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Inventory control model using the Two-Bin System methodology in the hospital network of the City of Cali, Colombia

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Abstract. One of the most frequent problems identified in the hospital network is the administration and control of inventories. When analyzing the logistic indicators, especially those related to inventories, we can observe how the availability indicator of some important items presents lower levels than previously established. It is also common to observe how the levels of inventories for some SKU (Stock-Keeping Unit) are very high while for others the levels of inventories are very low. This article seeks to provide a solution to the problems arising with the administration and control of inventories of a hospital in the City of Cali, Colombia. For this, the two-bin methodology with a periodic control system (R, S) will be used. This model will fit the needs of the hospital network and the resources available for the management of inventories in the organization.

Keywords: Traffic accidents, Pre-hospital care, Inventory control, Model two-bin system.

1. Introduction

Inventory control and management is one of the most complex issues within organizations. In the hospital network, it is particularly relevant because a lack of inventory can affect patients' health by not having the resources required for appropriate treatment and / or intervention. This makes it necessary to develop tools that facilitate effective management of stocks for this type of institutions. It is very common to hear logistics managers and analysts affirm that one of their main problems is the administration of inventories. The typical problem is the existence of excesses and shortages: "You always have too much of what is not sold, and not enough of what is sold." Serious incidents occurred in 2015 and 2016 in the hospital network of the City of Cali, Colombia due to the resignation of associate physicians from recognized hospitals in the city, such as the Hospital Universitario and Cafe Salud. Among the reasons that led doctors to terminate their contracts is the constant lack of supplies and medications due to poor inventory planning, which are of the utmost importance when it comes to caring for all patients in the emergency area.

At present, inventory control is carried out in most cases by administrative staff and chief nurses, who, according to their experience, manage the current inventory and generate purchase requisitions. This enables the purchasing area of the health promotion entity (EPS) or hospital to perform all the management corresponding to the acquisition of the medicines. The problem in most local organizations lies mainly in the fact that security inventories and their corresponding reorder points or maximum inventories are determined exclusively on the basis of average demand, ignoring their variability and the variability of replenishment times [1]. As for traditional models with probabilistic demand, there are several studies and authors that have approached the subject of inventory control under uncertainty conditions, looking for a balance between the levels and quantities of inventories to be maintained (and the costs involved), and customer satisfaction and quality of services. There are several inventory control policies and methods, the most common ones observed in industry are: continuous control systems (s,Q) and (s,S) and periodic control systems (R,S) and (R,s,S) [2]. Faced with the problem of inventories, it is stated that the management of the supply chain requires the inclusion of a process planning system; for this reason, planning the inventory levels together can lead to a decrease in the level of stocks in the system [3].

The complexity of these systems arises mainly from the coordination of the different localities and the close relationship and impact that a decision taken at one point in the chain has on all other points of the system [4]. An optimal control policy for a multi-stage inventory control system can be expected to be complex, even in cases where demand can be considered deterministic [5]. This work focuses on developing an inventory control and management policy addressing the problem with the following strategies:

- Carry out an ABC classification of the 60 drugs (SKU) used in Café Salud in the emergency area (Table 1) in order to facilitate the administrative function of inventories.
- The use of adequate forecasting systems that allow the calculation of security inventories based on the variability of demand and replacement times, according to the level of service desired. [6]
- Selection of the periodic control system (R, S) for probabilistic demand. With the above we try to solve three fundamental questions. How often should the inventory be reviewed? When should a purchase order be issued? And how much should be ordered? [7]

Table 1. List of medicines with highest frequency of use in the emergency area.

