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ARAŞTIRMA MAKALESİ /**RESEARCH ARTICLE**

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DECISION SUPPORT SYSTEM FOR INVENTORY MANAGEMENT IN A PHARMACEUTICAL WAREHOUSE

ABSTRACT

This study focused on inventory management in pharmaceutical industry. For this purpose a Decision Support System for inventory management is designed in one of the major distribution channels in the Turkish pharmaceutical sector. In pharmaceutical sector nearly all firms offer temporary sale prices for some products in certain parts of the year and warehouses usually want to purchase large amounts to use this offer. In case of temporary selling price to be asked how much quantity should be ordered to minimize total annual cost. For this purpose, the designed system helps decision maker in purchase decisions.

Keywords: Economic Order Quantity (EOQ) Model, Temporary Sale Price Model, Inventory Management System, Decision Support System, Pharmaceutical Warehouse

BİR ECZA DEPOSUNDA STOK YÖNETİMİ İÇİN KARAR DESTEK SİSTEMİ

ÖZ

Bu çalışmada, ilaç sektöründe stok yönetimi konusu ele alınmıştır. Bu amaçla, ilaç sektörünün önemli dağıtım kanallarından olan bir Türk ecza deposu için stok yönetimi karar destek sistemi tasarlanmıştır. İlaç sektöründe hemen hemen tüm firmalar yılın bazı bölümlerinde bazı ürünler için geçici satış fiyatları sunmaktadır ve ecza depoları bu fırsattan yararlanabilmek amacıyla büyük miktarlı alımlar yapmak istemektedir. Geçici satış fiyatı uygulamasının olması durumunda sorulması gereken toplam yıllık maliyeti enazlayacak en iyi sipariş miktarının ne olacağıdır. Bu amaçla, çalışmada tasarlanan sistem karar vericiye satın alma kararlarında yardımcı olacaktır.

Anahtar Kelimeler: Ekonomik Sipariş Miktarı (ESM) Modeli, Geçici Satış Fiyatı Modeli, Stok Yönetim Sistemi, Karar Destek Sistemi, Ecza Deposu

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1. INRODUCTION

Companies must hold a certain amount of inventory in order to carry out their activities. Some of important reasons to hold inventory are the economies of scale in production and procurement, requirements fluctuating in long term, the desire for flexibility in scheduling sequential facilities, speculation on price or cost, and the uncertainty about requirements and replenishment lead times (Johnson and Montgomery, 1974). As well as in many sectors, the appropriate inventory management is a remarkable problem in the pharmaceutical industry. Inventory control systems may be the first information technology application in pharmaceutical industry (Stephens, 2006). The pharmaceutical industry consists of manufacturers and pharmaceutical warehouses which are known as distribution channels and pharmacies. In this study, Bursa Eczacılar Kooperatifi (BEK), one of the pharmaceutical warehouses in Turkey, is being investigated.

The main purpose of pharmaceutical warehouses is to deliver the products by supplying from pharmaceutical firms to pharmacy at the right time and the right amount. To accomplish this goal, pharmaceutical warehouses should hold the appropriate amount of product stock. Therefore, a successful inventory control system and the determination of the most appropriate ordering policies for inventory structure are very important. According to relationship between pharmaceutical firms and pharmaceutical warehouse, the Economic Order Quantity (EOQ) Model is appropriate for this pharmaceutical warehouse. Also in pharmaceutical sector, almost all companies offer temporary sale prices for some products in certain parts of the year; warehouses want to purchase larger amounts in order to make more profit from those temporary prices. The thing which should be asked in this point is which amount of order is the best in special price situation. To the best of our knowledge there is not any paper that addresses a Decision Support System (DSS) for pharmaceutical warehouses which is considered in this paper. In this study, a Decision Support System (DSS) is designed to help decision maker in purchase decisions for this purpose. Among benefits of this system, decision maker can find answers of following questions; “Which amount of purchase makes the total cost minimum?”, “Which drug will be ordered and when?”, “How much quantity should be ordered?”, “In case of temporary sale price, how large should be the order quantity?”

This paper is organized as follows. In section 1, there is an introduction of the study. Section 2 includes concepts of inventory and inventory control systems. Designed inventory management Decision Support System is given in Section 3. Finally, conclusion and further works are given in Section 4.

2. INVENTORY MANAGEMENT AND CONTROL

2.1. Inventory Costs in the Purchase of Goods

An inventory may be considered as an accumulation of the commodity which will be used in order to satisfy some future demand for that commodity (Johnson and Montgomery, 1974). The common inventory classifications found in industry are; raw materials, material in process, finished products, component parts and supplies (Greene, 1974).

There are some costs arising from attaining and maintaining inventories of purchased goods; such as raw materials needed for production and finished goods stocked for sale (Garrett and Silver, 1973).

