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Review Article

Review Article on Pharmaceutical Inventory Models

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Abstract

The inventory management system plays a vital role in a pharmaceutical industry. For every business, managing an inventory is important whether it is small or big, domestic or international business. In a pharmaceutical company, the raw materials have an expiry date associated with them so it becomes important to set a minimal safety stock for such items. The companies mostly try out keeping a minimum stock of products which will help in tracking our business easily. In this article, we present an overall review of the Pharmaceutical Inventory literature since the early 1968 and the models available in the relevant literature have been suitably classified. The motivations and extensions of various models in each subclass have been discussed in detail.

Keywords: Inventory, Perishable items, Pharmaceutical inventory, RFID technology, Drug inventory

Introduction

Pharmaceutical is one of the most sensitive and major industry that deals with human and animal life. Purity is highly deserved in this industry. Quality, security, identity are the most important to maintain. Inventory is referred as the stock of pharmaceutical products retained to meet future demand in pharmacy operations. The inventory represents the largest asset in pharmacy, and its value continues to rise because of the growth in the variety and cost of pharmaceutical products. In both financial and operational perspectives, the efficient inventory management plays a great role in pharmacy. The financial viewpoint, efficient inventory management enhances gross profits and net profits by reducing the cost of procured pharmaceutical products and associated operational expenses in inventory. There are three types of costs associated with inventory in pharmacy: procurement costs, carrying costs, and shortage costs. The procurement costs are costs associated with purchasing the products, which include placing and receiving orders, stocking and paying invoices. The carrying costs refer to costs associated with product storage, which also include costs incurred as a result of crises. The shortage costs also known as stock-out costs are the costs of not having the product on the shelves when needed. There are two main goals for managing an inventory for a pharmacy. The first is to ensure medications are available when patients need them and the second goal of inventory management is to keep medication costs at a minimum. Properly managing stock by using medications before they expire and processing returns regularly can help keep medication cost down.

Classification of the pharmaceutical inventory models

The pharmaceutical inventory models are available in the relevant literature which can be classified broadly on the basis of pharmaceutical characteristics. Here we consider the following six categories:

Models for pharmaceutical inventory with RFID technology [5, 13,21,25,39]

Models for inventory with perishable pharmaceuticals [3,4,58]

Models for inventory management of pharmaceutical with hospital[9, 12, 24,29,33,38]

Models for pharmaceutical inventory with drug pharmacy [6,11,46,47,48,53,54]

Models for pharmaceutical inventory with blood pharmacy [2,8,14,17,19,23,26,27,35]

Models for inventory control techniques for pharmacy [7,16,20,36,37,40,41,50,51,55,57]

Pharmaceutical inventory with RFID technology

The inventory management is essential to maintain a large size inventory, for efficient and smooth production and the inventories should be maintained at an optimum level. The RFID technology can be useful tool in inventory management of the pharmaceutical units. RFID tags can store sufficient

information of the materials in the quarantine, including product name, manufacturer name, supplier name, batch number, manufacturing date, expiry date, etc. Hence, the status of the raw material (approved, unapproved, or under test) could also be depicted on the tag that would prevent accidental use of the wrong category of the material. The inventory status, including various stock levels like minimum stock level, safety level, reorder level, or danger level, can be identified from the stock level information stored in the RFID tags. Hence, these tags can serve as useful and the effective alternatives to conventional and complicated inventory control techniques. The incremental benefits of RFID technology over barcodes are analyzed[39] for managing pharmaceutical inventories unlike barcode technology and it enables accurate real time visibility, which in turn enables several process improvements. The industrial practice of apparel control in health care organizations is discussed in the article[21] in detail. An analytical study revealed when RFID systems will outperform and the bar-coding system in terms of reduction of the amount of required safety stock. Numerical analysis of the benefits[13] of RFID is provided that completely ignores the issue of shrinkage and differs in its emphasis on shrinkage resulting from content expiration. Analytical comparison of periodic and continuous review policies with an empirical study are combined in a radiology practice, identifying the operational problems of the practice that can be addressed by RFID technology. The radio frequency identification technology[25] applied to a number of pharmaceutical processes, as ample of the information can be stored and read rapidly from an RFID tag. The applications may range from inventory control, to access control, to telemedicine, to supply chain management and the combating counterfeit products. An inventory tracking is assumed to be accurate, in reality, actual on hand inventory[5] deviates from the inventory record, which distorts the replenishment process, compromises good inventory management and the inventory record. Physical stock has mainly three sources: shrinkage, misplacement and transaction errors. The periodic inventory audits are the most common approach to maintain inventory record accuracy. The inventory management processes[22] is provided in the pharmaceutical industry and introduced arena, a simulation software, that calculates process and production time in industry and radio frequency identification (RFID) technology, and their implementation in inventory management. The inventory control of the raw materials, finished products and tracing of the products are done by barcode and labeling and the conventional identification process require manual intervention and manual data collection. The use of information for inventory decision in the healthcare industry[10] is introduced and considered the scenario when the HO can make use of the information collected from some correlated products to enhance its inventory planning. The analysis demonstrates that RFID system will outperform the bar-coding system when the RFID system installation cost and the tag cost reduce to a level that is comparable with that of the bar coding system and also shown how an appropriately set wholesale pricing contract can achieve Pareto improvement in the HO supply chain.

