural and Applied Sciences, Dokuz Eylul University, Tinaztepe Campus, 35160 Izmir, Turkey
[b] Department of Industrial Engineering, Dokuz Eylul University, Tinaztepe Campus, 35160 Izmir, Turkey
[c] Department of Quantitative Methods, School of Business, Istanbul University, Avcilar, 34180 Istanbul, Turkey

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ABSTRACT

This paper formulates an approach for multi-product multi-period (Q,r) inventory models that calculates the optimal order quantity and optimal reorder point under the constraints of shelf life, budget, storage capacity, and "extra number of products" promotions according to the ordered quantity. Detailed literature reviews conducted in both fields have uncovered no other study proposing such a multi-product (Q,r) policy that also has a multi-period aspect and which takes all the aforementioned constraints into consideration. A real case study of a pharmaceutical distributor in Turkey dealing with large quantities of perishable products, for whom the demand structure varies from product to product and shows deterministic and variable characteristics, is presented and an easily-applicable (Q,r) model for distributors operating in this manner proposed. First, the problem is modeled as an integer linear programming (ILP) model. Next, a genetic algorithm (GA) solution approach with an embedded local search is proposed to solve larger scale problems. The results indicate that the proposed approach yields high-quality solutions within reasonable computation times.

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1. Introduction

Customer satisfaction has recently become one of the most important issues for companies as a consequence of globalization, increased competition, and shrinking profit margins. The most fundamental condition associated with customer satisfaction is the availability of products upon request. In order for companies to satisfy this condition, excellent inventory management is essential.

Much research has been conducted on inventory management, and results have shown that the type of inventory management needed varies according to the nature of the companies. To construct an inventory management policy, it is therefore necessary to conduct an in-depth analysis of the nature of the target company. The inventory manager must determine (1) when an order should be placed, and (2) how much should be ordered. Further, inventory, production, marketing, and finance managers should operate in concert in order to reach an agreement on how to reduce production costs and inventory investments, and increase customer responsiveness.

Good inventory management is closely linked to the inventory policy implemented, and is based upon a profound analysis of the system. Harris (1913) first estimated the economic order quantity to minimize the total cost of keeping stocks and placing orders. A model was developed for a single product without any constraints on the assumption that demand is known and lead time is zero.

However, in many real inventory systems, there is usually uncertainty with regard to demand and lead time. Continuous review inventory policy (Q,r) is one of the most common policies for cases in which the demand is uncertain and a supply lead time exists. In this policy, an order quantity Q is placed when the inventory level is at or below reorder level r. The (Q,r) policies applied on single items with fixed lead time have been studied by researchers such as Hadley and Whitin (1963), Federgruen and Zheng (1992), Zheng (1992), Axsäter (1993), Kim and Benton (1995), Axsäter (2007), Lau and Lau (2008), Mattsson (2010), Hajiaghaei-Keshteli, Sajadifar, and Haji (2011), and Ang, Song, Wang, and Zhang (2013).

In actual inventory systems, however, multi-item storage is an issue typically encountered. For instance, wholesalers, large distribution chains, and department stores manage an inventory system comprising a wide range of products. Garman (1976), Gardner (1983), Hopp, Spearman, and Zhang (1997) formulated multi-product (Q,r) inventory policy with some constraints such as inventory investment, service level and order frequency. Jeddi,

* Corresponding author. Tel.: +90 5324520069; fax: +90 2123665802.
E-mail address: ilkays@sbbdanismanlik.com (I. Saracoglu).

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Shultes, and Haji (2004) analyzed multi-product stochastic inventory system with backorders, shortages, and budget constraints. Betts and Johnston (2005) constructed a multi-item (Q,r) model with the objective of determining an optimal replenishment policy by reducing risks and increasing profit.

As in most of the inventory management problems, unfortunately, the model is naturally complex for the multi-product case and it is intractable to control optimal policies analytically due to the size of the solution domain. Therefore, it is observed that iterative procedures such as heuristics and metaheuristics are used in order to reach a solution in multi-product inventory systems. Pasandideh, Niaki, and Tokhmehchi (2011) developed a multi-item (Q,r) inventory policy for a two-echelon inventory system by using genetic algorithm (GA). Pasandideh, Niaki, and Nia (2011) proposed a multi-product *EOQ* model which does not only consider the storage capacity, but also assumes the number of orders limited, and they used GA to solve it. Mandal, Maity, Maity, Mondal, and Maiti (2011) formulated multi-item multi-period production problems with fuzzy-random parameters and space constraints and solved using GA. Yang, Chan, and Kumar (2012) developed a GA approach for solving the multi-retailer, multi-product and multi-period inventory system with backlogging and transportation capacity. Mousavi, Hajipour, Niaki, and Alikar (2013) suggested a heuristic using GA and simulated annealing for the multi-item multi-period inventory control problem with discounts, time value of money, and inflation.