Procurement costs: The most obvious costs are those involved in the acquisition of the inventory; including the expense of such clerical operations as filing and reviewing the requisitions, processing the purchase orders, checking the incoming vouchers, and paying the bills. The important feature of these costs is that they are “on-time costs”. Therefore may be treated like fixed costs.

Inventory holding costs: The second major category of costs is the cost associated with carrying the inventory itself such as capital costs, handling and storage costs, spoilage and shortage costs, insurance and tax payments, and systems costs.

Capital costs: As well as any other asset, inventories required capital investment. Funds allocated to inventories are not available for other uses; therefore, the opportunity cost is determined by the alternative use to which the funds could be allocated.

Handling and storage costs: The facilities required in order to store an inventory create costs such as rent, heating and lighting. Often storage facilities are available and have no alternative use; in that case, the costs of storage are fixed and do not vary with the inventory level. Beyond a given amount of inventory, however, these costs will begin to increase as more items are put in stock. The same considerations can be applied to handling costs.

Spoilage and shortage costs: Many products deteriorate over time in storage. The precise nature of deterioration varies from product to product, but whatever the cause; it represents a reduction in the company's assets and, as such, is a cost of holding inventories. This is called the *spoilage cost.*

Insurance and taxes: Because inventories often represent significant investment of a firm's capital, conservative management practice calls for insurance protection. Naturally, the cost of this insurance will vary according to the size and the value of the inventory. The same is valid for taxes.

System costs: The final type of inventory holding costs continue being discussed. They associate with the administration of the inventory system in use, such as information-gathering costs, supervision costs, physical-stock-checking costs, and record-keeping-equipment costs.

Stockout Costs: A company also experiences a cost, called a stock-out cost, if its supply of goods runs out before the demand for the product is satisfied. There are two types of stock-outs. The first occurs if an item is not available for sale or for maintaining the production schedule but can be obtained through an emergency. In case of finished goods, if an item is not available and cannot be obtained by emergency procedures, the seller loses a sale. Generally he loses more than that. At first glance, this type of stock-out cost might appear to be simply the loss of profits that would have resulted from the sale.

2.2. Importance of Inventory Control System

Companies need a good inventory control system and determining the most appropriate ordering policies for inventory structure is very important:

- A good inventory control system minimizes the possibility of delays in production. Depletion of an item's quantity in stock may indicate a bad and dangerous condition for a factory.

- A successful inventory control system allows a company to exercise economies in many ways. It eliminates duplication in ordering process and encourages a better utilization of available materials through interdepartmental or intercompany transfers. Purchasing economies can be exercised by obtaining quantity and shipping discounts.

- A good inventory control system is essential for the efficient accounting system.

- A good inventory control system stimulates taking care of the material, minimizes losses caused by damage in careless handling important (Greene, 1974).

Inventory control models are used to determine order quantity. In this study, designed Decision Support System includes deterministic models. These models often serve as useful approximations to many real-world inventory systems.

2.3. Deterministic Inventory Control Models

The fundamental problems for inventory systems are to determine when to place an order for additional stock and how much stock should be ordered. In deterministic inventory models demand rate is constant. So, the order policies can be accepted as ordering in lots of a fixed size whenever the inventory level drops to the reorder point. The problem is then what values to use for lot size and reorder point. To answer these questions, we shall formulate a mathematical model that expresses the average annual cost as a function of these two decision variables, and then determine the order quantity and reorder point that minimize this cost (Johnson and Montgomery, 1974). The relationship between these costs is shown graphically in Figure 1.

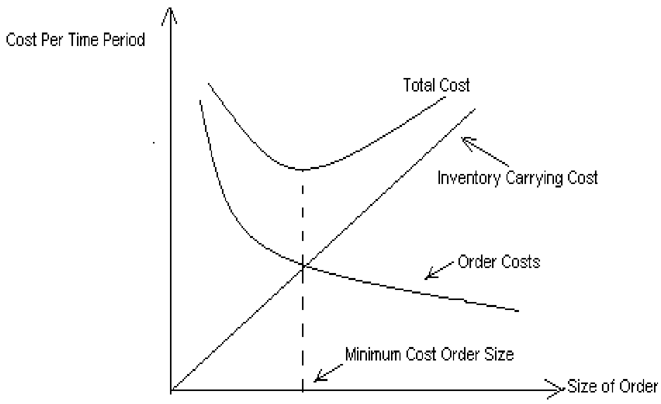


Figure 1. Order size-cost relationships (Garrett and Silver, 1973)

The purpose of the model is to find order quantity which minimizes the total order costs and total handling and storage costs.

We suppose that the demand rate at the retailer and the transportation time to the retailer are constant. Shortage is not allowed by retailer, so, inventory level at retailer is a simple EOQ model and behaves as depicted in Figure 2 (Baboli et al., 2006).