Pharmaceutical inventory management in perishable products

The perishable products can be divided into two parts. These are time dependent and time independent products. The examples of time dependent perishable product are green vegetables, fruits, milk, bread, flowers, meat, greeting cards, Christmas trees and more, because it has a short life in its use. Although the examples of the time independent perishable product are fashion products, clothes, mobile phones, personal computers, and others, because it was useful for the customers in a significant period of time but have much less economic value. A nation-wide, large-scale healthcare[58] of the supply chain that comprises several hundred medical organizations (hospitals, clinics, pharmacies, etc.) provides highly advanced medical care to several million people. These medical products in the system are perishable, meaning that they become unusable beyond a certain expiry date. The models developed, represent a multi-echelon, multi-supplier inventory system and unite together aspects of perish ability and outsourcing under deterministic demand for medical products, which include both perishable and deteriorating goods. Pharmaceutical expenditures are increasing for hospital systems nationwide. The inventory model and ordering policies for perishable drugs in the setting of an inpatient hospital pharmacy is developed and considered two stages of inventory: raw material and finished good (e.g. intravenous). In the article[3], two-phased approach is introduced to explore policy structures that could be implemented in the hospital pharmacy and developed a policy which is based on the idea that hospitals can improve both costs and patient demand fulfillment by using knowledge of patient mix to guide their drug inventory and preparation decisions. Drug shortages have increased over the past decade, tripling since 2006. Pharmacy material managers are challenged with developing inventory policies given changing demand, limited suppliers, and regulations affecting supply. In the article[4] the stochastic demand state introduced as a surrogate for patient condition and develops a Markov decision process to determine optimal, state-dependent two-stage inventory and production policies.

Pharmaceutical inventory management in hospitals

An inventory management is the branch of business management concerned with the planning and controlling inventories. The major aims of the hospital inventory management and the healthcare supply chains research is to reduce healthcare cost without sacrificing the quality of the service to the patient by improving efficiency and productivity of the healthcare system. The primary focus of the healthcare sector[24] is to provide patients with the best quality of care. Three major issues regarding inventory management practice has been identified such as overstock, unjustified forecasting technique and lack of IT support. Proposed (s,Q) policy using continuous review can reduce by 50% total inventory value on hand of oncology medication. EOQ model is formulated[29] for intravenous fluids under the assumptions of no waste or shortage costs and the stationary demand. A constraint programming optimization model is proposed[33] for determining the optimal stock levels for hospital supplies considering storage space restrictions, item criticality, and delivery frequency and suggest the need for a link between inventory systems and the complex demand patterns. The article[9] presents Markovchain probability model that uses maximum likelihood regression to predict the expectations and discrete distributions of transient inpatient inventories. The approach has a foundation in through put theory, has low model complexity, and provides statistical significance and quality-of-fit tests uniqueto this Markov chain. The Markov chain is shown to have superior predictability over Seasonal ARIMA models. To improve the purchasing and inventory management system[12] to transparent and checkable manner, before and after the improved system were compared. The retrospective data including rate of approved purchasing documents, rate of inspected products, rate of correct received products, rate of destroyed or expired products, rate of reserved products, and rate of product shortages during January 2010 to December 2011were collected. The identified problems of purchasing and inventory management were

solved by improving the purchasing and inventory management system. The specific problem addressed in this paper[38] is a comparison of inventory costs and service levels of an in-house three-echelon distribution network vs. an outsourced two-echelon distribution network. In comparing inventory policies in both networks, focus on non-critical inventory items. Based on analysis, they find that the recent trend of outsourcing to distribute non-critical medical supplies directly to the hospital departments using them, results not only in inventory cost savings but also does not compromise the quality of care as reflected in service levels.

