College of Health Sciences

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Optimal Pharmaceutical Replenishment Policy: The Case of Selected Health Centers in Addis Ababa

By

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Addis Ababa, Ethiopia

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This is to certify that the thesis prepared by Bezawit Negash Demissie entitled: Optimal Pharmaceutical Replenishment Policy: The Case of Selected Health Centers in Addis Ababa and submitted in partial fulfillment of the requirements for the degree of Master of Science in Health Supply Chain Management complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

***Background**: The primary goal of inventory management is to establish a replenishment policy that informs when and how much to order and how to maintain an appropriate stock level while optimizing various tradeoffs, such as carrying and re-ordering costs. The need for the healthcare sector to reduce costs has motivated many hospitals to adopt new technology to enhance existing operations. Since 2009, Integrated Pharmaceuticals Logistics System (IPLS) has been used in Ethiopian public health facilities to manage inventory. To the investigator's knowledge, the optimality of the replenishment system to the respective health facilities was not well investigated.*

***Objectives:** This study aimed to determine an optimal replenishment policy for managing inventory for selected health centers in Addis Ababa, Ethiopia.*

***Methods:** A multiple case study design was used in ten selected health centers. This study primarily uses quantitative data from the pharmacy stores' database system. Three years of data were extracted from the digital bin card and entered into the pre-tested excel-data extraction tool. Once the data was sufficiently cleaned, a descriptive statistic and correlation using Microsoft Excel 2019 and IBM SPSS version 26. A simulation-optimization approach was used to show the current total inventory cost and develop an optimal replenishment policy.*

***Result:** The monetary amount of the program medicines issued from the health centers within three years was 93,922,330.05 ETB, in which Anti-retroviral treatments took the highest percentage, 78.69%, followed by Mother and child health products, 10.8%. When the demand frequency is observed, there is zero demand 50% of the time; this shows high intermittent demand. Demand variability significantly correlates* $(r = 0.84)$ *with the health centers' total cost. The lowest total cost was observed in the replenishment policy of every other month with a target customer service level of 90% and realized customer service level of 92.7%. The highest total cost was observed in the replenishment policy of every month with target customer service level of 99% with a total cost of 141,706.4 ETB with realized customer service level of 99.4%.*

***Conclusion:** The analysis showed the segregation of products based on their characteristics has a potential advantage since the demand pattern significantly varies among products. The study showed the current IPLS method of determining order up to level resulted in less customer service level and increased the likelihood of overstock. Based on the simulation-optimization model, the less costly replenishment model is 90% target customer service level and every other month replenishment, but it is important to set a target service level based on product characteristics and integrate segregation of products, including the price and demand variability to achieve the optimal replenishment.*

***Recommendation:** Health centers may integrate characteristics of products, financial parameters, longer historical data and standard deviation of demand to identify order quantity and review period. The findings from this study can be used to commence further investigation in the fitness of IPLS inventory control system by considering other alternatives with technical and financial feasibility.*

***Key Words:** Replenishment, Inventory, Optimization, Pharmaceutical, Health Center*

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Acronyms and Abbreviations

AACAHB:	Addis Ababa City Administration Bureau
AM	Anti-Malaria
ART:	Anti-retroviral Treatment
Anti-TB:	Anti-Tuberculosis
CSL:	Customer Service Level
DOS:	Days of Stock Out
EOQ:	Economic Order Quantity
EPSA:	Ethiopian Pharmaceutical Supply Agency
EPSS:	Ethiopian Pharmaceutical Supply and Services
HCMIS:	Health Commodity Management Information System
HSTP:	Health Sector Transformation Plan
ICS:	Inventory Control System
IP:	Inventory Position
IPLS:	Integrated Pharmaceutical Logistics System
JSI-DHA:	John Snow Inc. – Digital Health Activity
MOH:	Ministry of Health
OI:	Opportunistic Infections
PFSA:	Pharmaceutical Fund and Supply Agency
RCSL:	Realized Customer Service Level
STI:	Sexually Transmitted Infections
RCSL:	Realized Customer Service Level
RDF:	Revolving Drug Fund
US$:	United States Dollar
USAID	United States Agency for International Development
WHO:	World Health Organization

Notations

N	Number of items
D_i	Demand rate of item I (Units/time)
C_t	Unit ordering cost at the health facility (ETB/order)
C_e	Holding cost per unit item i at the health facilities (ETB/Unit/Time)
C_S	Shortage cost per unit item (ETB/unit)
L	Replenishment Lead Time (Time)
Q	Health center replenishment order quantity (units/order)
σ_{DL}	Standard deviation of Demand over lead time (Units/time)
K	Safety Factor
CSL	Cycle Service Level (%)
TC_r	Total cost for the health Center per period

CHAPTER ONE: INTRODUCTION

The thesis is introduced in this chapter, followed by a description of the problem and research objectives, which are then broken down into four research questions. The scope of the study and operational definitions, and organization of the study are also included in this chapter.

1.1. Background of the Study

Pharmaceutical consumption continues to rise globally with changing demographics, an increase in chronic diseases, a greater emphasis on prevention and self-medication, and changes in clinical procedures (Howell, 2013; González Peña, López Zavala and Cabral Ruelas, 2021). In 2019, the world pharmaceutical market was valued at USD 1.25 trillion (González Peña, López Zavala and Cabral Ruelas, 2021), where the North American market (USA & Canada) remained the world's largest market with a 48.7% share (efpia, 2020). Likewise, in low-income countries, pharmaceuticals remain the most extensive public expenditure on health (WHO, 2019).

In many developing countries, pharmaceuticals account for a significant component of the total healthcare system, comprising up to 20-40% of healthcare budgets (Lu Y, Hernandez P, Abegunde D, 2011). Transportation contributes to one-third to two-thirds of total logistics costs, and inventory management accounts for the next significant portion of the supply chain costs (Rodrigue, Comtois and Slack, 2016). Even if healthcare costs are rising, health facilities are required to minimize their expenses without compromising the service they provide (Rosales, 2011; Choolwe, 2020).

The annual pharmaceutical market in Ethiopia is estimated to be worth US$ 400 to US$ 500 million and growing at an impressive rate of 25% per annum. By 2025, it is estimated to reach an approximate value of US$ 1.821 billion (EIC, 2018). The pharmaceutical supply chain is a complex structure that entertains the flow of products and services. It comprises a global network of manufacturers, distributors, and health care providers producing, transporting, and dispensing drugs (Singh, Kumar and Kumar, 2016).

The pharmaceutical supply chain in Ethiopia is a regulated system involving many stakeholders, including private and public sectors (Gebregeorgise, 2018). More than 70% of the country’s pharmaceutical needs are supplied by a government institution named Ethiopian Pharmaceuticals Supply Service (EPSS), formerly known as the Ethiopian Pharmaceutical Supply Agency (EPSA). EPSS distributes pharmaceuticals to nineteen regional branches organized into seven clusters, serving over 4000 health facilities throughout the country (EPSA, 2020). The current inventory replenishment system employed by health facilities supplied by EPSS is called Integrated Pharmaceutical Logistics System (IPLS). The inventory control system followed by IPLS is a periodic review, forced ordering min-max system (Shewarega, Abiy, Paul Dowling, Welelaw Necho, Sami Tewfik, 2015).

EPSS aims to enable public health facilities to sustainably supply quality essential pharmaceuticals at affordable prices for their clients. To this effect, efficient logistics is critical. Logistics service is not only comprised of physical activity such as transport and storage but also non-physical activities like decision-making and information system (Lakshmi, 2017). EPSS adopted a digital information system called Health Commodity Management Information System (HCMIS) in 2009 and has been supplying health facilities according to IPLS (Dires, 2017).

Pharmacies carry inventory to safeguard against fluctuations in demand, take advantage of bulk discounts, and withstand changes in supply and lead time (West, 2003). One of the strategies used to reduce supply chain costs is optimizing inventory. Despite efforts to improve the availability of essential health commodities, the current replenishment system's optimality is not well addressed. According to Koumanakos (2008), the goal of inventory managers is to balance the tradeoff between excess inventory costs and shortage costs. Holding too much inventory consumes physical space, creates a financial burden, and increases the possibility of damage, spoilage, and loss. On the other hand, stock-outs of medicines cause pharmacies to lose customers and may adversely affect patients’ well-being especially when the product is an essential lifesaving medicine (Ali, 2011).

Optimization is a type of operational research that tries to find the best alternative solution for a problem under consideration using models and analytics (Hillier and Lieberman, 2010). There is, therefore, a need for optimizing pharmaceutical replenishment to achieve cost-saving, waste reduction, and high-quality services. This study focuses on determining the replenishment policy of health centers by characterizing the current replenishment policy, reviewing inventory models, and proposing replenishment models.

1.2. Statement of the Problem

The healthcare supply chain ensures the right drug reaches the right people at the right time and in the right condition to treat patients and attain the program goal (Uthayakumar and Priyan, 2013). Inventory management is critical to achieving these goals; it helps to maintain a steady supply to patients by preventing overstock and product stock-outs, thereby lowering inventory-holding costs (Kefale and Shebo, 2019). The main goal of the pharmaceutical supply chain and inventory management is to reduce healthcare costs without sacrificing quality care (Uthayakumar and Priyan, 2013).

In recent years with an increase in the cost of medicines, the healthcare industry has been trying to reduce costs incurred by their supply chains. Strategies commonly used include supply standardization, lead time reduction, and information sharing among supply chain partners to improve inventory control. The need for the health care sector to reduce costs has motivated many hospitals to adopt new technology to enhance existing operations (Rosales, 2011).

Health facility store managers decide order quantities, ordering dates, and the inventory level they carry to avail essential pharmaceuticals and effectively serve their patients/clients (PFSA, 2015). They also have to manage their interactions with suppliers to minimize the total integrated cost for supply chain and inventory management without sacrificing service level. Therefore, health supply chains require effective inventory management policies and coordination among suppliers, distributors, and providers (Karamshetty *et al.*, 2022).

The government of Ethiopia is focusing on availing pharmaceuticals at affordable prices (MOH and MOI, 2015). Nonetheless, essential medicines stock out remain a common problem, though the extent varies from facility to facility, ranging from 26% to 91% (Kefale and Shebo, 2019;

Mohammed *et al.*, 2020). Poor pharmaceutical inventory management strategy is one of the challenges in the Ethiopian pharmaceutical supply chain and a primary cause of stockouts of essential medicines, with an estimated 4% to 9% of pharmaceutical waste (Jobira *et al.*, 2022).

EPSS introduced the IPLS to improve pharmaceuticals' supply chain management at health facilities. A pharmaceutical reporting and distribution system that aims to ensure patients get the medications they need consistently and integrates the management of essential pharmaceuticals (EPSA, 2019). This system focuses on Logistics Management Information systems (LMIS), Inventory Control systems (ICS), and pharmaceutical storage in health facilities (Shewarega, Abiy, Paul Dowling, Welelaw Necho, Sami Tewfik, 2015). It has been in place since 2009, and studies have shown its contribution to enhancing essential health commodities availability through better information recording, storage practice, and distribution systems (EPSA, 2019; Alemu *et al.*, 2020). However, challenges related to drug shortage and overstock continued (Getachew and Damtie, 2020).

Even though implementing Health Sector Transformation Plan I (HSTP I) has shown success and increased access to essential medicines, there remain challenges in forecasting, procurement, and inventory management of pharmaceuticals. One of the initiatives of the revised health sector transformation plan (HSTP-II), is to optimize good warehousing and inventory management (FMOH, 2021). Optimizing inventory replenishment is significant because a shortage of medicines and improper pharmaceutical management lead to financial losses and significantly impact patients' quality of life. An occurring task of the mathematical model's development and determining the best inventory control strategy is related to gain the best use of monetary value and improve customer satisfaction (Ziukov, 2015). Therefore, this study is conducted to determine an optimal replenishment policy for managing inventory in public health centers.

1.3. Objectives of the Study

1.3.1. General Objective

- To determine an optimal replenishment policy for managing inventory for selected health centers in Addis Ababa.

1.3.2. Specific Objectives

- To characterize the current replenishment policy of selected health centers in Addis Ababa, Ethiopia.
- To estimate the relevant inventory costs for selected health centers in Addis Ababa, Ethiopia.
- To determine the optimal reorder period for selected health centers in Addis Ababa, Ethiopia.
- To determine the optimal order quantities for selected health centers in Addis Ababa, Ethiopia.

1.4. Research Questions

Based on identified gaps and the objectives of the study, the following research questions were synthesized and presented as follows;

- What are the characteristics of the current replenishment policy of selected health centers in Addis Ababa, Ethiopia?
- What is the estimation of the relevant inventory costs for selected health centers in Addis Ababa, Ethiopia?
- What is the optimal reorder period for selected health centers in Addis Ababa, Ethiopia?
- What are the optimal order quantities for selected health centers in Addis Ababa, Ethiopia?

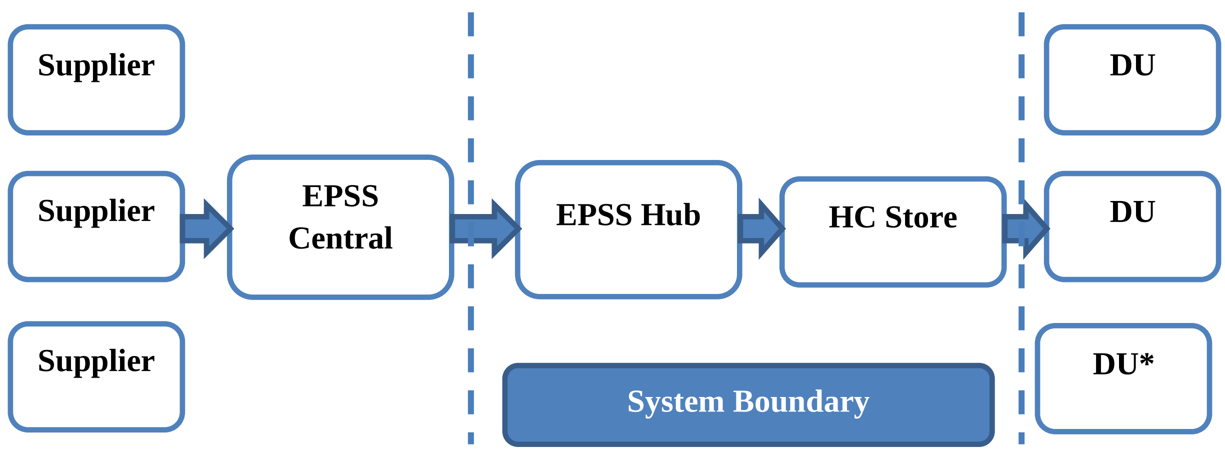
1.5. Significance of the Study

The study will help health centers to recognize different costs and the areas where costs can be minimized while ensuring the intended service level. Moreover, the findings from this study will greatly benefit the inventory control managers who would have to define when and how much to order to minimize costs. It would also help different stakeholders in the pharmaceutical supply chain to understand the benefits of using analytics in inventory management. The study's findings would clarify to those inventory management practitioners the relevance of data-driven decision-making and promoting good data management. The results can provide helpful insight into minimizing inventory cost and maximizing efficiency by suggesting applicable models for inventory management.

In addition, this study contributes to the existing scientific community (literature) by determining an applicable optimal replenishment policy for Health centers in Addis Ababa. Researchers and academicians would find the outcome of this research valuable to their study and advancement of knowledge.

1.6. Scope of the Study

The study is primarily bound to the health center and EPSS hubs replenishment system. Since the major supplier of program medicines to the health centers is EPSS, the relationship between other donner/suppliers and the health centers is excluded in this study. The theoretical scope of inventory management is vast in a way that includes the management of available physical space to future inventory price forecasting and quality management (Ogbo, Victoria and Ukpere, 2014), while this study is limited to service level attainment and replenishment of products. The currently employed IPLS system has three basic logistics functions: LMIS, inventory control, and storage (PFSA, 2015). This study is confined to the currently employed inventory control system and doesn't consider the storage practice and the performance of LMIS of health facilities. The study is delimited to the three years of data 2009-2011 E.C (2016/17-2018/19 G.C) that are pertinent to meet objectives of the study. The study boundaries are visualized in Figure 1.



DU: Dispensing Unit

Figure 1: A schematic illustration of the system boundaries in the thesis

1.7. Definition of Terms

Buffer Stock (safety stock): The inventory a health center holds above normal needs as a buffer against delays in receipt of supply or changes in customer demand (MSH, 2012).

Echelons: is a stocking point where replenishment decisions are made between any specific stage in the supply chain and the final customer(Nahmias and Olsen, 2015).