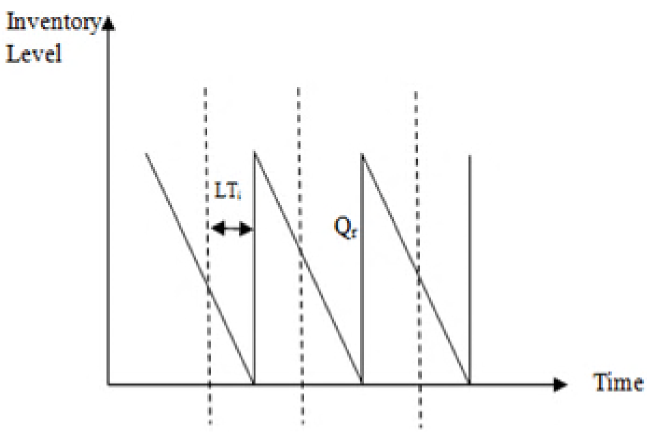


Figure 2. Inventory level at retailer (Baboli et al., 2006)

EOQ model's main assumptions are (Heizer and Render, 1996):

- The demand is known and stable
- Ordering range is known and stable
- Sudden stock purchases
- Quantity discount is not possible
- If orders are in the right place at the right time, out-of stock situations can be avoided completely.

Notations which are used in EOQ model:

D: demand rate in units per year

A: fixed cost of a replenishment order

c: unit cost, which is the sum of the direct labor, direct material, and overhead

h: inventory holding cost per unit per year

Q: order quantity

T: cycle length

TC: average annual cost which is a function of the inventory policy

$$Order\ replenisment\ cost = \frac{AD}{Q} \tag{1}$$

$$Inventory\ holding\ cost = \frac{Q}{2}h \tag{2}$$

$$Purchasing\ cost = Dc \tag{3}$$

So total cost is (Johnson and Montgomery, 1974);

$$TC = \left(\frac{AD}{Q}\right) + \left(\frac{Qh}{2}\right) + (Dc) \tag{4}$$

In the Eq(4); "h=ic" and "i" refers to the sum of all carrying charges expressed as a percentage of cost of the parts carried in stock for the year. Total cost function is a function of order quantity "Q". We have obtained the optimum Q by equating the first partial derivatives of TC to zero and solving the resulting equations. So optimal solution is (Johnson and Montgomery, 1974);

$$\frac{\partial TC}{\partial Q} = 0 \tag{5}$$

$$Q = \sqrt{\frac{2AD}{ic}} \tag{6}$$

The model described here is for inventory systems consisting of a single item. However, most of inventory systems stock many different items (Johnson and Montgomery, 1974). Also, there may be some constraints that affect inventory system such as warehouse capacity, upper limit on the number of orders, maximum investment and etc. We may write the average annual cost of multiple-item inventory system as just the sum of the average annual costs for individual items. For example, if there are n items in stock system and j = 1, 2, …, n denotes the item (Johnson and Montgomery, 1974);

$$TC = \sum_{j=1}^{n} TC_j = \sum_{j=1}^{n} \left((\frac{A_j D_j}{Q_j}) + (\frac{Q_j}{2} c_j i_j) + (D_j c_j) \right) \quad (7)$$

Johnson and Montgomery (1974) described the average annual cost of an n-item inventory system as a function of the 2n decision variables, "Q_j" and "r_j". The interaction between n items, or the constraint, may also be written as a function of the 2n decision variables. Here, we can always express the average annual cost as a function; say TC, of the 2n decision variables, and the constraint may be expressed as a function of the same decision variables. Thus, the problem is to choose "Q_j" and "r_j" so as to minimize (Johnson and Montgomery, 1974);

$$TC = TC\,(Q_1, Q_2, \ldots, Q_j\,;\, r_1, r_2, \ldots, r_j) \quad (8)$$

subject to the constraint

$$g = g\,(Q_1, Q_2, \ldots, Q_j\,;\, r_1, r_2, \ldots, r_j) = d \quad (9)$$

where d is some appropriate quantity depending on the nature of the constraint. This type of optimization problem may be treated by the method of Lagrange multipliers (Johnson and Montgomery, 1974);

$$L = TC(Q_1, Q_2, \ldots, Q_j\,;\, r_1, r_2, \ldots, r_j) + \lambda\,[g\,(Q_1, Q_2, \ldots, Q_j\,;\, r_1, r_2, \ldots, r_j) - d] \quad (10)$$

where λ is a Lagrange multiplier. The optimal Q_j" and "r_j" can be determined by solving the 2n + 1 equations in 2n + 1 unknowns given by

$$\frac{\partial L}{\partial \lambda} = 0; \qquad \frac{\partial L}{\partial Q_j} = 0; \qquad \frac{\partial L}{\partial r_j} = 0, \qquad j = 1,2,\ldots,n \quad (11)$$

It is well known that the set of "Q_j" and "r_j", which are the solution to (11), yields the absolute minimum of TC subject to the constraint (10) (Johnson and Montgomery, 1974).