Pharmaceutical inventory in drug pharmacy

Inventory is a detailed list of assets held by an organization or institution like goods in stock, drugs and equipment. It is a method of maintaining stock of drugs at a level of lowest purchasing and stocking cost. The effective and efficient management of medical stores entails close supervision of important drugs, prevention of the pilferage and priority in purchase and distribution of drugs. An efficient inventory control system would help the optimize use of resources and eventually help to improve patient care, by ensuring the availability of essential stocks and preventing stock-outs. The multivariate interaction of the raw materials' physical properties can be critical to the quality of the final drug product. A detailed discussion of the objective function used is presented in the article[45] and also reports the results of implementing the method to the manufacture of a pharmaceutical drug product in a commercial manufacturing setting. The effective management of medical stores entails supervision[46] of important drugs and the priority setting in purchase and the distribution of drugs. The inventory management at tertiary-care settings in explore of the optimal drug inventory management technique suitable for a secondary care hospital. Drugs stored in pharmacy department[34] according to their cost and criticality to access the inventory of drugs at SKIMS, the area of study included main drug of pharmacy store. The medical store[47] is one of the most extensively used facilities in the hospital and hence it is essential that the health managers use scientific methods to achieve management and patient satisfaction. The article[53] provides drug inventory control system seamlessly connected with the physician order-entry system and the control system application allows inventory functions to be faster and more efficient in the real time. The cost and need of these medicines[18] vary widely depending on the level of health care and the population catered. Effective and scientific drug inventory management techniques are necessary for efficient health care delivery. The health managers use scientific methods[48] to achieve efficient management and patient satisfaction and the scientific inventory control management to be applied for the efficient management of medical stores. Inventory control of drugs plays a pivotal role[55] in hospital management of the drug inventory control of hospital pharmacy is very essential in order to provide continuous supportive services. Inventory management of drugs is very essential, as it is adversely affected to the consumption rate and purchasing cost of drugs by using ABC and VED analysis. The Italian healthcare network, which evaluated the economic sustainability of logistics[6] outsourcing and the data were collected using interviews, documentation and observations in the hospital pharmacies and wards, and by referring to the public information available on the internet and inventory drug management in healthcare sector specifically in hospitals plays an important part[1] in achieving its ideal stage and development suggest improvements in the drug inventory management in hospitals. An economic order quantity of the appropriate time of reordering drugs to keep as an inventory control[11] and the included key formulae and calculation methods used to find out the economic order quantity of drugs at reorder point.

Pharmaceutical inventory in blood pharmacy

The primary use of the optimal decision rule will be to establish minimum cost inventory levels for blood cell inventories for a hospital blood bank or a transfusion service. Blood product is growing faster than donor recruitment, so the efficient management[43] of the available blood supplies is of great economic and social importance. The blood models dealt with two main issues expiration of blood products and limited shelf life vs minimizing blood inventory shortages and the blood storage technologies have resulted in the extended shelf lives for some blood products, as well as the ability to uses synthetic blood products at an additional cost. Blood banks [26] are facilities which procure, store, process, and dispense blood and the effectively in the face of both random supply and random demand, sizable buffer stocks of the blood are maintained. The analysis of the whole blood inventory problem at the individual hospital as well as the regional level, presents a realistic model of blood inventories for both the individual and regional cases, and analyzes the effects of several alternative inventory policies. The frequency of blood delivery[2] has no significant effect on the net saving of blood in the blood recycling plans evaluated. The implementation of an automatic blood recycling program, a practical and effective method for reducing blood outdating in a multi-hospital regional blood system, is discussed in detail. A number of methodological contributions[19] have been made in the areas of inventory theory and the combinatoric optimization that can use other products or systems. The optimal inventory level[14] daily demand level, the transfusion to crossmatch ratio, the crossmatch release period and the age of arriving units that determine the shortage and outdate rate and the blood bank administrator should establish optimal target inventory levels based on a simple equation relating these factors. This rule indicates that its implementation can lead to a very low shortage rate and a reasonable low outdate rate if use the blood bank administrator makes efforts to control the crossmatch release period and the average transfusion to crossmatch ratio. The curves relating recommended whole blood/red blood cell[8] inventory levels and mean daily demand for various specified shortage rates are developed by various authors. Adiscrete-time inventory system for a perishable product[23] where demand exists for product of different ages; an example of such a product is blood platelets and addition to the classical costs for inventory holding, outdating, and shortage, the model includes substitution costs incurred when a demand for a certain-aged item is satisfied by a different aged item and developed a simple inventory replenishment and allocation heuristic to minimize the expected total cost over an infinite time horizon. A standing order delivery[49] in the morning reduces complexity and workload while the ensuring blood supply; a second delivery later in the day gives a hospital enough flexibility to react to changes in demand and the standing order is exactly fixed order quantity and a second delivery option represents the expediting option in the model. A shelf life of 3 days for platelets [59]and shown the existence of an optimal inventory policy incorporating dual modes of replenishment and used the terms Young, Mature, and Old to differentiate among the products that expire in 3, 2, and 1 period's respectively, and used the terms younger /youngest and fresher/freshest interchangeably and the products age at the end of each period, transitioning from Young to Mature, Mature to Old, and Old to outdated unless used to satisfy demand. The effects of various stock levels are analyzed[35] for the common bloods. This is not usually the case for the rare bloods which are more difficult to control. A policy decision has to be made which balances the conflicting stock requirements of maintaining a high availability and also low