Holding cost: (sometimes called the storage cost) represents all the costs associated with the storage of the inventory until it is sold or used (Axsäter, 2015).

Inventory Control: These are activities that maintain stock-keeping items at desired levels (Bartmann and Beckmann, 1992).

Inventory policy: is a way to determine how much and when a product should be ordered to have a smooth flow through a supply chain(Nicholson, 2002).

Lead time: the time between placing an order and actual replenishment of an item (MSH, 2012).

Maximum Stock Level: It is the amount expressed in units of the issue above which the stock should not be allowed to rise. It helps avoid excess investments in stock (PFSA, 2015).

Minimum operating stock level: indicates the point of inventory consumption at which pharmaceuticals need to be replenished, just before the safety stock is used(PFSA, 2015).

Re-order Level: is the amount expressed in units of issue at which ordering action is indicated in time for the materials to be delivered before stock falls to a minimum(MSH, 2012).

Shortage cost is incurred when the commodity required (demand) amount exceeds the available stock(MSH, 2012).

Shortage: a situation in which there is less of something than people want or need(MSH, 2012).

Stock Keeping Unit (SKU): A category of unit with unique combination of form, fit, and function (i.e. unique components held in stock)(MSH, 2012).

Time horizon: is the length of time that the inventory level will be coincides with the intended use for which it was developed (CSCMP, 2013).

Operational definition

The current replenishment policy: in this study the current replenishment policy refers to the currently employed inventory control system in the Ethiopian public health facilities named IPLS system.

1.8. Organization of the study

The first chapter of this thesis is dedicated to providing background on the problem this thesis means to address, the objective, as well as the scope of the study. Chapter two presents literature on the major concepts surrounding the problem under discussion, including a variety of models to solving replenishment problems and different product segregation techniques as well as empirical evidences. The third section of this thesis addresses the methodology used to simulate the replenishment optimization problem. Chapter four provides the result and discussion by addressing each specific objectives as a sub-section. Lastly, chapter five summarize and gave recommendation based on the finding of the study.

CHAPTER TWO: LITERATURE REVIEW

This chapter is divided into two, the first section of this chapter is about theoretical review where the commonly used inventory models are discussed. Understanding of different inventory models in the context of demand will help to identify those models that are more compatible to deploy in this study. Second, since the objective of the study is to determine an optimal inventory replenishment model, a review of empirical research is presented to formulate literatures in the area.

2.1. Theoretical Literature Review

2.1.1. Inventory Management

Facilities keep inventories at several points along the supply chain to buffer operations at various places and times (Veinott, 2012). A facility's optimum inventory level is crucial as excess inventory increases stock-holding costs, such as rental charges and damage/expiries. On the other hand, an inadequate inventory level is also costly because of losing customers to competitors (Berling and Martínez-De-Albéniz, 2011). For these reasons, inventory management is important. It is defined as the continuing process of planning, organizing, and controlling inventory to minimize inventory investment while attaining the target service level (Zgarrick *et al.*, 2020). There are different ways to define service level. To mention some, it is the possibility that there won't be any stockouts during an order cycle or the likelihood that an order will be fulfilled before the stock runs out. It is also defined as the "ready rate," which is the percentage of time with positive stock on hand, or the "demand fill rate," which is the percentage of demand that can be quickly satisfied from stock on hand (A. Davis, 2015; Axsäter, 2015).

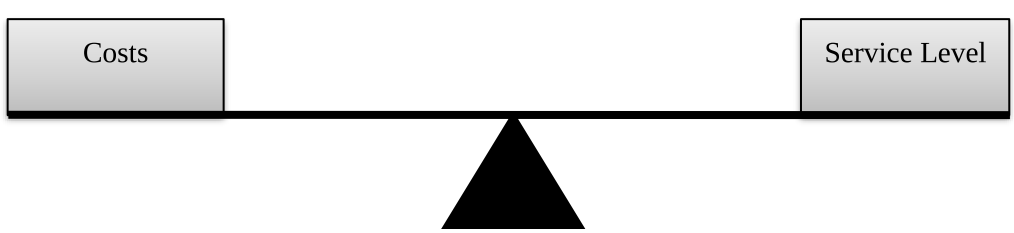


Figure 2: The balance between costs and service (Fernie & Sparks, 2019)

As shown in Figure 2, the goal is to manage the components of the logistics mix in such a way that an optimal trade-off between cost and service is achieved (Fernie and Sparks, 2019).

The primary aspect of inventory management is the type of inventory control policy. The inventory control policy relies on how often the inventory status should be determined, the review interval (R), and how much should be ordered. Review interval is the time that elapses between two consecutive moments at which the stock level is specified (Silver, Pyke and Thomas, 2016). Inventory review can be done in two ways: continuously or periodically. In the continuous review system, the stock status is always known by immediately updating the stock status after each transaction. While in periodic review, the stock status is determined in every pre-determined R time unit (Tijhuis, 2019). After deciding whether to conduct a continuous or periodic review, how much should be ordered must be determined (Silver, Pyke and Thomas, 2016).

2.1.2. Inventory Models

For optimal management of inventory, different inventory models can be used. Six of the common types of inventory models are described below;

2.1.2.1. Economic Order Quantity (EOQ)

The Economic Order Quantity **(**EOQ) is a well-known inventory control analysis and is one of the most significant findings in the field of operations management. In 1915, Harris and Wilson attributed this to the development of the calculation of EOQ (Freeman and Waters, 1993). They noted that EOQ derives the optimal lot size for replenishing order by minimizing the total operating cost. However, the classical EOQ model assumes constant demand, with fixed ordering cost and instantaneous replenishment (Vujosevic, Petrovic and Petrovic, 1996).

The portion of an inventory filled by replenishment orders with a different frequency and in larger quantities than the consumption rate is called cycle stock (Jonsson and Mattsson, 2009). Unlike safety stock, which is kept to cover uncertainty, cycle stock is needed to meet customer demand under specified situations (M.Lambert, Stock and M.Ellram, 1998).

The downside of EOQ is that it ignores the requirement for buffer stocks to account for changes in the lead time and demand, making it difficult to practice (Silver, Pyke and Thomas, 2016). In addition, the EOQ model doesn't account for seasonal or economic changes and it is limited by the assumption of a single product (Oballah and Waiganjo, 2015). While the EOQ doesn't allow stock out, hundreds of models were developed with an adjustment to the classical EOQ model for different circumstances. The widely used EOQ extensions are discounts in the unit cost, finite replenishment rate, planned shortages, back-orders, and added constraints on space or investment (Freeman and Waters, 1993).

2.1.2.2. The Newsvendor Model

EOQ assumes uniform and deterministic demand, while the single-period model allows demand to be variable and stochastic (MIT, 2016). A single-period model is the most basic periodic model. It is used when products cannot be sold after a certain period. Daily newspapers are an example of this; newsboys buy a stack of newspapers early in the morning and try to sell them throughout the day. The newsboy will lose money if left with unsold papers (Bartmann and Beckmann, 1992). This is a single period with stochastic demand. It is assumed that it is normally distributed with mean μ and standard deviation σ. There are penalty costs associated with ordering excess and too little compared to the unknown stochastic period demand. The problem is optimizing the order size (Axsater, 2000).

Increasing order quantity iteratively starts with a modest number, and the projected profit continues to rise while the inequality remains valid. The imbalance eventually breaks down, revealing that the last units will have an estimated loss, and net profit will begin to decline. This determines the optimal option for the order size (Freeman and Waters, 1993).

2.1.2.3. Order-Point, Order-Quantity System

Order-Point, Order-Quantity (s, Q) system is a continuous-review system where an inventory position is monitored continuously (Axsater, 2000). By the time the inventory position falls to the reorder point *s* or lower, a fixed amount Q is ordered. The values of *s* and Q are the two decisions required to implement the replenishment policy (Silver, Pyke and Thomas, 2016).

When placing a new replenishment order, the inventory level must cover the average demand over the lead period plus an additional quantity indicating a certain number of standard deviations (Jonsson and Mattsson, 2009).

The (s, Q) system is commonly referred to as a two-bin system; demand is satisfied as long as units remain in the first bin. The order point corresponds to the amount in the second bin. When the second bin is opened, a replenishment occurs. The advantages of the fixed order-quantity (s, Q) system include; it is quite simple, particularly in the two-bin form, for the stock clerk to understand and reduces the likelihood of error. The main limitation of an (s, Q) system is that it may not be able to handle big individual transactions in its unmodified form (Axsäter, 2015; Silver, Pyke and Thomas, 2016).

2.1.2.4. Order-Point, Order-Up-to-Level (s, S) System

In Order-Point, Order-Up-to-Level (s, S) inventory system, the inventory state is reviewed every T period, and the inventory position is monitored to make a replenishment decision. When the inventory position is below s, a variable amount of Q is ordered. In addition, the s, S policy system assumes continuously reviewing the inventory position, and a replenishment order is placed whenever the inventory position drops to the reorder point s or lower. The difference between (s, S) and (s, Q) is in case of (s, Q) a variable replenishment quantity is used while in (s, S), the quantity is determined by ordering enough to raise the inventory position to the order-up to level S a quantity of (S − s). Order is placed when the inventory position is at the level s or lower. In (s, S) policy, the cycle length for the inventory position to drop from S to s or lower is random (Schneider, 1979; Zheng, 2008; Silver, Pyke and Thomas, 2016).

2.1.2.5. Periodic-Review Order-Up-to-Level (R, S) System

The (R, S) policy is also known as a replenishment cycle system because for every R unit; the inventory position is raised to the order-up-to level S. Because of the periodic-review property, this system is much preferred compared to order point systems since it benefits from coordinating the replenishments of related items. For instance, in order to keep transport costs minimal, it is frequently required to fill the container by aggregating orders. The coordination afforded by a periodic-review system can provide significant savings. In addition, the *(R, S)* system offers a regular opportunity (every *R* unit of time) to adjust the order-up-to-level *S*, a desirable property if the demand pattern changes with time. The main disadvantages of the *(R, S)* system are that the replenishment quantities vary and the carrying costs are higher than in continuous-review systems (Hillier and Lieberman, 2015; Silver, Pyke and Thomas, 2016)

Keeping a safety stock serves to compensate for unanticipated uncertainties. Even if the underlying demand is stochastic by nature during the planning phase, it is frequently represented as deterministic. Scarcity is a possibility if demand is higher than forecast. The purpose of safety stock is to compensate for unanticipated high demand during the lead time, which is the time between when an order is placed and when the products are ready (Cedergren, Jonsson and Karlsson, 2015).

In (R,S) policy, the replenishment order is placed every R unit of time, its assumed to be predetermined based on different factors such as the fixed setup cost of reviewing inventory and other external variables such as the frequency of truck delivery (Silver, Pyke and Thomas, 2016).

2.1.2.6. Dynamic lot sizing methods

When using the dynamic lot sizing methods both order quantity and frequency vary between subsequent orders. These methods necessitate more sophisticated calculations and provide better order quantities. Calculations are conducted period by period for each order to ensure that the order covers the quantity for the next period. The Silver-Meal heuristic, often known as the least period cost approach, is one of the most widely used dynamic lot sizing algorithms. Both in terms of quantity and time, the approach is discrete and temporal variant (Jonsson and Mattsson, 2009). Demand for future time periods is taken into account while establishing the order quantity for a period. However, the first period's order amount must at least satisfy that period's demand (Axsäter, 2015).

2.1.3. Segmentation Analysis

Segmentation analysis is useful for deciding which commodities should be included in specific systems. Segmentation is identifying commonalities between products and customers attributes, then structuring the supply chain to best meet customer demands or product requirements (USAID Deliver, 2011).

Depending on various operating factors, different literature classifies stock items on other bases for ease of inventory control. The important bases of inventory classification are ABC-Analysis in which items are grouped into A, B and C- category. In ABC analysis, items are grouped based on their relative value or money usage. Another common type of analysis is VEN analysis, in which items are classified based on their criticality. Criticality can be expressed with three attributes: danger of loss of life, quality of treatment, and replacement with other treatments (Danas, Roudsari and Ketikidis, 2006). The last important bases of classification are FSN analysis. In this case, the quantity and rate of consumption of items by company is analyzed to group items for selective inventory management (Dessalegn and Roy, 2002).

2.2. Empirical Literature review

2.2.1. Inventory models in pharmaceutical replenishment

A study done by Guerrero et al. on a multi-echelon pharmaceutical system with batching and ordering constraints used (nQ, r, T) policy where an order is placed whenever the inventory position is dropped below the re-order point *r* and the order is placed in multiples of Q. The study also compared the benefits of having a two-echelon distribution system versus three on a hospital network. From the analysis using the proposed policy (Q, R) showed an average of 33% cost reduction and (s, S) policy for low profit SKU an average of 37% cost reduction (Guerrero, Yeung and Guéret, 2013).

A similar single case study design done in an Indonesian hospital proposed an (s, Q) policy using continuous review reduced total inventory value by 50% compared with the existing policy. The study used qualitative and quantitative data to get an in-depth understanding of the hospital pharmacy inventory system (Rachmania and Basri, 2013).

Huang and his colleagues considered a two-level supply chain, in which products are delivered to multiple retailers from a single warehouse. Each retailer faces a deterministic demand with an objective of determining an optimal stationary inventory ordering policy for both the warehouse and retailers, where the average transportation and inventory cost is minimized. The transportation cost consisting of fixed and variable costs were set to be linearly proportional to the amount of quantity ordered (Huang, Chew and Goh, 2005). Another study done in pharmaceutical supply chain with multiple products considered a variable lead time with a constraint on space availability and customers service level (CSL) using continuous review policy emphasized the difficulty of attaining 100% CSL (Uthayakumar and Priyan, 2013).

While most studies consider deterministic lead time, not including inventory miscount and non-inclusion of lead time variability have puzzled operational researchers by consistently lowering the prescribed service levels. An inventory miscount happens when the actual service level deviates from the quantity on a computer record (Samere, 2005).

A typical pharmaceutical supply chain consists of one or more primary/secondary/ manufacturing, distribution centers, wholesales, and retailers/hospitals (Shah, 2004). Different optimization strategies have been used in industries to maximize sales revenue or minimize operating costs (Papageorgiou, Rotstein and Shah, 2001). Depending on the situation, a supply chain can be characterized according to how re-ordering is done in a centralized or decentralized way. In the decentralized case, each supply chain company tries to optimize its own total cost independently from the other members of the same chain (i.e., local optimization). The decentralization strategy refers operating with different inventory strategy at each independent supply chain units. The order point and order quantity are decided by each facility in accordance with its own ordering policy and local inventory optimization strategy (Moorthy, 1988). While in the centralized strategy, the central unit is responsible for data integration and coordination tasks as well as the overall inventory control activities in upstream and downstream of the supply chain (Sun, 2020).

Axsäer considered a two-echelon distribution inventory system with a central warehouse and a number of retailers. The system is controlled by continuous review installation stock (R, Q) policies with given batch quantities. He developed an approximate technique to determine the backorder cost of the warehouse, and let the warehouse choose its reorder point so that the sum of expected holding and backorder costs is minimized (Axsäer, 2005).

Papachristos and Skouri (2000) considered deterioration of items in EOQ with the finite-planning horizon and deterministic varying demand. While it's very important to consider deterioration of pharmaceuticals, the assumption that constant demand rate would be practical is limited to the matured stage of the product's life cycle.

A study done in Children's Hospital of Pittsburgh applied management techniques to the healthcare implemented in other industries and successfully used nine potential variables: Criticality, Unit Price, Demand Level, Demand Frequency, Demand Variability, Demand Dispersion, Handling Characteristics, Physical Size and Weight, and Shelf Life (Expiry Date). After reviewing each characteristic, the study concludes that each hospital should be treated as a unique entity, and supply chains must be explicitly designed for themselves (Cheng, 2008).

2.2.2. Inventory practice in Ethiopian health supply chain

To name a few of the numerous studies that have been conducted to evaluate the inventory management practices in Ethiopian health supply chain. A descriptive cross-sectional study combined with a qualitative approach was conducted by Boche, Mulugeta and Gudeta, (2020) to assess the inventory management practices used for program medicines at EPSS. Metrics such order fill rate, wastage rate, frequency of emergency orders, acceptable storage condition, and stock out were used in the study to evaluate inventory management practices. In-depth interviews were conducted in addition to the quantitative assessment to examine the challenges in inventory management. Another study done by Kefale and Shebo, (2019) assessed essential medicines availability and inventory. An institution-based cross-sectional survey using indicators from an inventory management assessment tool was employed for the study. Similar study investigated the progress and challenges to the implementation of IPLS in a few health facilities in the Wollega zones of western Ethiopia's Oromia region. The study combined qualitative in-depth interviews with the logistics indicator assessment tool(Alemu *et al.*, 2020). Such studies and similar studies have been conducted in Ethiopia, and they have greatly contributed by identifying challenges including the gaps in logistics management information system, the shortage of essential medicines, and storage conditions. However, to the best of the researchers' knowledge, none of them attempted to characterize and optimize the replenishment policy, this study aims to fill this gap.