Suppliers sometimes offer temporary price discounts to pharmaceutical warehouse. In this situation pharmaceutical warehouse needs to determine the optimal special order quantity which minimizes total annual cost.

2.4. Temporary Sale Price Model

A temporary price reduction which presents a potential for reducing the total inventory cost has not been explored extensively (Ardalan, 1988). Inventory models considering the temporary price discounts have been studied extensively in recent years. It is observed that suppliers sometimes offer temporary price discounts in order to stimulate demand, to boost market share or to decrease inventories of certain items (Chang and Dye, 2000). When a supplier reduces its price temporarily, a buyer can reduce the total purchase cost by placing a special order during the sale period (Ardalan, 1988). The optimal size of special order at reduced price will be larger than those of the regular orders that are purchased at the regular price. The inventory system is illustrated in Figure 3 where Q' units are a special order and Q^* units are a regular order with normal price (Wee et al., 2003).

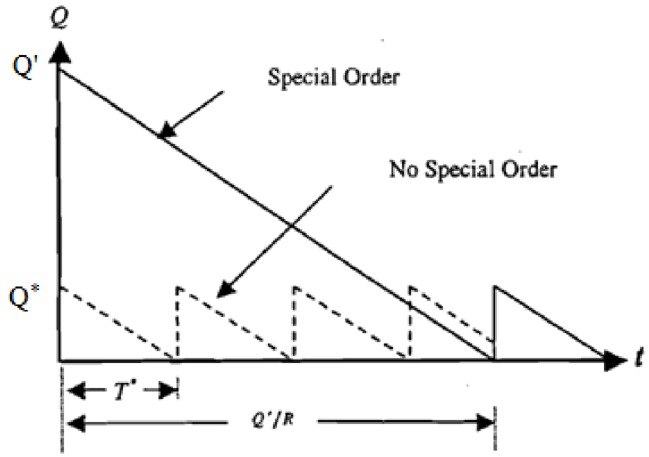


Figure 3. Inventory level with a temporary sale price (Wee et al., 2003)

Notations for temporary sale price model are as following:

Q^*: EOQ with normal price

Q': special order quantity

p: regular unit price

D: annual demand

d: unit price discount

i: annual percentage of holding cost

A: ordering cost per order

TC_s: the total relevant cost during the period with special order

TC_n: the total relevant cost during the same period with no special order

When a special order is purchased at unit price p-d, the total cost during the period Q'/D is as follows (Wee et al., 2003):

$$TC_s = (p-d)Q' + \frac{{Q'}^2(p-d)i}{2D} + A \tag{12}$$

If any special order is not placed during the same period Q'/ D, the total cost is as follows (Wee et al., 2003):

$$\begin{aligned} TC_n &= \frac{AQ'}{Q^*} + \frac{Q^*}{2}(p-d)i\,\frac{Q^*}{D} + \frac{Q^*}{2}pi\,\frac{(Q'-Q^*)}{D} + (p-d)Q^* + (Q'-Q^*)p \\ &= pQ' - dQ^* - \frac{di(Q^*)^2}{2D} + \frac{piQ'Q^*}{2D} + \frac{AQ'}{Q^*} \end{aligned} \tag{13}$$

The special order gain is the difference between TC_n and TC_s as follows (Wee et al., 2003):

$$g = TC_n - TC_s \tag{14}$$

$$g = \left(d + \frac{2A}{Q^*}\right)Q' - \frac{(p-d)i(Q')^2}{2D} - dQ^* - \frac{di(Q^*)^2}{2D} - A \tag{15}$$

To find the optimal one-time special order size "Q'^{*}", g must be maximized. So, following differential calculation was used in Tersine's model (Tersine 1994, Wee et al., 2003);

$$\frac{\partial g}{\partial Q'} = d + \frac{2A}{Q^*} - \frac{(p-d)iQ'}{D} = 0 \tag{16}$$

Optimal one-time special order size, Q'^{*};

$$Q'^{*} = \frac{dD}{(p-d)i} + \frac{pQ^*}{p-d} \tag{17}$$

The optimal cost saving can be found by substituting Eq. (17) into Eq. (15), one has (Wee et al., 2003);

$$g^* = \frac{A(p-d)}{p}\left(\frac{Q'^{*}}{Q^*} - 1\right)^2 \tag{18}$$

Designed DSS in this study captures these models to determine order quantity, special order quantity.