MEDICINE	MEDICINE	MEDICINE	MEDICINE
VALPROIC ACID	DIAZEPAM	ISOPROTENEROL	PARACETAMOL
ADENOSINE	DIFENYLHIDANTOIN	KETAMINE	PROCAINAMIDA
ADRENALIN	DIGOXINE	KETOROLAC	PROPAPHENONE
AMINOFILINE	DOBUTAMINE	LABETALOL	PROPANOLOL
AMIODARONE	DOPAMINE CHLORHYDRATE	LIDOCAINE CHLORHYDRATE	PROPOFOL
ATENOLOL	ETOMIDATE	MEPERIDINE	RANITIDINA
ATROPINE SULFATE	FENTANYL	MAGNESIUM METAMIZOL	SALBUTAMOL
BESILATO DE ATRACURIO	FITOMENIADONA	METHYLPREDNISOLONE	SOMASTOTATIN A
SODIUM BICARBONATE	FLUMAZENIL	METOCLOPRAMIDE	SUCCINILCOLIN
BUTILESCOPOLAMINA BROMURO	FUROSEMIDE	MIDAZOLAM	SULPIRIDE
DIPOTASSIC CHLORAZEPATE	DEXTROSE 33%	NALOXONE	TIAMINE
CALCIUM CHLORIDE	HALOPERIDOL	NITROGLYCERINE	TRAMADOL
MORPHIC CHLORIDE	SODIUM HEPARIN	SODIUM NITROPRUSIATE	VECURONIO
POTASSIUM CHLORIDE	SODIUM PHOSPHATE HYDROCORTISONE	NORADRENALINE	VERAPAMILO
DEXAMETHASONE	INSULIN	PANTOPRAZOL	DEXCLORPHENYRAMINE

Figure 1 shows the average availability of the 60 drugs previously selected for each year from 2012 to 2015. When analyzing this availability indicator, we can see that it has a decreasing trend, which indicates that occurrences of depleted drug stocks have been increasing gradually. For this reason, with the following work, it is sought to show how, through an inventory control system (R, S), we can directly reduce occurrences of depletion and thereby increase the availability indicator.

Fig. 1. Availability indicator for 2012 – 2015.

2. ABC classification of the most used drugs in the emergency area and selection of the inventory control system.

A periodic (R, S) control system was selected for the inventory control differentiated by product classes A, B and C. In doing so, it results in the following:

- Class A items: 3 Medications
- Class B items: 10 Medications
- Class C items: 47 Medications

This decision to make an ABC classification to develop a periodic control system (R, S) was mainly taken by the logistic and administrative aspects of the purchases. One of the fundamental aspects that was taken into account was the definition of demand forecasting techniques to be implemented. Different traditional forecasting techniques were used, such as moving average and simple and double exponential smoothing, self-adaptive methods using available historical data and no indication of seasonality was found, for which reason the following forecasting techniques were defined:

- Class A Products: Double exponential smoothing
- Class B Products: Simple exponential smoothing
- Class C Products: Moving Average

The items in Class A represent 80% of the inventory cost [8]. For this reason, it is very important to focus on them because they directly affect the customer service. The forecasting methods are fundamental in a good system of inventory control because they allow us to calculate trends and standard deviation of the data [9].

The calculations of the parameters of the inventory control system (R, S) with two-bin methodology were performed by the following equations:

$$(1) \quad R = \sqrt{\frac{2A'}{Dvr}}$$

$$(2) \quad \hat{x}_{R+L} = d \times (R + L)$$

(3) $\hat{\sigma}_{R+L} = \hat{\sigma}_1 \times \sqrt{R+L}$

(4) $S = \hat{x}_{R+L} + k\hat{\sigma}_{R+L}$

(5) SAFETY STOCK $= k\hat{\sigma}_{R+L} = k\hat{\sigma}_1\sqrt{R+L}$

- **R**: Pre-specified review interval or calculated based on EOQ (Economic Order Quantity) in time units.
- **A'**: Fixed cost of increased ordering in inventory review cost, in $ / order
- **D**: Total demand in units / year
- **v:** Value of the item in $
- **r:** Cost of maintaining inventory $ / ($ / year)
- **L:** Lead time
- **d:** Expected demand in the lead time in units
- $\hat{x}_{R+L}$: Forecast demand over a range R+L in units
- **K**: Safety factor
- $\hat{\sigma}_1$: Standard deviation of forecast errors in units
- $\hat{\sigma}_{R+L}$: Standard deviation of forecasts errors over time R + L in units
- **S**: Level of inventory up to which it is ordered in units