2.3. Conceptual Framework

The study developed replenishment policy with a spread sheet by optimizing the order policy and comparing the previous replenishment policy. A conceptual framework was adopted from A. Davis, (2015), which looks at the information flow from inputs to outputs to better grasp how inventory optimization affects the service level and the total cost. Below, the conceptual framework where input data which are the costs, demand, and lead time. The model aims to determine the policy that optimizes the inventory position by changing the order up to level. The model is expected to optimize the total cost while keeping the service level in balance.

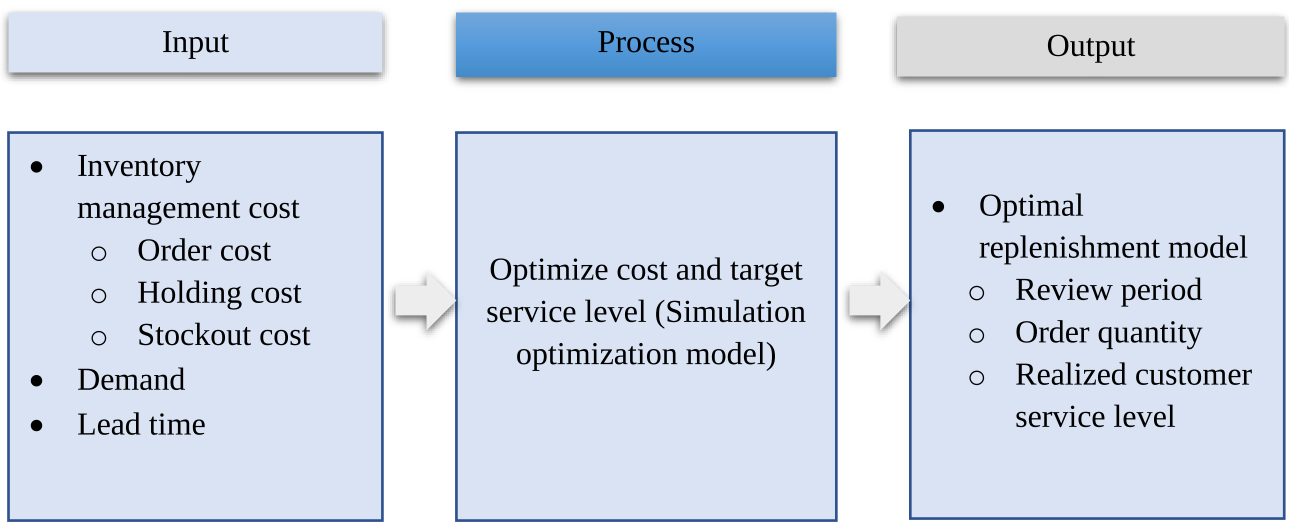


Figure 3: Conceptual Framework

Key:

Flow of information in simulation optimization model

CHAPTER THREE: RESEARCH METHODOLOGY

The research approach and design are described in the methodology chapter. Data collection methods and the sampling are discussed. The chapter concludes with methodology thoughts on ethical consideration and dissemination plan.

3.1. Study Area and Study Period

Addis Ababa, the capital city of Ethiopia, is by far the largest city in the country, located in the central part of Ethiopia. The city has three layers of administration; the City Administration at the top, ten sub-cities, and the city administration recently added a new sub-city to become a total of 11 sub-cities (World Bank Group, KRIHS and AACAB, 2021). There are 101 public health centers and two EPSS branches located in Addis Ababa (EPSA, 2020; AACAHB, 2021). The study was conducted in ten selected health centers from August 31 to September 18, 2020.

3.2. Study Design and Approach

A multiple case study design with quantitive approach is used to analyze the currently employed inventory replenishment policy and simulate a proposed replenishment model. The case study methodology is appropriate when it is challenging to investigate the organization outside of its normal context. One frequently stated scenario is when it is decided to research a phenomenon, feature, or aspect of an organization or department (Ghauri, Gronhaug and Strange, 2020). This study design is selected because, compared to a single case study, the evidence from multiple cases is often considered more compelling and robust (Herriott & Firestone, 1983). The multiple case study design selects cases to predict similar or contrasting results for anticipatable reasons (Yin, 2018). Moreover, it is impossible to identify product characteristics and their effect on the replenishment policy based on highly aggregated data. Every health center is unique because, in every case, there is a different set of parameters and variables that depend on the facility's strategies, characteristics, and policies that are followed (Satoglou, 2016).

3.3. Source and Study Population

The subject of the study is the health centers and the pharmaceuticals served at the health centers. All functional health centers located in Addis Ababa and served by the EPSS Addis Ababa branch were considered as a source population, whereas health centers that are selected by the sampling method and fulfill the inclusion criteria were selected as a study population. With regard to the pharmaceuticals within the public health system and served at health centers, there are two types of drugs, the program (donated and dispensed free of charge) and the Revolving Drug Fund pharmaceuticals (RDF) (Gebru and Demelash, 2018). The program pharmaceuticals, comprising of Anti-Retroviral Treatment (ART), Anti-Tuberculosis (anti-TB), anti-Malarial, family planning products, OI (opportunistic infections), Maternal and Child health commodities (MCH), is financed by the Government of Ethiopia and support from external donors (Ali, 2014). All of the aforementioned health program items were considered as a source population. Only program items were chosen for this study because they are the only items delivered to health centers via the IPLS, with the exception of a few health centers that have a contractual agreement with EPSS to receive either item delivery.

3.4. Sample Size Determination and Sampling Technique

This study employed a case study methodology, to select the cases and to include the specific number of health centers. Then purposive sampling method was followed since it illuminates the theoretical propositions of a case study (Yin, 2018). Experts' opinion were collected and consecutive steps were followed to select and identify the appropriate sample health centers (Figure 4). Experts contributing to this study's sampling were those who have been closely working with the health centers, providing supportive supervision and monitoring. Hence, they recommended to select health centers with a good record of data management and progress of DAGU implementation. The good record of data is expected from chosen health centers because minimum of two to seven years data is recommended to synthesize the model (Ellison and Cook, 2020; Antic, Milutinovic and Lisec, 2022).

Following identification of the short-listed health centers, in-person visits to fifteen health centers were made. During the visit, it was noticed that some of the health centers were using DAGU system albeit its frequent disruption. This made them automatically excluded, but some health centers were eligible and, all electronic bin cards were collected. On the other hand, number of items with complete three-year demand data was checked, and a minimum of eleven items and a maximum of forty-nine items was found with a sample of ten health centers from each sub-city.

3.4.1. Eligibility Criteria

3.4.1.1. Inclusion Criteria

- Government health Centers that have been supplied by EPSS
- Health Centers that have been serving for more than four years
- Health Centers that have an electronic record of demand data from 2009-2011 E.C (2016/17-2018/19 G.C)
- Health Centers that use the DAGU system for managing inventory

3.4.1.2. Exclusion Criteria

- If two health centers are located within the same sub-city, and both have three years of continuous inventory data, then the one with fewer data per item was excluded.
- Vaccines were excluded from the study since they require especial cold chain management that can affect the cost estimation

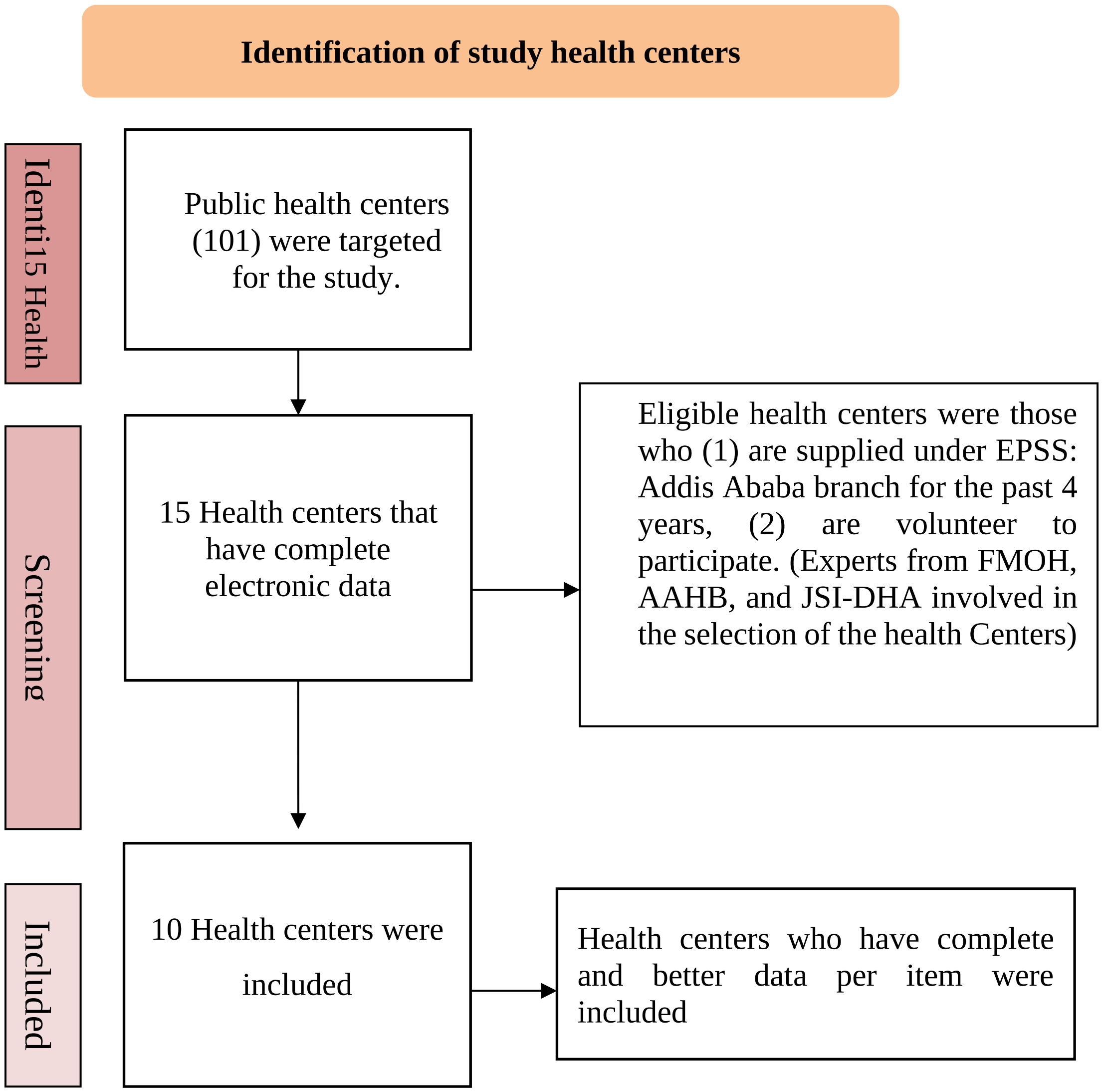


Figure 4: Sampling steps

3.5. Data Collection and Management

3.5.1. Data collection instrument

After reviewing literatures on inventory cost aggregation and consumption data extraction (Azzi et al., 2014; Johnson et al., 2014), the instrument was designed in a hybrid way where primary and secondary data were captured. The first section contained general background information, description of health center and products stored in the store. The second section focused on product consumption and lead time. Consumption data for the past three years was extracted to get the monthly demand from electronic Bin-card (Annex II). Lead time for each health center was collected, and the minimum and maximum lead time was identified and used to generate random lead time. Simultaneously, days of stock out and amount of expired/damaged product were extracted. The third section was about costs incurred by the health centers, including holding costs, ordering costs, and stock-out costs.

3.5.2. Data collection procedure

The principal investigator collected all data. Since the study was primarily quantitative, the primary data is collected regarding cost using section three of the data collection tool, where cost data is filled in by the responsible personnel (such as the salary of personnel working in the health center store). The secondary data was obtained by reviewing the store database system (DAGU). A total of 650 electronic bin cards were extracted using a USB flash disk then a trained data clerk entered the data into a pre-tested excel data extraction sheet. Based on the screening process, 211 electronic bin cards were used as an input data for the simulation-optimization model while the rest were used to synthesize information regarding the stock out rate, wastage and monetary value of program pharmaceuticals.

3.5.3. Data Quality Assurance

The data collection tool's validity and appropriateness were assessed using a pre-test. The pre-test was done in a single health center that was not included in the study. Accordingly, some component of the data extraction tool was improved and re-designed. Moreover, a trained data clerk entered the data, and the principal investigator monitored the quality of the data by randomly checking the entered data with the source data.

3.6. Methods of Data Analysis

The data was entered into the pre-tested excel-data extraction tool. The excel spreadsheet summarized each demand series, stock out, and wastage into a monthly time bucket. Parallel excel sheets were made for cost parameters. Before running the model, the data was cleared for missing data. To yield consistent data for the simulation, list-wise deletion was used where any Stock Keeping Units (SKUs) with missing demand data was deleted. Other options such as mean substitution, could introduce bias (Schumacker, Lomax and Group, 2010). Once the data was sufficiently cleaned, a descriptive statistic (Mean, Median, IQR, SD), cumulative frequency distribution (cost and demand), consumption rate, stock out, unit cost, and wastage and correlation was done using Microsoft Excel 2019 and IBM SPSS version 26. Consumption rate of the pharmaceuticals was calculated by dividing the total issue quantity with the total period (Fitriana, Moengin and Riana, 2016; P and Ranganathan, 2017) . A stock-out was recorded every time the inventory position of an SKU falls to zero, and it is difficult to record the actual demand during the zero-stock period. Therefore, the average Days of Stock Out (DOS) and the percentage of stock out for the products for the last three years indicate the system's capacity to maintain the supply of products over time. A simulation-optimization approach was used to show the current total inventory cost and develop an optimal replenishment policy.

3.6.1. Demand data generation

To generate random monthly demands of the selected SKUs, actual monthly demand of the pharmaceuticals for the last three years was collected from the health centers' stores. The model assumed a normal demand distribution as it is the most commonly used distribution for various reasons. The central limit theorem states that a sum of many independent random variables will have a distribution that is approximately normal under very general conditions. In many cases, demand is generated by a number of different clients; therefore, a normal distribution is a fair representation (Axsater, 2000). Empirical demand data, price, and criticality of products was used to characterize the product-specific pattern, such as demand variability, demand frequency, and consumption rate.

3.6.2. Model Formulation

This study investigated a single-echelon consisting of health centers with multiple pharmaceutical products. The model simulates the current inventory policies of health centers by using the actual review periods and delivery trends. A heuristic approach that combined simulation and optimization was used in the model to find the optimal inventory replenishment that offers minimal relevant cost. To ensure that the optimal result applies to the actual healthcare setting, the model considered constraints, such as a high target service level at health center stores and a minimum stock on hand quantity.

The study assumed that the demand faced by each health facility is stochastic, normally distributed, and has independent products. An emergency ordering point was safety stock, and the safety factor was assumed to satisfy a customer service level of 90%,95%, and 99%, as recommended by Babai, Ali and Nikolopoulos, 2012. In addition, every product "i" at the health facility employs a periodic review (R, S) with a review every R period for all products simultaneously and replenish with variable lead time L. Furthermore, the health facility must order in a pack from the supplier.

Objective Function

The objective function was to minimize the health center's total relevant cost. A simulation was done to compare the different replenishment strategies. The variables in the simulations were the order-up-to level and re-order period. The effect of changing the review period was studied for each replenishment strategy by varying the review period from one month to two months. Through simulation, the performance of each replenishment strategy was analyzed and compared to each other. The two features used to compare the performance of replenishment strategies were total relevant cost and occurrences of stock-outs. Total relevant costs are the cost of holding inventory, ordering cost, and cost of stock out.

Cost Aggregation

Each health center incurs holding costs, ordering costs, and shortage costs. Different kinds of inputs were used to estimate holding costs, and ordering costs according to assumptions used by (Azzi *et al.*, 2014; Johnson *et al.*, 2014)("Annex 2").

Assumptions

- Health Centers rental cost is calculated based on the government house agency rental scale. A fixed location is assigned to store program medicines.
- Once the annual holding cost is calculated, the estimation of program medicine holding cost is assumed to fixed for five Dixon shelf space. Then the unit holding cost is assumed to proportionate the percent demand quantity for program medicine.
- Utility cost component of holding cost assumes the health facility will consume 5% of the total utility cost of communication, water, and electricity.
- Every time, an order is made ordering cost is incurred where the unit ordering cost is calculated based on order processing time.
- This study assumes whenever a stock out occur an emergency order cost is incurred.