outdating rates and the Markovian structure is exploited in this paper for this purpose and the effects of the key variables are shown to be interrelated. A hospital blood bank and whole blood inventory system[27] is developed, shown to provide an accurate representation of the actual blood bank operations, and analyzed by means of digital computer simulation and the control of hospital blood inventories is examined with primary emphasis on the specification of the most basic and most flexible policy the desired beginning inventory level policy and studied graphically in terms of a function which relates the two most important measures of effectiveness-blood shortage and blood outdating-to the inventory level and less flexible decisions are studied in terms of the shift which they produce in this curve. A particular blood bank[17] were simulated on an electronic computer, are used to obtain values that permit the establishment of inventory levels appropriate for the critical ranges of mean uses and inputs.

Pharmaceutical inventory control techniques for pharmacy

ABC cost analysis of all the drugs in the inventory of the hospital was done and the annual drug expenditure of individual drugs was arranged in descending order. The cumulative percentage of the expenditure was calculated as well as the cumulative percentage of the number of items. Then the list was subdivided into three categories based on the cumulative cost percentage. Approximately, 10% of drugs consuming 70% of ADE constituted category A, 20% of drugs consuming about 20% value constituted category B while, the remaining 70% of drugs consuming 10% of ADE formed category C. Hence cutoffs were not exactly at 10/20/70 but differed marginally. The hospital inventory and drug expenditure by inventory control techniques [40] and include ABC and VED analysis are studied. In the article[28] introduced the annual hospitals budget is spent on buying materials and supplies, including medicines. They bring about substantial improvement in the hospital inventory and expenditures by the inventory control techniques. The limitation of ABC analysis[57] that it is based only on monetary value and cost of consumption of items and some items of low monetary value are vital or lifesaving are analyzed. The importance cannot be overlooked because they are not in category A. The additional parameter of the assessment is their criticality by VED analysis. V is for vital items without which a hospital cannot function, E for essential items without which a hospital can function but may affect the quality of the services and "D" stands for desirable items, unavailability of which will not interfere with functioning and the combination of ABC and VED analysis (ABC-VED matrix) can be gainfully employed to evolve a meaningful control over the material supplies. The ABC and VED analysis of the pharmacy store of Post Graduate Institute of Medical Education and Research, Chandigarh, India, was proposed[16] to identify the categories of the items needing stringent management control. The annual consumption and expenditure incurred on each the item of pharmacy for the year 2007-08 was analyzed the inventory control techniques and the ABC and VED techniques need to be adopted as a routine practice for optimal use of resources and elimination of out-of-stock situations in the hospital pharmacy. A hospital materials manager[15] must established efficient inventory system policies for the normal operating conditions that also ensure the hospital's ability to meet the emergency demand conditions. The pharmacy store of the tertiary care, teaching, research and referral institute of the northern India[50] to identify the categories of drugs needing strict management control and inventory control techniques. ABC inventory classification with multiple-criteria[44] using weighted linear optimization a hospital materials efficient inventory system policies for the normal operating conditions to the inventory control. An inventory EOQ in conjunction with ABC has been proposed[36] to be effective and efficient. Most of the savings with the ABC-EOQ were reported[7] with the low value items (B and C items) which were being purchased too frequently. The inventory management[42] for medical supplies in the surgery department is improved at a hospital. The demand forecasting model is presented, trend-corrected exponential smoothing model (Holt's model) is chosen for demand forecasting of the medical supplies inventory. The annual drug expenditure is introduced[41] at the medical stores in a Tertiary care hospital using the ABC-VED inventory control techniques. CGHS reported[51] that 15 items (5.1%) were found to be Vital, 172 items (58.1%) were classified as essential and 109 items (36.8%) were considered desirable and the shortage