This paper analyzes a pharmaceutical distributor that buys medicines from pharmaceutical manufacturers and resells them to pharmacies. The objective of the distributor is to meet the demands of the pharmacies on time. Because a large number of distributors is available in the sector, competition is intense. Consequently, customer satisfaction is viewed with the utmost priority. However, because distributors have to operate within the confines of budget constraints, they need to make optimum use of their budgets. In addition to the budget, shelf life and storage area – for drugs that require cold storage – are additional constraints that have to be satisfied. Further, pharmaceutical manufacturers may desire to deliver an additional amount of drugs for free to induce increases in the number of medicines sold in the pharmacies, instead of offering discounts on the basis of quantity ordered. A further item to bear in mind is the fact that pharmaceutical manufacturers may provide convenient payment options to the distributor who, in turn, may pass on these payment options to the pharmacies. Regarding the pharmaceutical sector, Bijvank and Vis (2012) provided an overview on the literature for hospital inventory systems. Lapierre and Ruiz (2007) modeled the multi-product, multi-period logistics system as a mixed-integer program under the limitation of storage and manpower capacities, and developed a tabu search to solve the problem owing to the large scale of the problem.

This paper constructs a multi-item multi-period (Q,r) inventory policy considering items with variable demand and determines the optimal order quantity (Q) and reorder point (r) for each item to maximize the profit for the pharmaceutical distributor in question, considering all these constraints.

When we examine the companies in the pharmaceutical sector, it can be seen that they are using a particular database and the functionality of their systems is no more than keeping track of past sales and current stock information. Yet they are not capable of performing an optimization like the one we are suggesting in this study. To give an example, among one of the most developed Enterprise Resource Planning (ERP) programs, SAP uses Materials Requirements Planning (MRP) and Distribution Requirements Planning (DRP). MRP makes calculation for the dependent demand by taking the input value (such as days of supply, lead time, forecast, Master Production Scheduling (MPS), safety stock) introduced to the system as a base and provides purchase of needed amount and determines order time by considering lead time, whereas DRP system performs the distribution planning for the customers. While advanced planning and scheduling (APS) models are embedded to SAP to perform optimization using mathematical programming techniques, these models work under the assumption that all parameter values are constant and known absolutely (Kallrath & Maindl, 2006, Louly & Dolgui, 2013), they do not address the specific inventory management problem in this study.

The remainder of this paper is organized as follows: Literature review is presented in Section 2. Problem description and assumptions, and our proposed mathematical model are given in Section 3. A GA based solution approach is developed to solve the problem in Section 4. An illustrative computational case study is given in Section 5. In order to demonstrate how the proposed methodology is applied, a real case study and sensitivity analysis are carried out in Section 6. Finally, conclusions and recommendations for future research are provided in Section 7.

2. Review of current literature

In this paper, a multi-item perishable inventory management system is proposed. Many products may lose their market value over time as they become outdated, called perishability. Perishability is divided into two categories: fixed and random lifetime. Fixed lifetime is used for items that have a specific physical lifetime, such as photographic film, drugs, vitamins, and ready packed food and milk. Random lifetime is used for items whose spoilage time cannot be estimated, such as fresh vegetables, fruits, and meats. The fixed lifetime and exponential decay inventory study performed by Van Zyl (1964) is among the first perishable items study conducted. Nahmias (1982), Nahmias (2011, 1991) and Goyal and Giri (2001) reviewed the current literature on ordering policies for perishable items.

Continuous review policy (Q,r) has been used for nonperishable items in a number of studies. The first such study was conducted by Berk and Gurler (2008). The results of our literature survey performed to date show the (Q,r) inventory model being used as single period in multi-product problems and for nonperishable products, as illustrated in Table 1.

Zhao, Fan, Liu, and Xie (2007) tackled optimization with storage-space constraint for the single-item (Q,r) policy, and proposed an efficient algorithm with polynomial time computational complexity that obtains the optimal solutions. Then, they extended their proposed method to enhanced multi-item (Q,r) policies. Wang and Hu (2010) studied a continuous review (Q,r) model to find the optimal lot size and reorder point for a multi-item inventory model with interactions among items under budgetary constraints. They formulated the problem as a nonlinear one and constructed a simple heuristic approximating procedure to solve it. Kundu and Chakrabarti (2012) analyzed uncertain lead time and demand condition for multi-item production. They created a mathematical model that can determine the safety factor and order quantity and proposed a continuous review model for a multi-product system with both backorders and lost sales under budget constraints. Zhao, Qiu, Xie, and He (2012) investigated single- and multi-item (Q,r) inventory systems with a stochastic demand, limited resources, constant lead time, and backorders.

We discovered from our literature review that the (Q,r) inventory policy has not yet been carried out as multi-item multi-period. The multi-period studies reviewed primarily dealt with lot-sizing problems in production. Veinott (1965) considered a dynamic nonstationary multi-product inventory model in which the system was reviewed in equal-length time periods, unsatisfied demand was backlogged, and deterioration of stock did not occur in storage.

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