Ordering Cost

Ordering costs include the hours it takes to make, validate, send and store orders, order confirmation, monitoring order status and processing status, and expediting. The pharmacist/pharmacy technician is expected to open the store for 8 hours a day, and the monthly salary is changed to an hourly wage. The total order cost is then calculated as per the hours they ranked it will take them to process the order.

$$Ct = C_{ti}\frac{D}{Q}$$

Where; C_{ti} is a unit ordering cost [ETB/month].

Holding costs

The holding cost consists of handling cost (Human resource cost), utility cost, and rental cost (even if the health center owns the store; in this case, the rental cost is an opportunity cost; the possibility of using the store for other purposes is given up).

The unit holding cost, C_e at each health center is:

$$C_e = RP + UC + HRC,$$

Where;
RP: Rental price
UC: Utility cost
HRC: Human resource cost; whose units are ETB/month.

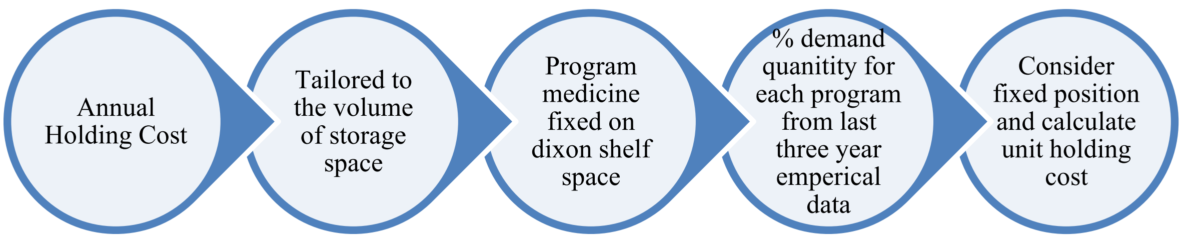


Figure 5: Stepwise figure for holding cost estimation

Utility cost;

Utility costs are composed of different components: equipment costs, communication costs, electricity, maintenance, and water.

Shortage cost

According to MSH, (2012) only considering cost of emergency order or loss of revenue from clients are considered a realistic measure of unit shortage cost for public pharmaceutical supply system. This study considers cost of emergency purchase.

The shortage cost is calculated;

$$C_s = s_u \frac{D}{Q}$$

That means considering product *i* the shortage cost becomes;

$$S_c = \sum_{i=1}^{N} S_{ui} \frac{D}{Q} P[x \geq K],$$

The total cost equation then becomes;

$$TC_r = C_t \frac{D}{Q} + C_e \left(\frac{Q}{2} + K\sigma_{DL}\right) + S_u \frac{D}{Q} P[x \geq K]$$

Where K is the safety factor identified as the probability of not stocking out (Cycle Service Level)

Constraints

- Order quantity couldn't exceed annual demand
- Target service level is set to be 90,95 and 99%
- Minimum order quantity is set to be safety stock

3.7. Ethical Consideration

Ethical approval was obtained from the Ethics Review Committee of the School of Pharmacy (SoP), College of Health Sciences (CHS), and Addis Ababa University (AAU) with a reference number ERB/SOP/171/07/2020. To get the data required, a support letter was written from the department of Pharmaceutics and Social pharmacy, School of Pharmacy, College of Health Sciences, Addis Ababa University to EPSS, FMOH, AACAHB, JSI-DHA. In addition, The FMOH and AARHB, then, wrote a support letter for JSI-DHA and health centers, respectively. The confidentiality of raw data was maintained throughout the study by ensuring that only PI could access the information. The health center's name was kept anonymous to avoid personal identifier information.

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter is divided into two sections the result and discussion. The result section incorporates interpretation of each analysis as well as subsection of result outlined as per the specific objectives. In order to describe the current replenishment policy. Different multi-attribute characteristics of the replenishment are presented. The next subsection of the result shows the relevant costs of inventory policy. Final subsection of the result compares the current inventory policies with the proposed inventory policy. In the literature review section, the relationship that exists between the service level and safety stock were discussed. In final subsection of the result sensitivity analyses are performed to assess how a service level can affect the other safety stock.

4.1. Introduction

This study characterized the current replenishment policy, estimated the relevant costs, and determined an optimal replenishment policy. Petropoulos, Wang and Disney (2018) suggest the performance of a replenishment policy should be evaluated through financial, operational, and service-related metrics. The financial metrics consider costs incurred in the system, such as inventory holding and ordering, and operational metrics include the order and inventory variance. The service-related metrics consider the cycle service level.

4.2. Characteristics of Current Replenishment Policy

It is crucial to characterize the products that are replenished under the inventory management policy. This section of the result describes the demand using different segmentation structures. Health centers follow IPLS to replenish the inventory and the spreadsheet model used three years of historical demand data to simulate the current replenishment policy. The current replenishment policy runs according to IPLS, where the maximum months of stock are four months of Average Monthly Consumption (AMC), the minimum months of stock are two months of AMC, and the emergency order point is two weeks of AMC.

Based on the list wise deletion of products from the ten health centers, 211 program medicines had three years of complete Bin-card information that fell into nine categories. These 211 program medicines are in type 64 SKUs. At the time of the three-year data extraction period 1 USD exchanged for maximum of 29.21 ETB (μ =25.95ETB and Minimum value= 22.05ETB). The monetary amount of the program medicines issued from the health centers valued 93,922,330.05 ETB. ART products take the highest percentage, 78.69% of the total amount, followed by MCH products, 10.8%. Below is the monetary (ETB) value of the total program medicines within the three years,

Table 1 : Monetary value of products dispensed within the three years in selected health centers, September 2020

S. No	Categories of the products*	2016/17	2017/18	2018/19	Total
1.	Anti-Retroviral Treatment (ART)	18,471,283.71	28,033,091.92	27,401,287.52	73,905,663.15
2.	Maternal and Child Health	8,979,658.32	223,369.59	261,564.74	9,464,592.65
3.	Family Planning Products	2,275,022.83	1,276,615.84	2,315,200.58	5,866,839.24
4.	Opportunistic Infections Drugs	550,223.87	559,385.20	1,405,479.39	2,515,088.46
5.	Nutrition Commodities	391,715.17	973,872.89	155,804.14	1,521,392.20
6.	Anti-Tuberculosis Drugs	88,318.99	100,911.08	251,507.42	440,737.48
8.	Sexual Transmitted Infections Treatment	132,787.20	68,936.12	6,013.49	207,736.80
9.	Anti-Malarial Medicines	140.13	-	140.13	280.26
		30,889,150.21	31,236,182.63	31,796,997.41	93,922,330.24

**Product categorization is based on Report and Requisition Form*

Different characterizations were used to understand the fitness of the current replenishment policy of IPLS to the health center, such as stock out rate, wastage, demand variability, and frequency. Below those characteristics are presented.

Stock out and Wastage of Program Pharmaceuticals

From the three years transaction the total of number of days of stock out, stock out rate and the wastage were calculated. Based on the analysis the minimum days of stock out rate in one health center was 0.05% and maximum stock out rate was found as 18.61% in another health center. The wastage was high in a health center that had high number of products with ETB 98, 706.13 from a total of 48 products and lowest wastage was observed in a health center with a total of 11 products with ETB 393 (Table 2).

Table 2 :Stock out rate and wasted value of program pharmaceuticals in selected health centers, Addis Ababa, September, 2020

Facility	**Stock out rate (Average DOS)**	**Wastage (ETB)**
HC one(*n=48*)	5.87 % (64)	98,706.13
HC two(*n=11*)	3.28 % (36)	393
HC three(*n=20*)	5.33 % (58)	9,985.92
HC Four(*n=14*)	5.65 % (61)	633.5
HC Five(*n=17*)	18.61 % (202)	12,129.05
HC Six(*n=29*)	0.05 % (64)	82,512.74
HC Seven(*n=20*)	6.35 % (69)	53,886.29
HC Eight(*n=16*)	7.78 % (106)	1,712.35
HC Nine(*n=20*)	9.19 % (9.2)	61,681.12
HC Ten(*n=16*)	9.71 % (106)	1,219.2

n indicates the number of products taken for the calculation, HC: Health center

Criticality of Products

Among the different segmentation analysis products were characterized in the health center using the VEN analysis which corresponds to the criticality of the product. However, it was showed that none of the studied health centers use the VEN classification for decision making with regard to establishing expected service levels for each product throughout the three years.

Demand Vs. Unit Price

Figure 6 shows monthly total demand versus the unit price. There are few outliers, where there is high price with lowest demand product and low price with a highest demand. Most of the product relied on the bottom axis of the scatter plot. Characterizing products by their price and demand is the initial step in identifying the relationship between product turnover and price. However, the demand for pharmaceuticals is unique because the user frequently does not choose which product to use and usually does not pay for it (Merino-Castello, 2011). Similarly, in this study, elasticity of demand couldn't be studied since the products are dispensed for free. Further product characterization will help to determine the flow of this product in the health center store.

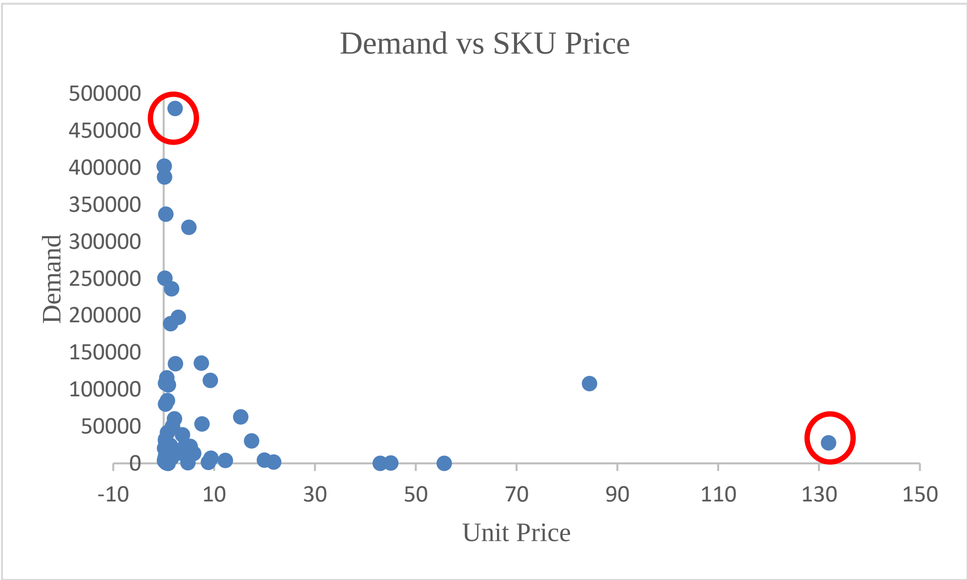


Figure 6: Scatter Plot of Demand Vs SKU Price in selected health centers, September 2020

Demand Frequency and Variability

Regarding the product demand distribution for all health centers, three years of demand data was obtained. On average, 50% of the time, there was no demand for products. This shows high intermittent demand characteristics of the product; while this can be justified if any stock out existed within the three years, the maximum stock rate was recorded as 18.61%. One example of SKU is Sulphamethoxazole + Trimethoprim - Tab - (800mg + 160mg). It takes 55.66% of the annual demand with an annual cost percentage of 13.8% and a consumption rate of 45.662. Another example is Etonogestrel Subdermal Implant Cap - 68mg demand, which was zero for half of those three years with an annual demand percentage of 0.45% with a consumption rate of 0.373 and it takes 36.09% of the annual cost. Since the demand has high variability, it creates an order less than the needed amount. With the proposed method, the replenishment order quantity considers the last 36 months' demand and calculates the variation; it optimizes the order up to level with the target service level. The existing replenishment strategy has the disadvantage of not only underestimating demand during periods of high demand that occur repeatedly but also overestimating demand during periods of low demand, which could result in inventory carryover. DeScioli (2005) noted that hospitals should pay attention to spare parts demand where inventory policies are intermittent. A similar pattern can be simulated for medical/surgical items using Croston (1972) intermittent demand method.

Figure 7 shows the monthly demand and its frequency. It could be seen that the product has a higher demand frequency relative to other slow-moving items; these items are moving faster, with a consumption rate of 45.662.

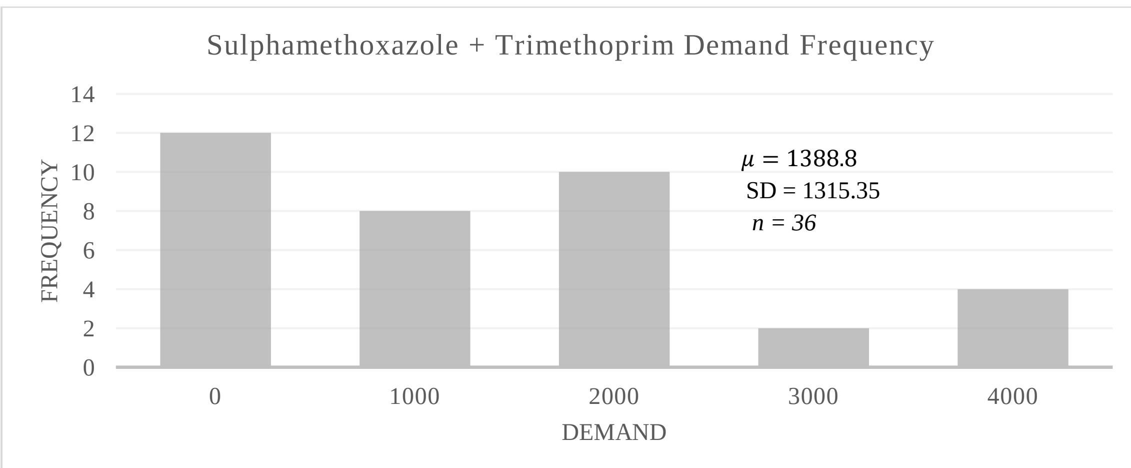


Figure 7: Sulphamethoxazole + Trimethoprim Demand Frequency

Below figure 8 shows an item with high demand-variability and low demand frequency.

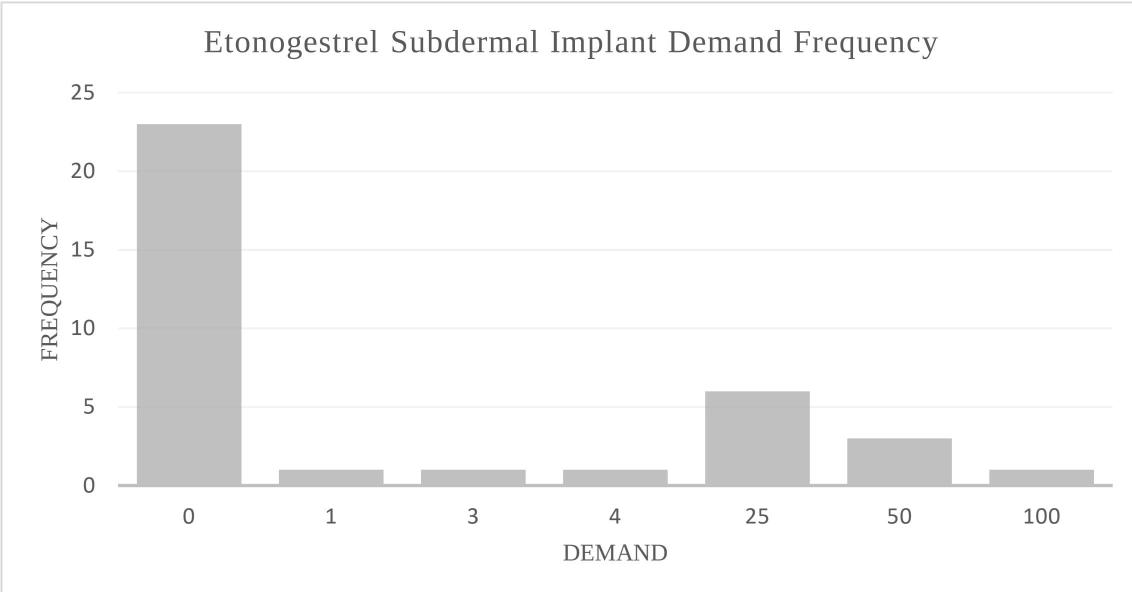


Figure 8 : Etonogestrel Subdermal Implant Demand Frequency

From the total health centers, 221 pharmaceuticals (64 in type) were analyzed for cumulative cost, quantity percentage and consumption rate. The consumption rate of the pharmaceuticals was calculated by dividing the total issue quantity with the total period of the study, for example 3TC+ EFV+TDF-Tab/300mg +600mg+300mg/ had three-year consumption of 112,280 units this results a consumption rate of ~103 units/day. It took 25.16% of the total demand of all the program medicines within the health centers with a total price of 817,211.27 and cost percentage of 35.74%. Pharmaceuticals that take the highest budget from the program medicines with their consumption rate are presented below.