3. DECISION SUPPORT SYSTEM FOR INVENTORY MANAGEMENT IN A PHARMACEUTICAL WAREHOUSE

A Decision Support System is an approach for supporting decision-making. It is extendible systems capable of supporting ad hoc data analysis and decision modeling, oriented toward future planning (Turban et al., 2005). DSS characteristics and capabilities allow decision makers to make better, more consistent decisions in a timely manner. A DSS application can be composed of three main subsystems: Data management subsystems, model management subsystem and user interface subsystem. The data management subsystem includes a database that contains relevant data for the situation. Model management subsystem includes financial, statistical, management science, or quantitative models that provide the system's analytical capabilities. The user communicates with and commands the DSS through user interface subsystem. The user is considered part of the system (Turban et al., 2005).

In this study, a DSS for inventory management in a pharmaceutical warehouse is designed. Data are obtained from Bursa Eczacılar Kooperatifi (BEK). BEK established in 1979 and now has seventeen distribution centers in Turkey: Bursa, Balıkesir, Konya, Eskişehir, Ankara, Çanakkale, Yalova, Tekirdağ, Kütahya, Sakarya, Düzce, Edremit, İzmit and Gebze. Every day in these seventeen distribution centers, approximately twenty thousand orders are prepared and three thousand pharmacies' drug supply is made. BEK works with nearly fifty drug companies in order to provide this supply. In this study, we focused on BEK's inventory management and control problem. In this respect, DSS is designed by using Microsoft Excel Macros and VBA. This DSS helps the management of the inventory in not only pharmaceutical warehouses but also in pharmacies. In designed system, the economic order quantity model and the temporary sale price model are used in order to determine the optimum order quantity with minimum cost for BEK.

There are seven different interfaces in the DSS. In home page, there is a list of firms' names. The user can access to page of any of firms by only selecting it. In this page, user can enter product information which belongs to firm. Also there are some buttons in the home page like "Save New Firm", "Delete Firm" and "Help" to access related interfaces (Figure 4).

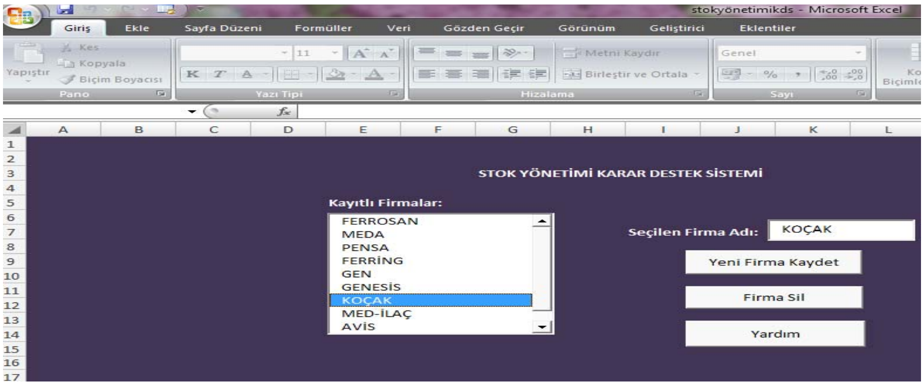
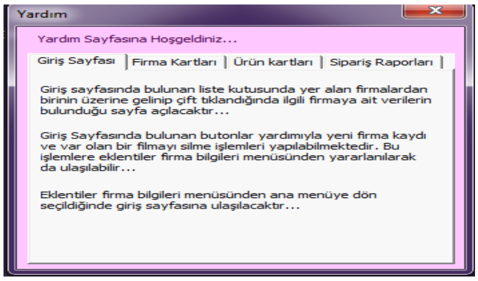


Figure 4. Homepage of the DSS

To access interfaces easily, “Information about Firm” sub-menu is created under the plug-ins command (Figure 5a). User can add a new firm by selecting “Add Firm” or delete a firm by selecting “Delete Firm”.

a

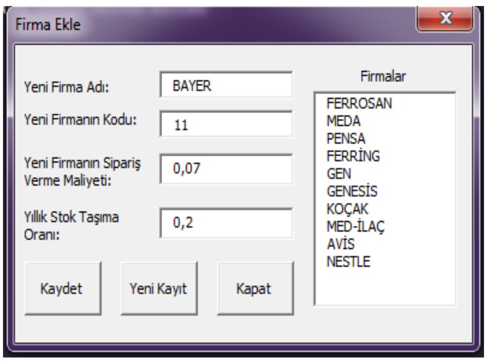


b

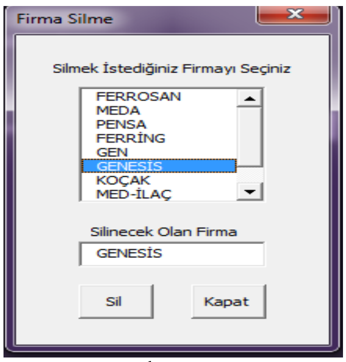
Figure 5 (a). “Firms” sub menu; (b) “Help” interface

By using “Help” button in home page user can activate “Help” interface in order to take information about DSS (Figure 5b).