Equation (1) was initially used to determine the review interval R, from the optimum order quantity, rounded to a logical integer value. After determining the review period using equation (2) we calculate the standard deviation. Note that σ1 is the standard deviation of the forecast errors, so by equation (3) we can calculate the forecast demand over a time interval equal to R+ L. Finally, by equation (4) we calculate the maximum level of inventory up to which it is ordered in units. It was necessary to estimate the costs of ordering, maintenance of inventory and shortages, to start up the control systems. The policy of the organization stated that it wanted to reach a level of confidence of 99% for the estimation of parameter K. It should be noted that this system of inventory control was initially implemented on items in Class A. For future research it is possible to evaluate the implementation of a control system for the Class B and C items. Figure 2 shows the behavior of the demand and the safety inventory for the Class A items using equation (5). It is important to note that all parameters and variables were calculated with historical sales data provided by the organization.

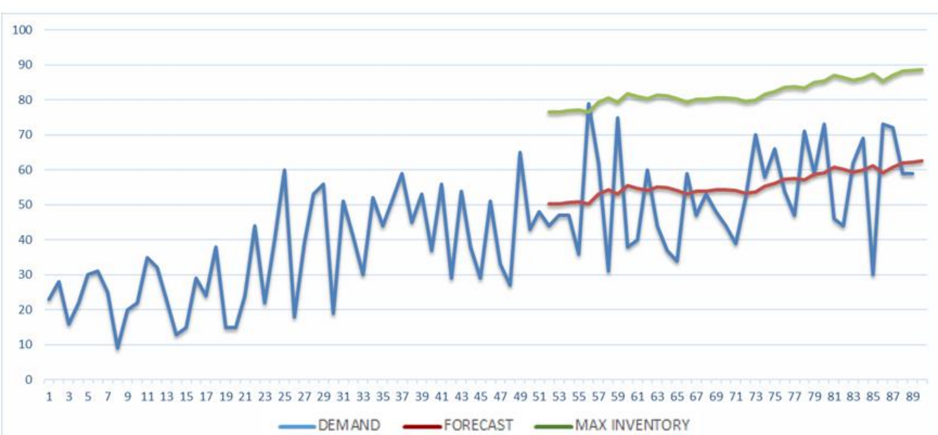

Fig. 2. Demand behavior vs. safety stock.

The evaluation of the effectiveness of the inventory policies (R, S) formulated to solve the problem was done by forecasting of the inventory levels for the Class A items, observing in the last five months an increase of the indicator of availability (Figure 3).

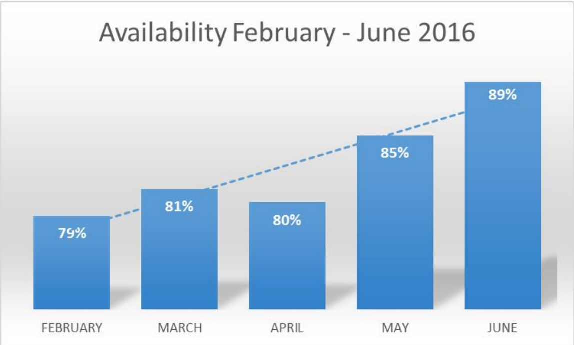

Fig. 3. Availability indicator for February - June 2016

3. Conclusions and Future Research

The fluctuations or variations in the demand behavior and the variability in the replenishment times are the main reasons for the maintenance of the inventories in any organization, creating the need to design systems for the optimal management of inventories. In the case study, it is possible to observe how the formulation of an inventory policy is able to guarantee availability of a product under conditions of uncertainty, which generates a key factor for the success in this class of organizations.

The main objective of a hospital regarding inventory control, especially in the emergency area, should be the availability of drugs and the level of service. However, it is necessary to balance the costs associated with inventory levels. The variability of lead time with regard to procurement as well as fluctuations in demand are the main reasons why a system of inventory control should be implemented, especially in hospitals where a depleted drug directly impacts the health of patients [10].

Through a policy of inventory control according to the type of organization and demand behavior, hospitals can shorten their replacement times and thus improve customer service. As future research, it is recommended to use more sophisticated forecasting systems for items with erratic demand, as well as estimates of costs associated with different inventory control systems.

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