of the vital drugs for even a short period of time can cause serious problem in patient care. The essential drugs are in short supply for a number of days or a week, functioning of the hospital could be adversely affected (e.g. drugs like antibiotics) and the shortage of desirable drugs would not adversely affect the patient care or hospital functioning even if shortage is prolonged (Drugs like vitamins). Tikur Anbessa Hospital[52] is the largest general specialized referral hospital in Ethiopia having total of 600 beds. It is also a teaching hospital providing pre-service and in-service trainings in various fields and specialties. Majority of the patients receive a prescription containing one of more drugs. This indicates the need for proper organization of the hospital pharmacy in a manner that results in efficient and effective management of pharmaceuticals. To conduct the economic analysis of drug expenditure in the Government Medical College Hospital, Nagpur[54] and to identify the categories of drugs needing stringent management control. A matrix based on the coupling of cost (ABC) analysis and vital/essential/ desirable (VED) criticality analysis was formulated for prioritization, to narrow down the group of drugs requiring greater managerial monitoring. The difference between actual expenditure and the inflation factor-derived expenditure was found. Expenditure for forthcoming years was fore- casted by regression analysis using NCSS software. A system dynamics model[30] of a hospital logistics system is introduced to evaluate different inventory management techniques and developed a multi-criteria inventory classification method that takes into account the criticality, cost, and usage value of the items. They evaluated the cost of inventory management for items based on the criticality of need, service level assignments and consumption rates and the guidelines for the health practitioners and decision makers how inventory management cost could be optimized using a classification system depending on the criticality of the items. The annual drug expenditure[56] is developed at a Rural Health Centre using ABC VED analysis and Inventory control techniques ABC, VED and ABC-VED matrix analysis were utilized to study the drug expenditure at the health centre. Computer software programs play[31] an important role in the inventory management of a pharmacy. The novel software Medz helped in giving a priority management and economic forecasting of all the items in a community pharmacy. An inventory control is considered[20] ABC based on cost criteria and VED on criticality and used ABC-VED matrix, economic analysis of drug expenditure of priced vocabulary of medical stores. Approximately 40% of annual hospital budget[32] is spent on drug procurement. The objective of the study was to design and evaluate suitable inventory management formula for a community pharmacy attached to a tertiary care government medical college hospital. The new model called AVSER matrix analysis is developed by combining all conventional Inventory control methods along with the ROL calculation formula. This new model helped in giving a better priority management and economic forecasting of the items in a community pharmacy. The modern system of medicine has

evolved [37] into a complex, sophisticated and the expensive treatment modality in terms of cost of medicines and consumables. The ABC (Always, Better Control)-VED (Vital, Essential, Desirable) analysis of the medical stores of a large teaching, tertiary care hospital of the armed forces was carried out to identify the categories of the drugs needing focused managerial control.

Conclusion

In this article, we have provided an up to date review literature of Pharmaceutical Inventory Models. Inventory management can make it easy and effective and reduces material handling time and counterfeiting of the pharmaceutical products up to a high rate. There are two main goals for managing an inventory for a pharmacy. The products that are regularly kept in stock are based on the needs of the pharmacy and its customers. Efforts should be made to keep the medications used regularly in stock and available for use not outdated or damaged, while some rarely used, extremely expensive or cumbersome products may be ordered in as needed,. The second goal of inventory management is to keep medication costs at a minimum. Many pharmacies have preferred wholesalers to order from or contract pricing with specific drug companies to decrease the cost of purchasing medications. Preventing profit loss is also a contributing factor to controlling medication costs. Properly managing stock by using medications before they expire and processing returns regularly can help keep medication cost down.

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