When “Information about Firm” is clicked, user can also create or access information about a firm, order reports etc. In this interface, there are boxes to enter firm’s name, firm’s code, ordering cost and annual stock removal rate information. After this information is entered and “Save” button is clicked, there will be created new page for new firm in which you can enter firm’s product information (Figure 6a).



a

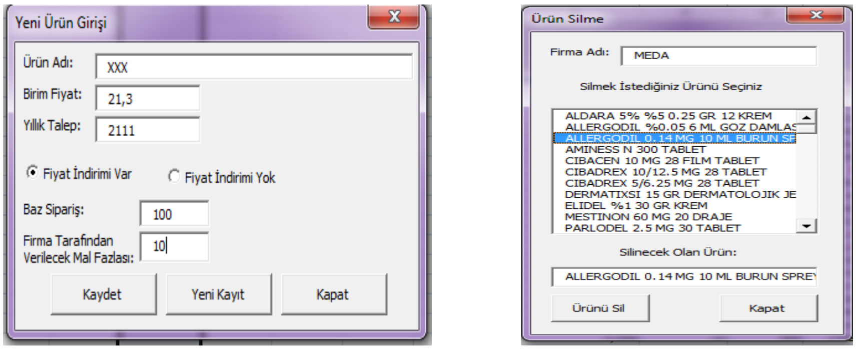


b

Figure 6 (a). “Add Firm” interface (b) “Delete Firm” interface

Like “Add Firm” interface, “Delete Firm” interface is accessible from “Delete Firm” button on home page and “Firms’ Cards” command under “Firm’s Information” sub-menu. In this interface, there is a list containing firms’ names. When a firm name is selected from list and then “Delete” button is clicked selected, firm’s page will be delete (Figure 6b).

Designed inventory management DSS also provides the chance to enter product entry and to delete the existing product opportunity to user. These processes are done by different interfaces which can only accessible on selected firm’s page. When “Product Cards” command is selected under “Information about Firm” sub-menu on selected firm’s page and click “Save New Product”, “Save New Product” interface will be activated (Figure 7a). In this interface, there are boxes to enter product’s name, unit cost, annual demand, base order quantity and the firm’s surplus amount. After this information is entered and “Save” button is clicked by user, a row will be created on firm’s page for new product.



a b

Figure 7 (a). “Save New Product” interface (b) “Delete Product” interface

If “Product Cards” command is selected under firm’s page and “Delete Product” is clicked, “Delete Product” interface will be activated. There is a list which contains firm’s products’ names on this interface (Figure 7b). When one of the product names is selected and “Delete” button is clicked, the product and its row will be deleted. After entering products’ names to firms’ pages, firms’ pages will be like Figure 8.