Table 3: High-cost products with consumption rate at health centers, Addis Ababa, September 2020

	Product	Annual Demand (%)	Total cost	Annual Cost (%)	Cumulative Cost (%)	CR
HC 1	3TC+ EFV+TDF-Tab/300mg +600mg+300mg/	25.16	817,211.27	35.74	35.7	102.54
	Etonogestrel - Subdermal Implant Cap - 68mg	0.45	265,190.57	11.60	47.34	1.84
	Levonorget -Implant Capsule (Subdermal) - 75mg/cap	0.15	186,219.8	8.14	55.49	0.61
	Mifeprostone + Misoprostol - Tab/200mg + 200mcg/	0.38	142,720.5	6.24	61.73	1.54
	Medroxyprogesterone Acetate – Injection/150mg/ml	2.06	140,484.56	6.14	67.87	8.38
	Vitamin A (Retinol) – Cap/100,0000IU	9.95	129,292.39	5.66	73.53	40.55
HC 2	Etonogestrel -Subdrmal Implant/68mg/	0.45	53,802.96	36.09	36.09	0.37
	Vitamin A (Retinol) – Capsule/100,000 IU/	16.14	42,221.1	28.32	64.42	13.24
	Co-trimoxazole-Tab/800mg + 160mg/	55.66	20,572.5	13.80	78.22	45.66
HC3	3TC+ EFV+TDF-Tab /300mg +600mg+300mg/	36.73	30,27,932.23	46.50	46.50	379.93
	3TC+ NVP+ AZT-Tab/150mg +200mg+ 300mg/	36.32	2,723,884.11	41.83	88.33	375.69
HC 4	INH – Tab/300mg/	11.89	538,298.47	24.74	24.74	98.81
	EFV - Tab/600mg/	16.71	378,027.09	17.37	42.11	138.85
	3TC+ AZT- Tab/150mg+300mg/	15.47	354,148.75	16.28	58.39	128.52
	3TC+ TDF- Tab/300mg + 300mg/	14.02	290,703.09	13.36	71.75	116.45
	Etonogestrel - Subdermal Implant/68mg/	0.12	144,661.39	6.65	78.40	1.00
HC 5	Etonogestrel - Subdermal Implant/68mg/	2.30	2,429,441.01	47.66	47.66	16.82
	3TC+ NVP+ AZT- Tab/150mg+200mg+ 300mg/	30.29	1,604,613.92	31.48	79.15	221.31
HC 6	3TC+ EFV+TDF- Tab/300mg +600mg+300mg/	22.71	4,117,425.95	49.29	49.29	516.60
	3TC+ AZT- Tab/150mg+300mg/	29.64	1,857,506.94	22.24	71.53	674.13
	Efavirenz – Tab/600mg/	13.69	847,491.58	10.15	81.68	311.20
HC 7	3TC+ EFV+TDF- Tab/300mg +600mg+300mg/	51.79	5,260,051.5	76.42	76.42	660.00
	3TC+ AZT- Tab/150mg+300mg/	18.21	639,249.32	9.29	85.71	232.00
HC 8	3TC+EFV+TDF - Tab/300mg +600mg+300mg/	55.34	531,690	72.97	72.97	485.56
	Medroxyprogesterone Acetate – Inj/150mg/ml	3.92	37,623	10.86	83.83	34.35
HC 9	INH – Tab/300mg/	5.56	133,793.48	18.97	18.97	24.55
	Etonogestrel - Subdermal Implant /68mg/	0.16	100,484.94	14.25	33.22	0.69
	Co-trimoxazole/Tablet/800mg + 160mg/	39.07	77,764.05	11.03	44.25	172.61
	RUTF /Paste/92gm in sachet	1.89	68,498.73	9.71	53.96	8.35
	Levonorget-Implant capsule(Subdermal) - 75mg	0.05	66,705.6	9.46	63.42	0.21
	Etonogestrel Subdermal Implant Capsule - 68mg	0.09	59,209.63	8.40	71.82	0.41
	3TC+ TDF- Tab/300mg + 300mg/	3.69	40,671.53	5.77	77.59	16.29
HC 10	NVP- Tab/200mg/	34.42	550,698.84	34.14	34.14	292.57
	EFV – Tab/600mg/	12.84	297,017.38	18.41	52.55	109.09
	INH – Tab/300mg/	6.10	282,483.31	17.51	70.07	51.85

4.3. Inventory Costs

Holding Cost

Holding cost was calculated based on the assumptions and the calculations stated in the method section. From all health centers, the one which have the highest volume had the highest total holding cost with ETB of 409,544 per annum. The program items holding cost is proportionated and become ETB 1675.41 per annum and the lowest holding cost is observed with health center store with total holding cost 301, 844 ETB and program item holding cost of ETB 1234.82 (Table 4).

Table 4: Holding cost estimation in selected health centers, Addis Ababa September 2020

	m^3	*Rental Price*	*Utility*	*HRC*	*THC*	*Program items HC*
HC 1	132	69,300	31,525	269,520	370,345	1515.050
HC 2	115.2	60,480	26,120	221,880	308,480	1261.96
HC 3	153.6	80,640	57,609	241,512	379,761	1553.57
HC 4	192	100,800	34,180	244,584	379,564	1552.76
HC 5	249.6	131,040	33,920	244,584	409,544	1675.41
HC 6	192	100,800	35,400	261,096	397,296	1625.30
HC 7	100.8	52,920	33,248	221,880	308,048	1260.20
HC 8	179.2	94,080	42,270	261,096	397,446	1625.92
HC 9	156.8	82,320	35,564	269,520	387,404	1584.83
HC 10	102.4	53,760	35,408	212,676	301,844	1234.82

**Maximum 5 Dixon (0.54 m3) shelf is assumed to carry program items*
HC: Health center, m3: Shows the volume of the store, HRC: Human resource cost, THC: Total health center cost

Once the program item's annual holding cost was calculated, each item's unit holding cost was proportionated per its stake from the total quantity. The highest proportion of program medicine holding costs is estimated to be taken by ART medications (78.67%), followed by MCH (10.08%)

medications and family planning medicines (6.25%). The following figure shows the proportion of holding costs under each category.

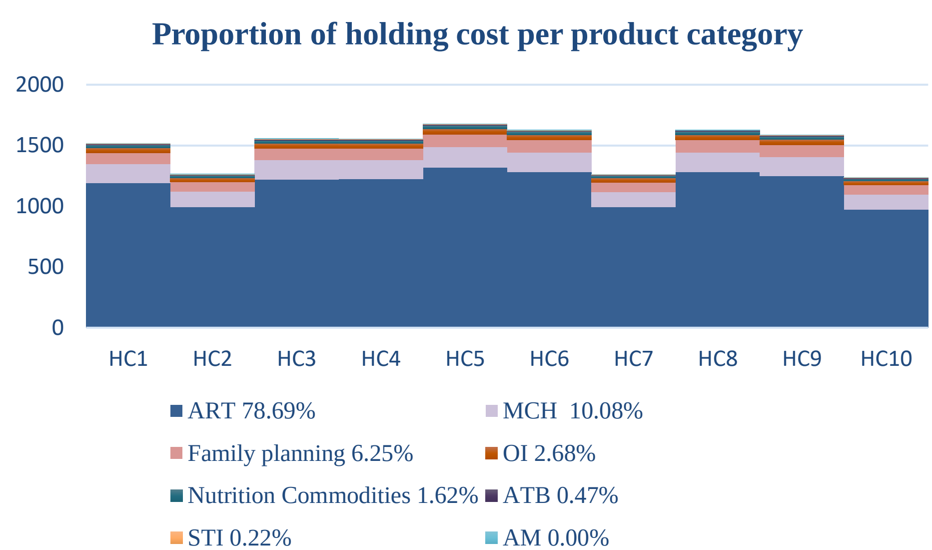


Figure 9: Proportion of holding cost per product category

Ordering Cost

For each order, the health center incurs an ordering cost per the time it took to undertake the ordering. Store managers/pharmacists were asked to estimate the time it took them to undertake ordering. Each health center answered the question (annex II, section c) as follows,

Description	HC1	HC2	HC3	HC4	HC5	HC6	HC7	HC8	HC9	HC10
Hours	4	6	8	6	8	4	8	4	8	6
Salary per hour	47.2	36.8	52.9	41.8	41.8	45.3	34.8	36.8	45.3	47.2
Total	188.7	220.9	422.9	250.5	334.0	181.2	278.6	147.3	362.6	283.0

Table 5: Estimation of ordering cost in selected health centers, Addis Ababa, September 2020

Shortage Cost

For each stock out event within each period, the simulation model estimates the unit shortage cost to be equal to the ordering costs since any shortage within the period could cause an emergency order.

In this study, cost estimations are used as input for the model. Nevertheless, the findings can be used to identify cost drivers in a replenishment policy. In line with a previous study in Bennin and Kenya, transport, labor, and utilities are cost drivers (Johnson *et al.*, 2014).

4.4. Optimal Reorder Period and Order Quantities

Model Validation

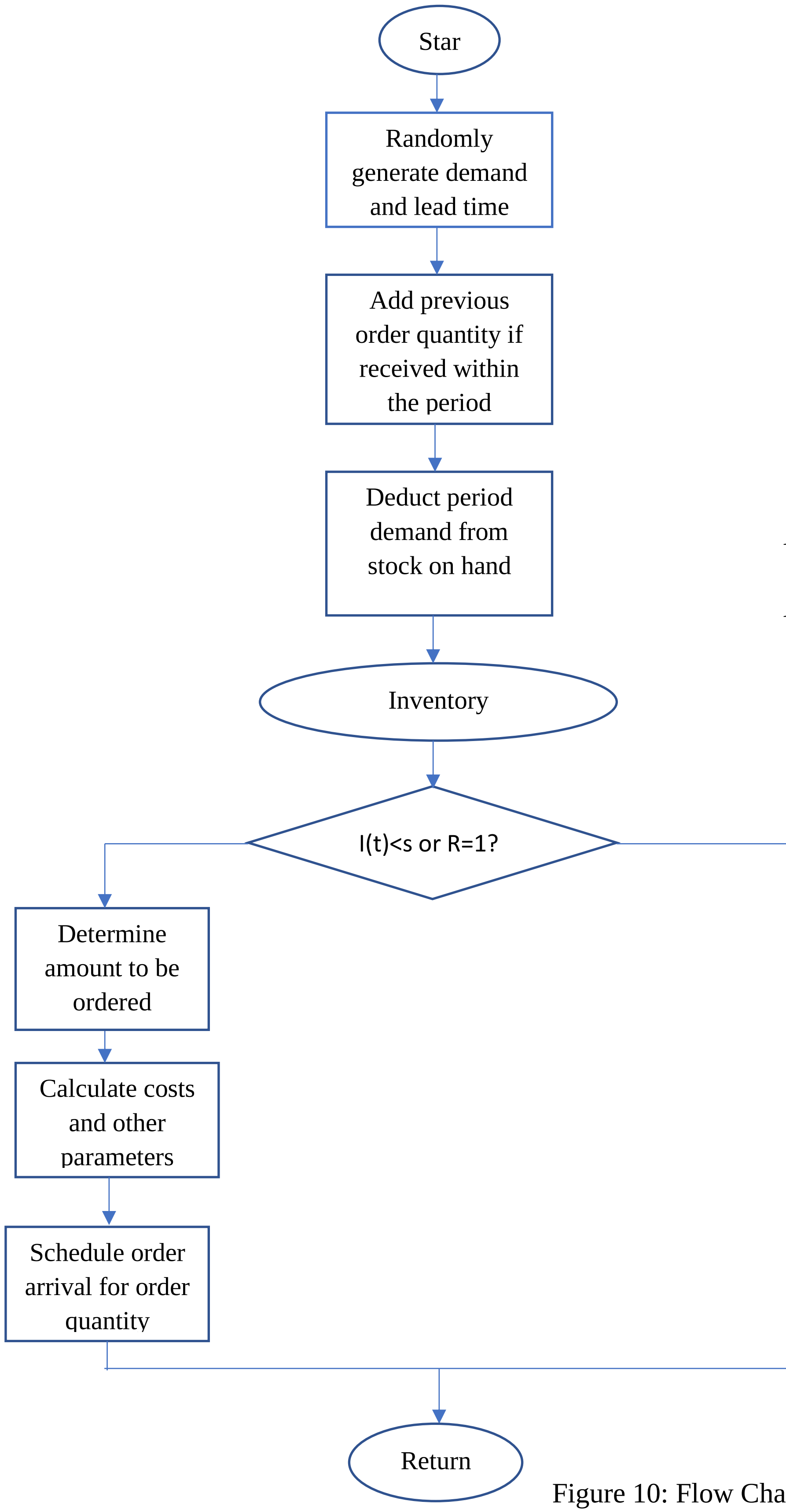
It is important to test the simulated demand whether it resembles the historical data or not. To accomplish the validation, the simulated demand was compared with the historic data. The total health centers demand compared to the simulated demand is summarized in the table below. The difference between the actual demand and simulated demand ranged from 0.23% to 14.26% which shows the model fits with the half of the health centers demand data with less than 5% deviation.

Health Centers	Actual Demand	Simulated Demand	Percent Difference
HC 1	44,6289	445,276	0.23%
HC 2	91,032	87,232	4.17%
HC 3	1,132,200	1,124,662	0.67%
HC 4	905,241	1,008,039	10.20%
HC 5	800,031	822,788	-2.84%
HC 6	2,490,537	2,254,590	9.47%
HC 7	1,395,438	1,301,425	6.74%
HC 8	960,743	947,905	1.34%
HC 9	483,696	552,677	-14.26%
HC 10	930,606	842,860	9.43%

Table 6: Comparison between actual and simulated demand in selected health centers, Addis Ababa, September 2020

Simulation-Optimization Model

The simulation-optimization model inputs randomly generated monthly demand data, lead time, and costs. Then the model calculates the stock on hand before deducting the monthly demand. After that, based on the input parameter, the model will decide to evaluate the inventory and order. Finally, run the solver and find the optimal order up to level *(S)*. The review period R was set at every month and every other month. The target CSL considered in the model is 90%, 95%, and 99%. (See Annex IV for the spread sheet model)



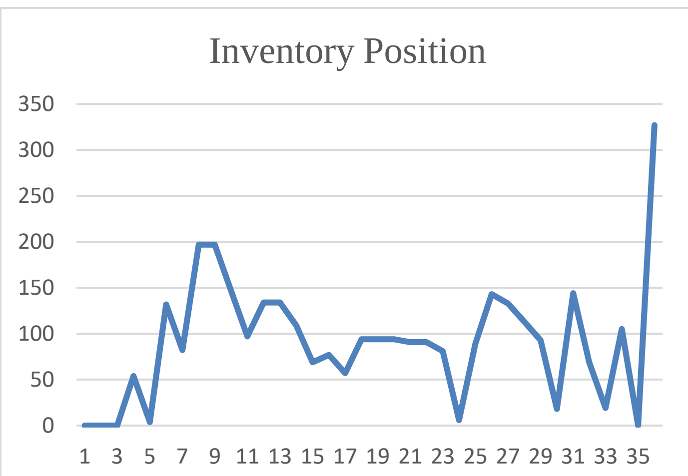
I(t): inventory position at a time t

R=1: order in that period

Figure 10: Flow Chart of Simulation-Optimization Model

Each inventory position figures below shows the pattern of the inventory position and the response of the model for the specified SKU (Etonogestrel with insertion accessory-subdermal implant capsule- 68mg). Different scenarios are presented and all of them are fed with similar demand across the period. When compared between each other the lowest cost is observed in R2 with TCSL of 90% and total cost of 5.12 ETB. But since the TCSL is 90%, the stock out event is five times within the three-year period with a total of 111 SKU stock out. When the TCSL is set to 99% the total cost is increased to 6.95 ETB with stock out unit of 43 SKUs and 2 stock-out event. When the maximum inventory position is compared between the models, the highest maximum inventory position is observed in IPLS with 327SKUs and RCSL of 89.846%, but comparable service level is achieved with R2, TCSL 90% with maximum inventory position of 86 SKUs and 90% RCSL. Further product characteristics is annexed (Annex-III).