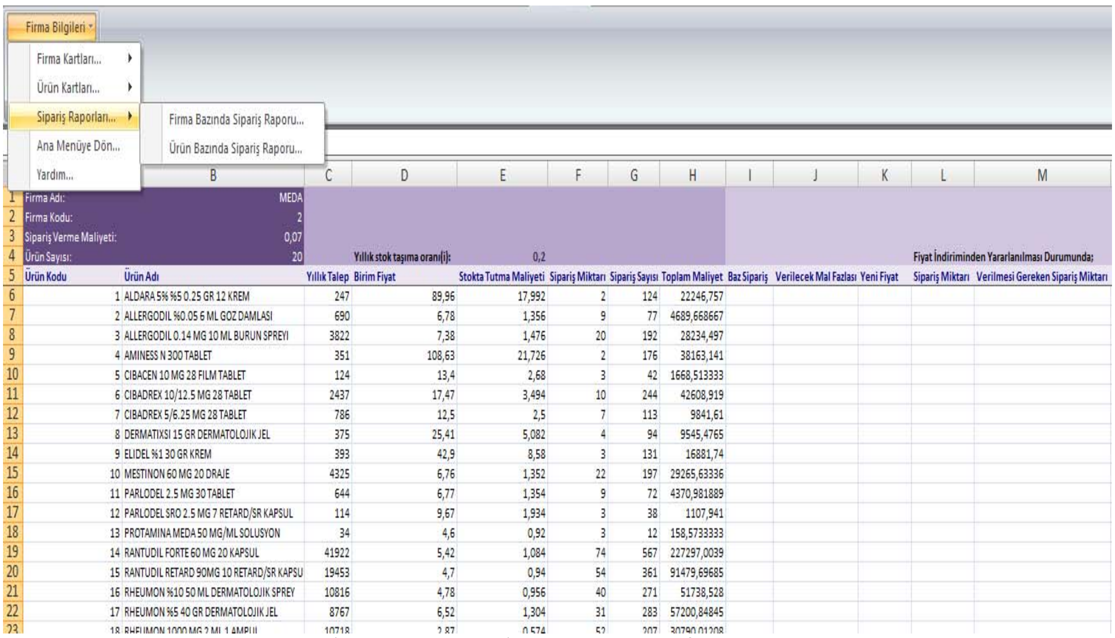


Figure 8. An order report page from DSS

Interfaces that show order quantities and costs obtained from inventory models can be reached by "Order Reports" command. This command has two sub-commands. First one is "Order Report Based on Firm" command which helps accessing to "Order Report Based on Firm" interface. In this interface, there are a table for products of firm, which includes the products' order quantities, order numbers, and total costs calculated by using EOQ model. Also if there is a temporary sale price application the table will include new unit costs, order quantities, total cost for product calculated by temporary sale price model. In the other hand, by this interface user can see total cost for firm's all products which is calculated by EOQ model (Figure 9).

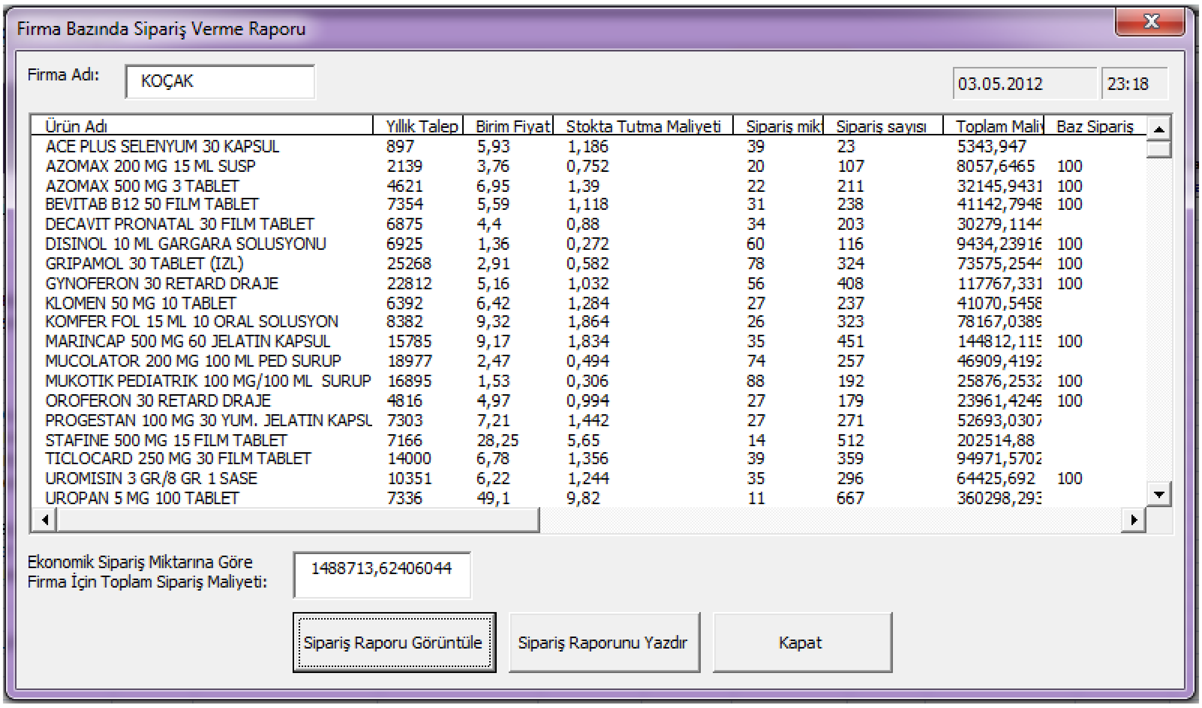


Figure 9. "Order Report Based on Firm" interface

Second command is "Order Report Based on Product". By using this command, user can access to "Order Report Based on Product" interface (Figure 10). In this table there is a list of firm's products. When user selects a product and click "Order Report" button system automatically calculates the order quantity, order number and total cost by EOQ model in one frame, the special order quantity and number, special price period's total cost and annual total cost by temporary sale price model in the other frame. When system calculates this, it uses annual data to minimize total annual cost.