Etonogestrel with Insertion accessory - Subdermal Implant Capsule - 68mg



RSL: 89.846%

TC: 8.17 ETB

Average Inventory: 92

Stock out unit: 112

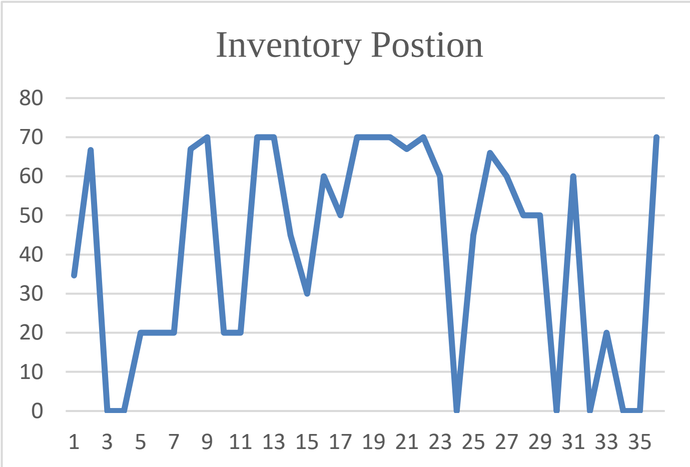
Stock out event: 4

Min inv. Position: 0

Max inv. Position: 327

No. of Orders: 21

Figure 11: IPLS



RSL: 90%

TC: 7.67 ETB

Average Inventory: 41

Stock out unit: 111

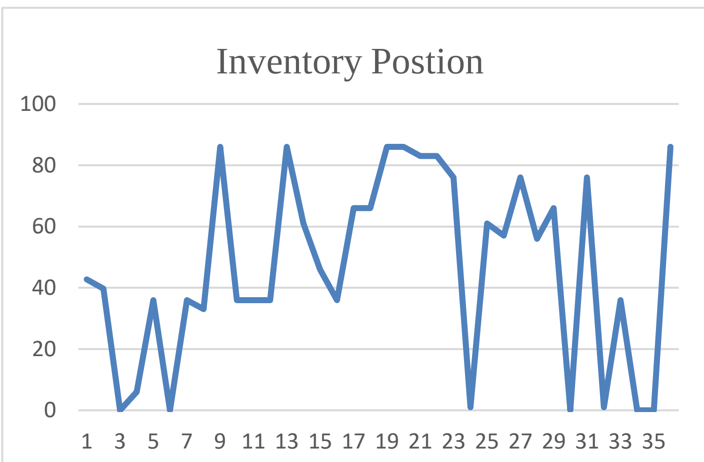
Stock out event: 7

Min inv. Position: 0

Max inv. Position: 70

No. of Orders: 36

Figure 12: Reorder period 1, target CSL 90%, proposed model



RSL: 90%

TC: 5.21 ETB

Average Inventory: 47

Stock out unit: 111

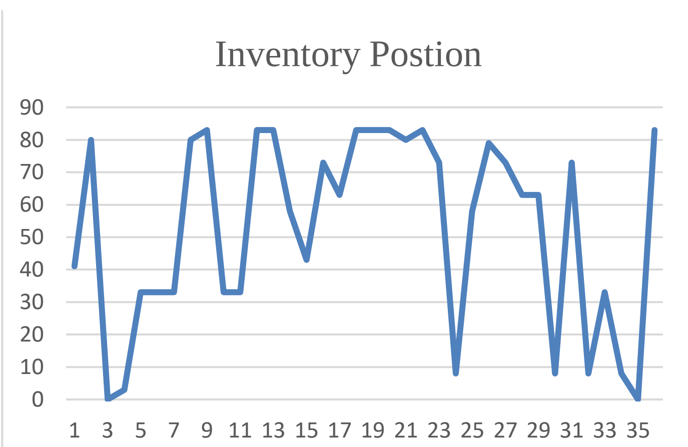
Stock out event: 5

Min inv. Position: 0

Max inv. Position: 86

No. of Orders: 20

Figure 13: Reorder period 2, targe CSL 90%, Proposed model



RSL: 95%

TC: 8.50 ETB

Average Inventory: 53

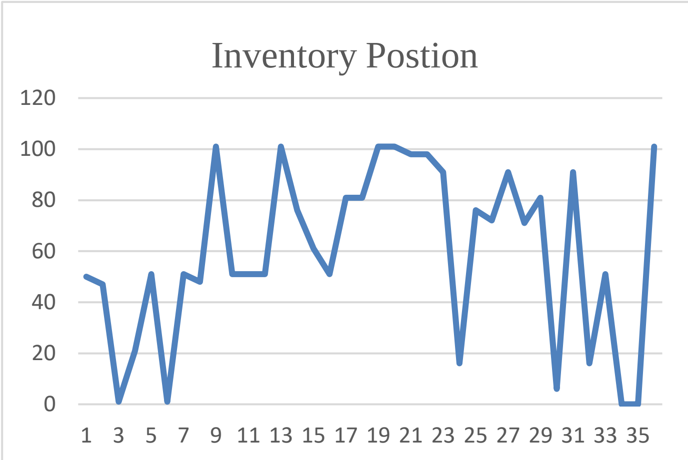
Stock out unit: 54

Stock out event: 2

Min inv. Position: 0

Max inv. Position: 83

Figure 14: Reorder period 1, target CSL 95%, proposed model



RSL: 96%

TC: 5.71 ETB

Average Inventory: 59

Stock out unit: 43

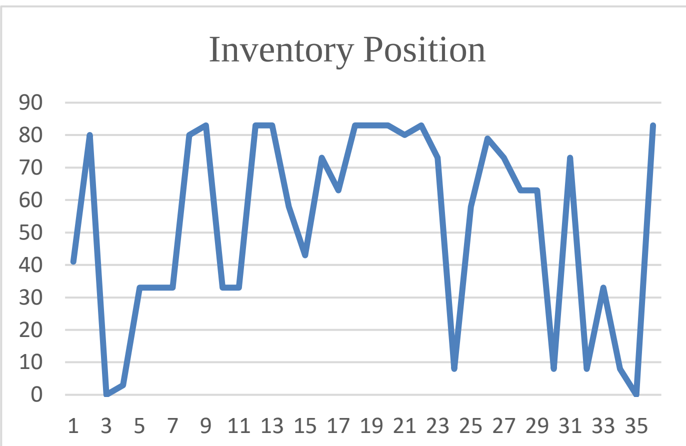
Stock out event: 2

Min inv. Position: 0

Max inv. Position: 101

No. of Orders: 20

Figure 15: Reorder period 2, targe CSL 95%, Proposed model



RSL: 99%

TC: 11.78 ETB

Average Inventory: 77

Stock out unit: 54

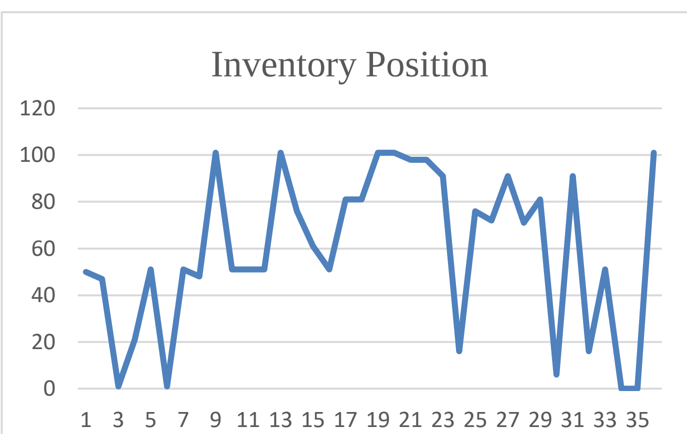
Stock out event: 2

Min inv. Position: 0

Max inv. Position: 110

No. of orders: 36

Figure 16: Reorder period 1, target CSL 99%, proposed model



RSL: 99%

TC: 6.95 ETB

Average Inventory: 74

Stock out unit: 43

Stock out event: 2

Min inv. Position: 0

Max inv. Position: 117

No. of orders: 20

Figure 17: Reorder period 2, targe CSL 99%, Proposed model

After each SKU simulation model was done, optimization was run according to three target CSL 90%, 95% and 99%. Each target CSL was run under two scenarios; the replenishment period of every month (R1) or every other month(R2). Each Scenario resulted in a different total cost and realized customer service level (RSL).

Table 7: Total cost comparison among different replenishment policies in selected health centers, Addis Ababa, September 2020

	IPLS		90%				95%				99%			
			R1		R2		R1		R2				R2	
Health Centers	TC	RSL (%)	TC	RSL (%)	TC	RSL (%)	TC	RSL (%)	TC	RSL (%)	TC	RSL (%)	TC	RSL (%)
HC 1	8432	84	10354	92.6	6683	93.0	11843	96.6	7186	97.2	13516	99.5	8061	99.7
HC 2	1401	77.8	1850	92.8	1200	92.7	1986	96.9	1321	96.8	2104	99.7	1521	99.6
HC 3	6181	87.0	6288	91.8	4112	92.7	6857	96.0	4417	96.3	9703	99.6	5374	99.6
HC 4	9287	78.2	5559	90.4	5559	91.3	14945	95.4	9521	96.6	5559	99.4	5559	98.0
HC 5	7883	92.1	4737	91.6	3703	93.7	5534	96.4	4385	97.7	6847	99.7	5816	99.7
HC 6	22550	93.5	15969	91.9	11841	91.9	17766	95.5	14492	96.3	23353	99.3	18760	99.5
HC 7	9014	85.6	7925	91.4	5542	92.1	9414	95.5	6236	96.9	14400	99.2	8815	99.4
HC 8	30302	70.5	26880	91.0	15878	92.5	30425	95.9	18177	97.2	42506	99.4	23193	99.0
HC 9	6055	85.0	6412	91.9	4366	93.1	7369	95.4	4695	97.0	8636	99.5	5439	99.8
HC 10	11385	80.0	12083	92.7	7488	93.9	13380	96.9	8285	97.4	15083	98.9	9340	99.8
	112490.6	83.4	98055.9	91.8	66371.5	92.7	119518.5	96.1	78713.9	96.9	141706.4	99.4	91877.1	99.4

When the total cost and the RCSL of the all-health center is calculated, the lowest total cost (66,371.5 ETB) was observed in the replenishment policy of every other month with TCSL of 90% and realized CSL of 92.7%. The highest total cost was observed in the replenishment policy of every month with TCSL of 99% with total cost of 141,706.4 ETB with realized customer service level of 99.4%.

Table 8: Change and incremental total costs and CSL for IPLS and R2 of high-cost products in health centers, Addis Ababa, September 2020

Health Center	Product	IPLS		Every other month (R2)		Change		Incremental cost/CSL	%Maximum order R2/IPLS
		TC	RCSL	TC	RCSL	ΔCost*	ΔCSL		
HC 1	3TC+ EFV+TDFTab/300mg +600mg+300mg/	1032.43	98.0%	666.16	100.0%	-366.27	2.00	-183.13	40.7%
	Etonogestrel Subdermal Implant Cap - 68mg	13.9	99.6%	9.3	100.0%	-4.61	0.40	-11.52	51.6%
	Levonorget + Implant Capsule (Subdermal) 75mg/cap	13.3	92.3%	12.4	100.0%	-0.86	7.70	-0.11	65.2%
	Mifeprostone + Misoprostol Tab/200mg + 200mcg/	37.1	91.8%	38.2	100.0%	1.15	8.20	0.14*	74.9%
	Medroxyprogesterone Acetate Injection/150mg/ml	68.6	94.2%	65.3	99.1%	-3.28	4.90	-0.669	65.7%
	Vitamin A (Retinol) Cap/100,0000IU	415.4	95.6%	299.6	99.0%	-115.80	3.40	-34.05	40.4%
HC 2	Etonogestrel Subdermal Implant/68mg/	5.6	46.7%	16.0	100.0%	10.48	53.3	0.1966*	74.6%
	Vitamin A (Retinol) Capsule/100,000 IU/	211.6	55.0%	261.6	100.0%	49.97	45.00	1.11*	75.0%
	Co-trimoxazole Tab/800mg + 160mg/	515.6	100.0%	449.5	99.0%	-66.11	-0.01	6,611.0*	80.0%
HC3	3TC+ EFV+TDF-Tab /300mg +600mg+300mg/	2023.0	97.9%	1666.4	99.0%	-356.53	1.1	-324.11	55.5%
	3TC+ NVP+ AZT Tab/150mg + 200mg + 300mg/	352.9	98.8%	400.4	99.1%	47.52	0.3	158.4*	56.6%
HC 4	INH Tab/300mg/	721.9	78.1%	1794.9	100.0%	1073.05	21.9	48.99*	69.7%
	EFV Tab/600mg/	1462.2	100.0%	1277.3	99.0%	-184.93	-0.01	18,493*	45.3%
	3TC+ AZT Tab/150mg+300mg/	933.9	86.9%	1063.1	99.0%	129.20	12.10	116.9*	47.4%
	3TC+ TDF Tab/300mg + 300mg/	865.7	74.6%	814.6	100.0%	-51.06	25.4	-2.01	54.5%
	Etonogestrel Subdermal Implant/68mg/	8.2	89.8%	6.9	99.0%	-1.23	9.2	-0.1336	35.8%

HC 5	Etonogestrel Subdermal Implant/68mg/	1950.9	93.6%	236.9	100.0%	-1714.04	6.4	-267.81	7.0%
	3TC+ NVP+ AZT Tab/150mg + 200mg + 300mg/	2010.1	98.9%	2578.9	99.0%	568.71	0.1	5687.1*	90.0%
HC 6	3TC+ EFV+TDF Tab/300mg +600mg+300mg/	6246.4	79.2%	5454.8	100.0%	-791.62	20.8	-3,800.34	37.5%
	3TC+ AZT Tab/150mg+300mg/	4737.4	100.0%	4435.6	99.0%	-301.82	-0.01	30,182.00	67.7%
	Efavirenz Tab/600mg/	2477.7	99.7%	1796.8	100.0%	-680.90	0.3	-2,269.66	54.7%
HC 7	3TC+ EFV+TDF Tab/300mg +600mg+300mg/	3694.2	100.0%	4536.1	99.4%	841.92	-0.01	-84,192	50.1%
	3TC+ AZT Tab/150mg+300mg/	1572.3	99.8%	1007.7	100.0%	-564.56	0.2	-2,822.8	44.6%
HC 8	3TC+EFV+TDF Tab/300mg +600mg+300mg/	11695.1	100.0%	10262.1	100.0%	-1433.03	0.00	--	50.0%
	Medroxyprogesterone Acetate Injection/150mg/ml	685.1	21.0%	724.2	100.0%	39.05	79.00	0.49*	73.4%
HC 9	INH Tab/300mg/	673.2	100.0%	509.3	100.0%	-163.85	0.00	--	50.0%
	Etonogestrel Subdermal Implant /68mg/	7.1	82.4%	6.4	100.0%	-0.66	17.6	-0.039	54.5%
	Co-trimoxazole/Tablet/800mg + 160mg/	2663.9	90.1%	2002.5	100.0%	-661.42	9.9	-66.81	62.8%
	Ready to use Therapeutic food/Paste/92gm in sachet	51.5	97.3%	47.5	99.0%	-3.98	1.7	-2.34	57.1%
	Levonorget Implant capsule (Subdermal) 75mg	2.2	83.7%	2.4	100.0%	0.18	16.3	0.011*	74.1%
	Etonogestrel Subdermal Implant Capsule 68mg	7.1	82.4%	6.4	100.0%	-0.66	17.6	-0.039	54.5%
	3TC+ TDF Tab/300mg + 300mg/	191.2	95.1%	205.3	100.0%	14.08	4.90	2.873*	53.4%
HC 10	NVP Tab/200mg/	5397.5	100.0%	3258.5	100.0%	-2139.02	0.00	--	44.7%
	EFV Tab/600mg/	952.9	90.7%	1425.4	99.0%	472.47	8.30	5,689.88*	67.8%
	INH Tab/300mg/	271.7	100.0%	242.0	99.0%	-29.69	-0.01	2,968.96*	48.1%

The above table presented the high-cost products to compare the total cost of IPLS with R2 and TCSL of 99%. In most health centers, the proposed model shows a reduction in cost and an increase in CSL, but for some products, the IPLS have shown less total cost. For example, in health center one, Mifepristone + Misoprostol Tab/200mg + 200mcg/has RCSL of 91.8% and 37.1ETB of total cost in IPLS when compared with R2, which shows a total cost of 38.2ETB and RCSL of 100%. In another case, a comparable RCSL is observed in health center three with product 3TC+ NVP+ AZT Tab/150mg + 200mg + 300mg/ where the IPLS RCSL is 98.8% and R2 RCSL of 99.1%, but when the total cost is compared the R2 shows a reduction in total cost by 47.52ETB. Unlike this, in health center five, 3TC+ NVP+ AZT Tab/150mg + 200mg + 300mg/ insignificant difference in the service level with 568.71ETB less cost in the IPLS.