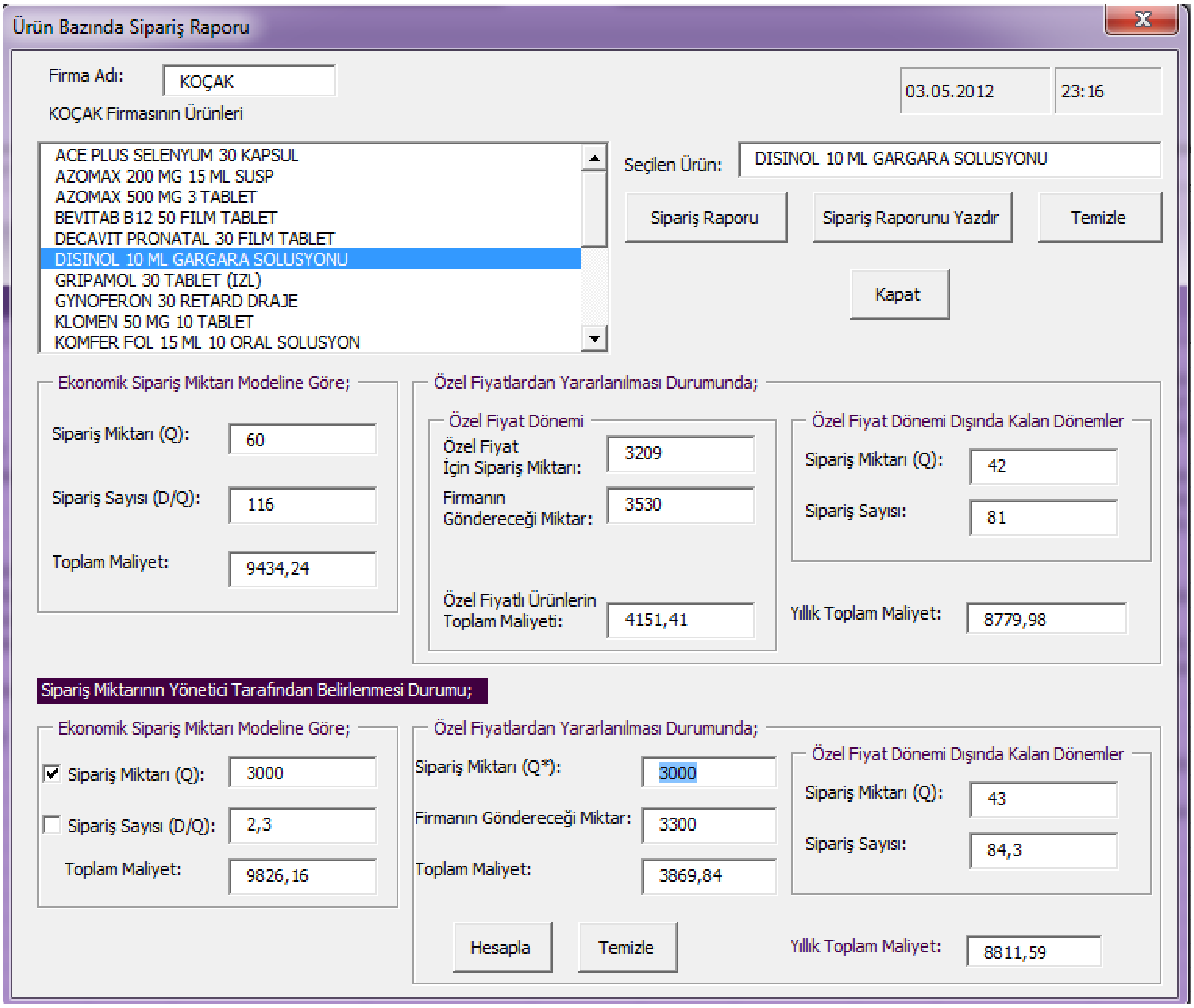


Figure 10. “Order Report Based on Product” interface

Designed DSS also provides the chance to choose order quantity or order number. When user enter the order quantity to related box in EOQ model frame, system calculates order number and minimum annual total cost. Additionally, user can calculate this in “Temporary Sales Model” by entering special order quantity. So, the user have chance to see differences in total costs.

4. CONCLUSION

In this study, a Decision Support System for inventory management is designed in one of the major distribution channels in the Turkish pharmaceutical sector. In pharmaceutical sector nearly all firms offer temporary sale prices for some products in certain parts of the year and warehouses usually want to purchase large amounts to use this offer. In case of temporary selling price to be asked how much quantity should be ordered to minimize total annual cost. Model based of DSS is designed by using EOQ and temporary sale price models.

Problem solving is also opportunity evaluation. The designed system helps decision maker to decide order quantity of products by using effective order policies. In the choice phase, alternatives are compared and a search for the best solution is launched. So, he/she can select appropriate order quantity for the firm. The DSS helps the management of the inventory in not only pharmaceutical warehouses but also pharmacies.

This study can be developed by adding budget constraints and constraints such as effects of generic drugs on demand, drugs shelf life, storage conditions, cold chain conditions related to the nature of the pharmaceutical industry.

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