Even if the service level is relatively better for some products in the IPLS, the order volume tends to be high, and the inventory cost is parallelly increased. This result is supported by a study by Zwaida, Pham and Beauregard (2021), who tried to optimize the inventory to prevent drug shortages. The result of the study showed that as the order up to level increased, the service level increased but with extra cost incurred for each service level gained. Overall, the proposed model shows a less incremental cost per increase by 1% of service level. The proposed model has shown

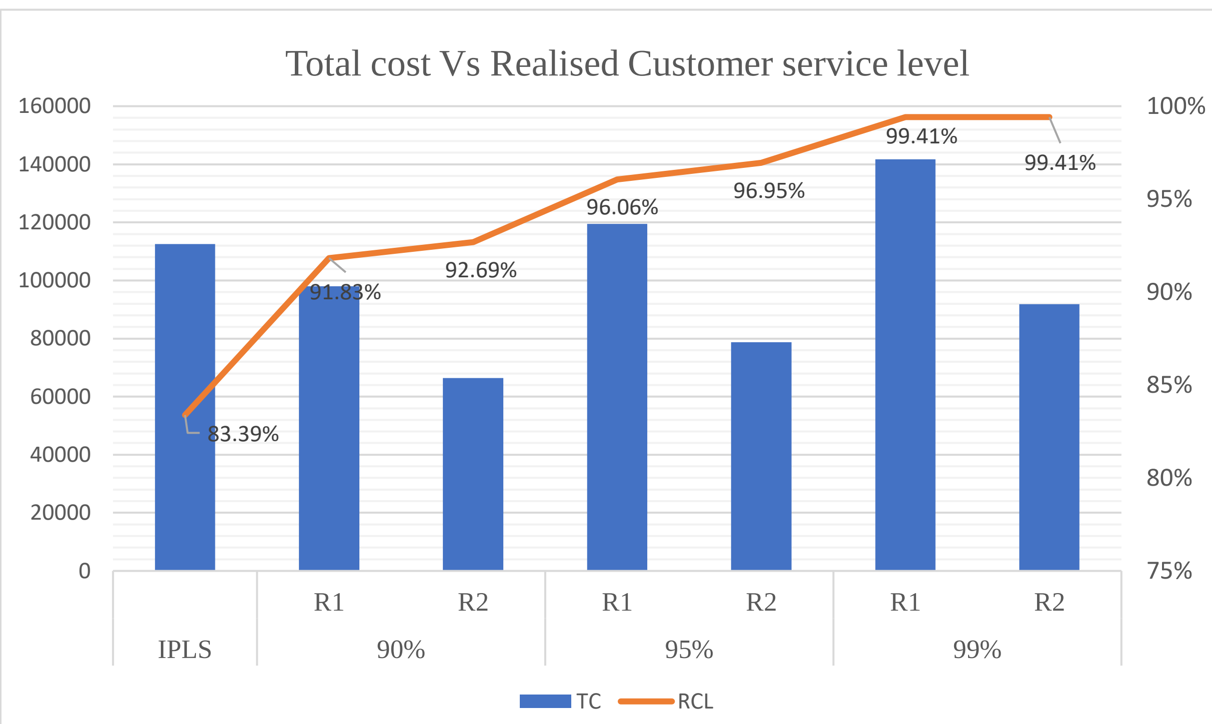


Figure 18: Total cost Vs. Realized customer service level

that the maximum order level can be reduced to 7-90% from the current replenishment model with better service level attainment. This is similar to another study where pharmacy stores carry a large amount of inventory to avoid stock out (Leaven, Ahmmad and Peebles, 2017). Accumulating a large amount of stock in store in turn has high inventory holding costs for facilities.

The correlation between total cost and standard deviation of demand showed a strong positive relationship with *R 0.838*. It was revealed that, as the demand variability increases, the total cost the health centers incur would increase (table 9 below shows the Pearson correlation).

Table 9: Pearson correlation between SD of demand and total cost of IPLS inventory control system, Addis Ababa, September 2020

		SD Demand
TCL	Pearson Correlation	.838**
	Sig. (2-tailed)	.000

*** Correlation is significant at the 0.01 level (2-tailed), n=211*

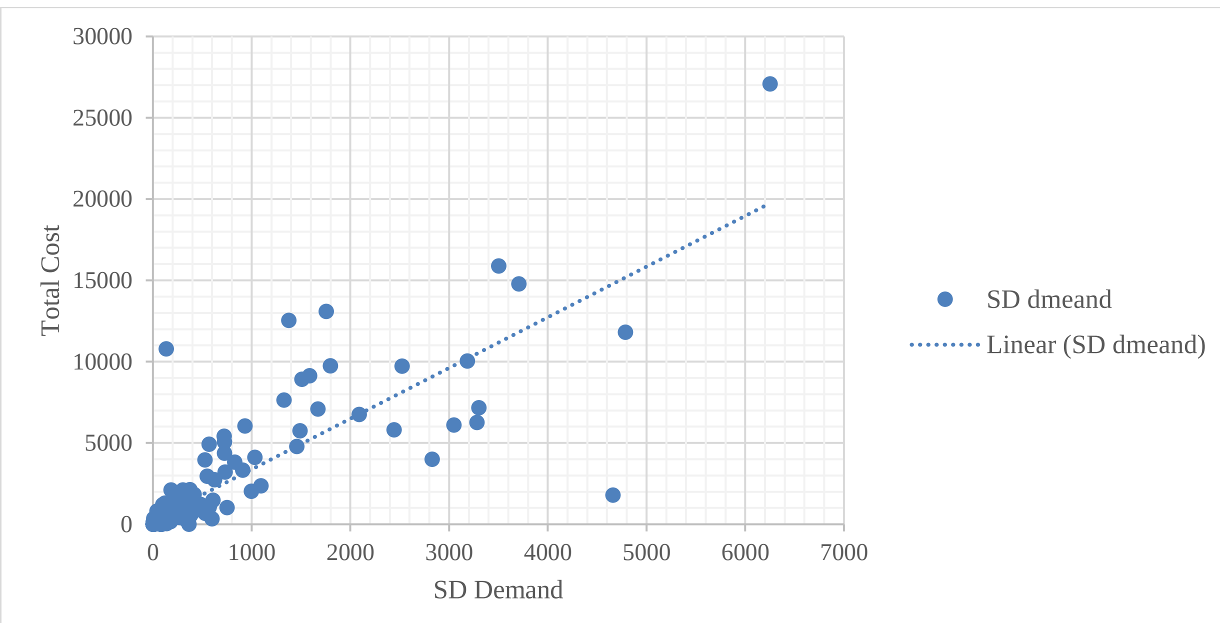


Figure 19: Scatter plot of SD of Demand and total cost in IPLS system

The above scatter plot showed the product's total cost relationship with the SD of demand when the IPLS system is simulated. A positive relationship between the two variables is observed, with most points in the vicinity of other points aligning with linear line. The trend in the data shows higher total cost is associated with higher SD of demand. In addition, when the correlation of IPLS inventory total cost is tested against the standard deviation of demand, it shows a significant positive relationship. This can be due to the nature of the IPLS order up-to-level determination, where order quantity is calculated using four months of AMC. This could under or overestimate the demand, especially as the products have highly intermittent patterns. It is important to consider demand variation and frequency as noted by Zhang et al, 2014, where, the demand for the vast majority of drugs is highly variable, intermittent, and irregular (Zhang *et al.*, 2014).

Another study by Babai, Ali and Nikolopoulos (2012) using a sample of 5000SKUs over seven years of demand history showed an aggregate-disaggregate intermittent demand approach that showed an improved forecasting method. Similarly, this study showed that a better data set for determining upcoming demand helped decrease average inventory, thus reducing the total cost. Not only was the total cost shown to be minimized, but the CSL was achieved with minimal cost. Every month's replenishment was not as optimal as every other month's; this could be because the unit inventory carrying cost is less than the ordering cost. When observing the probability of overstock, both models showed a lesser average inventory than the current replenishment model.

The results of this study provide an important implication in inventory management. Silver, Pyke and Thomas, 2016 explain that a periodic review, the order-up-to-level policy, is commonly used when multiple items are ordered from the same supplier or when resource sharing is required. This system creates an order for every R time unit to lift the inventory position to S. The proposed simulation model offers a relatively good service level and better cost savings. Specifically, it reduces the volume of order up to level significantly compared to the current replenishment policy. The IPLS inventory control policy also ignores the demand variability and changes in delivery lead times.

While both IPLS and the proposed replenishment policy in the simulation-optimization model assumes 100% fill rate from the supplier, in practice major reason for unavailability of pharmaceuticals in the downstream is the inability of supplier to fill the requested order (Mohammed *et al.*, 2020). It is essential to consider the echelons' interrelationship when setting up the inventory policies to ensure that they work well together and reduce the possibility of excess safety stock and service failure (Guerrero, Yeung and Guéret, 2013).

Poor information management, inadequate storage facilities, and lack of standard procedures are the main challenges of pharmaceutical supply chains in sub-Saharan Africa (Schöpperle, 2017). Yet, the implementation of IPLS to the full extent is another issue that could have a significant implication since the store collects demand data from its dispensing unit. If the staff and the process don't adhere to the prescribed inventory control policies, the zero demands that are found in the result could be observed due to under-report. A study assessing the availability of bin cards and their accuracy in Addis Ababa facilities stated that bin cards, IFRRs, and RRFs were available among 96.2% of the health facilities. Among these facilities, 61.5% of health facilities update bin cards regularly, and 84.6% complete and send internal facility report and resupply forms to their respective facility stores (Tilahun *et al.*, 2016). The poor performance of LMIS within the health centers could indirectly affect the interpretation of the result.

A study done by Alemu et. al., 2020 showed the relationship between IPLS and essential medicines availability to be weak ($r = 0.32, p = 0.01$). Despite this, considering health centers limited technical capabilities and resource-constrained environments, the implementation of IPLS has been beneficial in the past (Alemu *et al.*, 2020; Tefera, Yihunie and Bekele, 2021). It is important to investigate further IPLS fitness for different pharmaceutical products and facilities supplied under the system.

CHAPTER FIVE: SUMMARY, CONCLUSION, AND RECOMMENDATIONS

This section of the study summarizes major findings, draw a conclusion, and recommend to the relevant stakeholders. Additionally, the areas that can be further investigated by future researchers are mentioned below.

5.1. Summary of Findings

The study aimed to find the optimal replenishment policy in a health center. The objective is to find the optimal replenishment policy while still allowing the health center to achieve a high target customer service level. The study is based on the case of ten health centers. To achieve its first objective, which is to describe the current replenishment policy, it tried to characterize the products replenished under the current policy. Then to achieve the second specific objective, the study estimates costs relevant to optimizing the replenishment policy. Finally, the study approaches the problem with two scenarios to find the optimal pharmaceutical replenishment policy. The first one is when the product is replenished every month under 90, 95, and 99 % target service level. The second scenario is to replenish under 90, 95, and 99 % target service level every other month.

When the replenishment polices are compared to each other the 90% target service level showed the lowest cost. In addition, the correlation shows the standard deviation of demand to be positively related to the total cost of the current replenishment policy. Deviations were seen in incremental cost value when products that take the high cost of the health centers were analyzed in detail with most products achieving cost saving with an incremental service level. While those products that have positive incremental costs compared to the current replenishment policy still show a reduction in inventory level with a comparable or better service level.

5.2. Conclusion

It can be inferred from the current study that inventory cost estimation could be adapted to the broader context of other health centers and can be used to determine cost center areas to improve financial performance. Moreover, the analysis showed that the segregation of products based on their characteristics has a potential advantage since the demand pattern significantly varies among products. The study further uncovered that the IPLS method of determining order up to level resulted in less CSL and increased the likelihood of overstock. Based on the simulation-optimization model, the less costly replenishment model is 90% TCSL and every other month replenishment. However, in order to achieve optimal replenishment, it is crucial to set a target service level based on product criticality and price and demand variability.

It is evident from the study that there is a strong positive correlation between total cost and standard deviation of demand; implying that the total cost rises as the demand variability increases. The study revealed that applying standard deviation of demand and Leadtime in determining order can not only reduce maximum inventory level but also the cost of carrying inventory.

5.3. Recommendations

Health Centers:

- Setting health centers target service level is an important task for store managers. The study shows that segmentation of products by their criticality could be beneficial because some products may be slow moving and might take high-cost percentage. Thus, the decision to set up a target service level should consider the criticality of the product.
- May consider longer historical data and integrate the characteristics of product demand to identify the order quantity rather than relaying only in the moving average they should also ponder the standard deviation of demand.
- It is also important to identify costs and integrate financial parameters on continues performance monitoring so as to understand the cost center areas and intervene accordingly. To do so, data sets such as lead-time, fill rate, operational hours, and resources, should be recorded in every task performed in the pharmacy store.

FMOH and EPSS

- The implementation of IPLS have been in place for more than decade, it’s important to question current strategies and operations. The findings from this study can be used to commence further investigation in the fitness of IPLS inventory control system by considering other alternatives that are technically and financially feasible.
- Health centers require a continuous support from the FMOH, EPSS and other stakeholders especially in capacity building to use such models and segmentation analysis.

To future researchers

- Multi-echelon optimization could give a more realistic and optimal solution than single-echelon optimization. Failure of the upstream echelon to serve the demand of the lower echelon may result in declining service levels at the lower stream of the supply chain. Therefore, other studies should consider a multi-echelon system.

5.4. Strengths and Limitations of the Study

The study integrated the characterization of products with inventory control. It used input data such as costs, demand, and lead time to attain the optimal inventory level. Compared to the currently employed IPLS system, the proposed model is advantageous because it integrates the financial parameters into the replenishment policy. Through the process, it shows how health center can focus their limited resource on critical and highly costly products and optimize their inventory position to attain the service level they set with minimal cost. The model resembles the actual demand pattern since it considered a stochastic demand and lead time. Despite all the strengths, there are limitations to the study. The model is developed using certain assumptions, including the estimation of costs, distribution of demand, and lead time, which are worth considering for further analysis. Another limitation of the present study is the disadvantage of secondary data, which is incompleteness.

References

A. Davis, R. (2015) ‘Demand-Driven Inventory Optimization and Replenishment’, *Book*, p. https://news.ge/anakliis-porti-aris-qveynis-momava.

AACAHB (2021) ‘AACAHB-HSTP II’.

Alemu, T. *et al.* (2020) ‘Integrated Pharmaceutical Logistics System Implementation in Selected Health Facilities of Ethiopia : the Case of Four Wollega Zones Pharmaceutical Care & Health Systems’, *Research in Social & Administrative Pharmacy* [Preprint]. Available at: https://doi.org/10.1016/j.sapharm.2020.07.026.

Ali, A.K. (2011) ‘Inventory Management in Pharmacy Practice : A Review of Literature Abstract’, *Archives of Pharmacy Practice*, 2(4), pp. 151–157.

Ali, E.E. (2014) ‘Health care financing in Ethiopia: Implications on access to essential medicines’, *Value in Health Regional Issues*, 4(1), pp. 37–40. Available at: https://doi.org/10.1016/j.vhri.2014.06.005.

Antic, S., Milutinovic, L.D. and Lisec, A. (2022) ‘Dynamic Discrete Inventory Control Model with Deterministic and Stochastic Demand in Pharmaceutical Distribution’, *Applied Sciences (Switzerland)*, 12(3). Available at: https://doi.org/10.3390/app12031536.

Axsäer, S. (2005) ‘A simple decision rule for decentralized two-echelon inventory control’, *International Journal of Production Economics*, 93–94(SPEC.ISS.), pp. 53–59. Available at: https://doi.org/10.1016/j.ijpe.2004.06.005.

Axsater, S. (2000) *Inventory Control*, *Customer Satisfaction Evaluation: Methods for Measuring and Implementing Service Quality*.

Axsäter, S. (2015) *International Series in Operations Research & Management Science Associate Series Editor*.

Azzi, A. *et al.* (2014) ‘Inventory holding costs measurement: A multi-case study’, *International Journal of Logistics Management*, 25(1), pp. 109–132. Available at: https://doi.org/10.1108/IJLM-01-2012-0004.

Babai, M.Z., Ali, M.M. and Nikolopoulos, K. (2012) ‘Impact of temporal aggregation on stock control performance of intermittent demand estimators: Empirical analysis’, *Omega*, 40(6), pp. 713–721. Available at: https://doi.org/10.1016/j.omega.2011.09.004.

Bartmann, D. and Beckmann, M.J. (1992) *Inventory Control: Models and Methods*. Springer Berlin Heidelberg.

Berling, P. and Martínez-De-Albéniz, V. (2011) ‘a Characterization of Optimal Base-Stock Levels for a Continous-Stage Serial Supply Chain’, *IESE Business School, University of Navara*, 3(5), pp. 180–28023.

Boche, B., Mulugeta, T. and Gudeta, T. (2020) ‘<p>Assessment of Inventory Management Practices at the Ethiopian Pharmaceuticals Supply Agency, Addis Ababa, Ethiopia</p>’, *Integrated Pharmacy*

Research and Practice, Volume 9(October), pp. 175–183. Available at: https://doi.org/10.2147/iprp.s269421.

Cedergren, J.F., Jonsson, O. and Karlsson, O. (2015) ‘Improving retail store replenishment A case study of Hemtex AB’.

Cheng, S. (2008) ‘An Engineering Approach to Improving Hospital Supply Chains An Engineering Approach to Improving Hospital Supply Chains’, *Massachusetts Institute of Technology June* [Preprint].

Choolwe, K. (2020) ‘Effects of Inventory Management Practices on Service Delivery At Adult Hospital-the Case Study of University Teaching Hospital (Uth)’.

Croston, J.D. (1972) ‘Forecasting and stock control for intermittent demands’, *Palgrave Macmillan Journals and Operational Research Society are collaborating with JSTOR to digitize, preserve and extend access to Operational Research Quarterly (1970-1977).*, 23(3), pp. 289–303.

CSCMP (2013) ‘Supply Chain Management terms and glossary’. Available at: https://cscmp.org/CSCMP/Academia/SCM_Definitions_and_Glossary_of_Terms/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx?hkey=60879588-f65f-4ab5-8c4b-6878815ef921.

Danas, K., Roudsari, A. and Ketikidis, P.H. (2006) ‘The applicability of a multi-attribute classification framework in the healthcare industry’, *Journal of Manufacturing Technology Management*, 17(6), pp. 772–785. Available at: https://doi.org/10.1108/17410380610678792.

DeScioli, D.T. (2005) ‘Differentiating the Hospital Supply Chain For Enhanced Performance’, *Industrial Engineering*, (2001), p. 63.

Dessalegn, A. and Roy, R.N. (2002) ‘Computer assisted inventory control system’, *Zede Journal*, 19(0), pp. 65–77.

Dires, T. (2017) ‘Creating better ownership and use of Information Systems: The case of health commodity management information system (HCMIS) in Ethiopia’, *10th Global Health Supply Chain Summit, Accra (Ghana)*, pp. 1–20.

efpia (2020) ‘European Federation of Pharmaceutical Industries and Associations: The Pharmaceutical Industry in Figures’.

EIC (2018) ‘Investing in Ethiopia : The future pharmaceutical hub of Africa Ethiopia : Country Profile Ethiopia has a clear vision for development , which builds off of its rapid’, pp. 1–15.

Ellison, P.B. and Cook, R.A. (2020) ‘Health economic analysis of pharmaceutical inventory levels’, 10(4), pp. 603–628. Available at: https://doi.org/10.1108/JHLSCM-01-2020-0001.

EPSA (2019) ‘Ethiopia, National Survey of the Integrated Pharmaceutical Logistics System’, (FEBRUARY), p. 84.

EPSA (2020) *About Us - Ethiopian Pharmaceuticals Supply Agency - EPSA*. Available at: https://epsa.gov.et/about-us-2/ (Accessed: 23 January 2020).

Fernie, J. and Sparks, L. (2019) *Logistics and Retail Management: Emerging issues and new challenges in the retail supply chain*. Koganpage.

Fitriana, R., Moengin, P. and Riana, M. (2016) 'Information system design of inventory control spare parts maintenance (valuation class 5000) (case study: Plant kw)', *IOP Conference Series: Materials Science and Engineering*, 114(1). Available at: https://doi.org/10.1088/1757-899X/114/1/012076.

FMOH (2021) 'Health Sector Transformation Plan II 2020/2021-2024/2025', *Ethiopian Ministry of Health*, 25(February), pp. 1–128.

Freeman, J. and Waters, C.D.J. (1993) *Inventory Control and Management, The Journal of the Operational Research Society*. Available at: https://doi.org/10.2307/2584204.

Gebregeorgise, D.T. (2018) *Detailed countries case study- Ethiopia's health supply chain system*. Available at: https://www.researchgate.net/publication/325216570_Detailed_countries_case_study-_Ethiopia%27s_health_supply_chain_system (Accessed: 3 January 2020).

Gebru, Z.L. and Demelash, M. (2018) 'Center of Biomedical Engineering School of Graduate Studies Certificate of Examination', (June).

Getachew, S. and Damtie, K. (2020) 'Determinants of Pharmaceuticals Inventory Control System performance in Public Health Facilities of North Wollo and Waghimera zones , Northern Ethiopia : Clinton Health Access Initiative , Child Survival Program , Bahir Dar , Ethiopia Wollo Universities ',.

Ghauri, P., Gronhaug, K. and Strange, R. (2020) *Research Methods in Business Studies*.

González Peña, O.I., López Zavala, M.Á. and Cabral Ruelas, H. (2021) 'Pharmaceuticals market, consumption trends and disease incidence are not driving the pharmaceutical research on water and wastewater', *International Journal of Environmental Research and Public Health*, 18(5), pp. 1–37. Available at: https://doi.org/10.3390/ijerph18052532.

Guerrero, W.J., Yeung, T.G. and Guéret, C. (2013) 'Joint-optimization of inventory policies on a multi-product multi-echelon pharmaceutical system with batching and ordering constraints', *European Journal of Operational Research*, 231(1), pp. 98–108. Available at: https://doi.org/10.1016/j.ejor.2013.05.030.

Hillier, F.S. and Lieberman, G.J. (2010) *Introduction to Operations Research*.

Hillier, F.S. and Lieberman, G.J. (2015) *Introduction to Operations Research*.

Howell, P. (2013) 'Pharmaceutical industry', *Pharmaceutical Processing*, 28(1), pp. 20–23. Available at: https://doi.org/10.1007/978-1-4020-5614-7_2616.

Huang, H.C., Chew, E.P. and Goh, K.H. (2005) 'A two-echelon inventory system with transportation capacity constraint', 167, pp. 129–143. Available at: https://doi.org/10.1016/j.ejor.2004.01.051.

Jobira, T. *et al.* (2022) 'Assessment of Knowledge, Practices, and Challenges of Pharmaceuticals Inventory Control Among Pharmacy Professionals Working in Selected Public Health Facilities of West

Arsi Zone, Oromia, Ethiopia', *Health Services Insights*, 15. Available at: https://doi.org/10.1177/11786329211066403.

Johnson, B. *et al.* (2014) 'Estimating the In-Country Distribution Costs of Malaria Commodities in Benin and Kenya', (April), p. 63.

Jonsson, P. and Mattsson, S.-A. (2009) *Manufacturing Planning and Control*.

Karamshetty, V. *et al.* (2022) 'Inventory Management Practices in Private Healthcare Facilities in Nairobi County', *Production and Operations Management*, 31(2), pp. 828–846. Available at: https://doi.org/10.1111/poms.13445.

Kefale, A.T. and Shebo, H.H. (2019) 'Availability of essential medicines and pharmaceutical inventory management practice at health centers of Adama town, Ethiopia', *BMC Health Services Research*, 19(1), pp. 1–8. Available at: https://doi.org/10.1186/s12913-019-4087-0.

Koumanakos, D.P. (2008) 'The effect of inventory management on firm performance', *International Journal of Productivity and Performance Management*, 57(5), pp. 355–369. Available at: https://doi.org/10.1108/17410400810881827.

Lakshmi, S. (2017) 'The Role of Transportation in Logistic', *International Journal for Research in Applied Science and Engineering Technology*, V(XI), pp. 1267–1270. Available at: https://doi.org/10.22214/ijraset.2017.11184.

Leaven, L., Ahmmad, K. and Peebles, D. (2017) 'Inventory management applications for healthcare supply chains', *International Journal of Supply Chain Management*, 6(3), pp. 1–7.

Lu Y, Hernandez P, Abegunde D, E.T. (2011) 'Medicine expenditures in: The World Medicines Situation', *Who*, p. 4.

Merino-Castello, A. (2011) 'Demand for Pharmaceutical Drugs: A Choice Modelling Experiment', *SSRN Electronic Journal* [Preprint]. Available at: https://doi.org/10.2139/ssrn.562962.

MIT (2016) 'CTL . SC1x - Supply Chain Fundamentals Key Concepts'.

M.Lambert, Stock, R. and M.Ellram, L. (1998) 'Fundamentals of Logistics Management'.

MOH and MOI of Ethiopia (2015) 'National strategy and plan of action for pharmaceutical manufacturing development in Ethiopia (2015 – 2025): Developing the pharmaceutical industry and improving access', (July).

Mohammed, S.A. *et al.* (2020) 'Pharmaceutical Logistic System in Ethiopia : Systematic Review of Challenges and Prospects', *Journal of Biology and Medicine*, 1(2), pp. 1–12.

Moorthy, K.S. (1988) 'Strategic Decentralization in Channels', *Marketing Science*, 7(4), pp. 335–355. Available at: https://doi.org/10.1287/mksc.7.4.335.

MSH (2012) 'MDS-3: managing access to medicines and other health technologies'.

Nahmias, S. and Olsen, T.L. (2015) *Production and Operations Analysis*.

Nicholson, L.A. (2002) 'IMPROVING INVENTORY MANAGEMENT IN HEALTHCARE SYSTEMS', *Social and Economic Studies*, 51(3), pp. 65–103.

Oballah, D. and Waiganjo, E. (2015) 'Effect of Inventory Management Practices on Organizational Performance in Public Health Institutions in Kenya : a Case Study of Kenyatta National Hospital', 3(3), pp. 703–714.

Ogbo, A.I., Victoria, O.I. and Ukpere, W.I. (2014) 'The impact of effective inventory control management on organisational performance: A study of 7up bottling company Nile Mile Enugu, Nigeria', *Mediterranean Journal of Social Sciences*, 5(10 SPEC. ISSUE), pp. 109–118. Available at: https://doi.org/10.5901/mjss.2014.v5n10p109.

P, M. and Ranganathan, R. (2017) 'Prioritized Fsn Analysis of Inventory Management in Private and Hospital Pharmacy Followed By Questionnaire', *International Research Journal of Pharmacy*, 7(12), pp. 104–113. Available at: https://doi.org/10.7897/2230-8407.0712155.

Papachristos, S. and Skouri, K. (2000) 'An optimal replenishment policy for deteriorating items with time-varying demand and partial – exponential type – backlogging', 27, pp. 175–184.

Papageorgiou, L.G., Rotstein, G.E. and Shah, N. (2001) 'Strategic supply chain optimization for the pharmaceutical industries', *Industrial and Engineering Chemistry Research*, 40(1), pp. 275–286. Available at: https://doi.org/10.1021/ie990870t.

Petropoulos, F., Wang, X. and Disney, S.M. (2018) 'The inventory performance of forecasting methods : Evidence from the M3 competition data', *International Journal of Forecasting* [Preprint]. Available at: https://doi.org/10.1016/j.ijforecast.2018.01.004.

PFSA (2015) 'Standard Operating Procedures (SOP) Manual for the Integrated Pharmaceuticals Logistics System in Health Facilities of Ethiopia'.

Rachmania, I.N. and Basri, M.H. (2013) 'Pharmaceutical inventory management issues in hospital supply chains', *Management*, 3(1), pp. 1–5. Available at: https://doi.org/10.5923/j.mm.20130301.01.

Rodrigue, J.P., Comtois, C. and Slack, B. (2016) *The geography of transport systems*, *The Geography of Transport Systems*. Available at: https://doi.org/10.4324/9781315618159.

Rosales, C.R. (2011) 'Technology Enabled New Inventory Control Polices in Hospitals'.

Samere, K. (2005) *Parts Management Models and Applications A Supply Chain System Spri*.

Satoglou, A. (2016) *Towards the Optimal Inventory Review Intervals, Unpublished*.

Schneider, H. (1979) 'The Service Level in Inventory Control Systems', *Engineering and Process Economics*, 4, pp. 341–348.

Schöpperle, A. (2017) ‘Analysis of challenges of medical supply chains in sub-Saharan Africa regarding inventory management and transport and distribution’, *International Journal of Health Planning And Management*, 97(8), pp. 1–70.

Schumacker, R.E., Lomax, R.G. and Group, F. (2010) *A Beginner’s Guide to Structural Equation Modeling*. 3rd edn.

Shah, N. (2004) ‘Pharmaceutical supply chains: Key issues and strategies for optimization’, *Computers and Chemical Engineering*, 28(6–7), pp. 929–941. Available at: https://doi.org/10.1016/j.compchemeng.2003.09.022.

Shewarega, Abiy, Paul Dowling, Welelaw Necho, Sami Tewfik, and Y.Y. (PFSA) (2015) ‘Ethiopia: National Survey of the Integrated Pharmaceutical Logistics System [Internet]. Arlington: USAID | DELIVER PROJECTTask Order 4,and Pharmaceuticals Fund and Supply Agency (PFSA)’, (FEBRUARY), p. 84.

Silver, E.A., Pyke, D.F. and Thomas, D.J. (2016) *Inventory Management and Production Planning and Scheduling*, *Inventory and Production Management in Supply Chains*. Available at: https://doi.org/10.1201/9781315374406-3.

Singh, R.K., Kumar, R. and Kumar, P. (2016) ‘Strategic issues in pharmaceutical supply chains: a review’, *International Journal of Pharmaceutical and Healthcare Marketing*, 10(3), pp. 234–257. Available at: https://doi.org/10.1108/IJPHM-10-2015-0050.

Sun, J. (2020) ‘A Review of Multi-Echelon Inventory Control in Supply Chain’, *Open Journal of Business and Management*, 08(02), pp. 881–891. Available at: https://doi.org/10.4236/ojbm.2020.82054.

Tefera, B.B., Yihunie, W. and Bekele, A. (2021) ‘Integrated Pharmaceutical Logistics System Implementation in Chagni Primary Hospital and Injibara General Hospital , Awi Zone , Ethiopia’, pp. 1673–1682.

Tijhuis, L. (2019) ‘Cycle time reduction by inventory management’, *University of Twente*, i(2020006), pp. 2019–2020.

Tilahun *et al.* (2016) ‘Assessment of Integrated Pharmaceutical Logistic System for the Management HIV/AIDS and Tuberculosis Laboratory Diagnostic Commodities in Public Health Facilities in Addis Ababa, Ethiopia’, *Journal of Pharmaceutical Care & Health Systems*, 3(2). Available at: https://doi.org/10.4172/2376-0419.1000158.

USAID Deliver (2011) ‘The Logistics Handbook: A Practical Guide for the Supply Chain Management of Health Commodities’, *USAID | DELIVER PROJECT, Task Order 1*, p. 174.

Uthayakumar, R. and Priyan, S. (2013) ‘Pharmaceutical supply chain and inventory management strategies: Optimization for a pharmaceutical company and a hospital’, *Operations Research for Health Care*, 2(3), pp. 52–64. Available at: https://doi.org/10.1016/j.orhc.2013.08.001.

Veinott, A.F. (2012) ‘Lectures in Supply-Chain Optimization’, pp. 1–261.

Vujosevic, M., Petrovic, D. and Petrovic, R. (1996) 'EOQ formula when inventory cost is fuzzy', *International journal of production economics*, 45, pp. 536–543. Available at: https://doi.org/10.1016/B978-0-444-52512-3.00121-2.

West, DS. (2003) *Purchasing and inventory control, McGraw Hill*.

WHO (2019) 'Global Spending on Health: A World in Transition 2019', *Global Report*, p. 68.

World Bank Group, KRIHS and AACAB (2021) 'Future of Addis Ababa 2021', (April).

Yin, R.K. (2018) *Case Study Research and application Design and Methods*.

Zgarrick, D.P. *et al.* (2020) *Pharmacy Management: Essentials for all practice settings*. 5th edn, *Angewandte Chemie International Edition, 6(11), 951–952.* 5th edn.

Zhang, X. *et al.* (2014) 'Kroger uses simulation-optimization to improve pharmacy inventory management', *Interfaces*, 44(1), pp. 70–84. Available at: https://doi.org/10.1287/inte.2013.0724.

Zheng, Y.-S. (2008) 'Finding optimal (phs,phS) policies is about as simple as evaluating a single policy', *Operations Research*, 39(4), pp. 654–665.

Ziukov, S. (2015) 'A literature review on models of inventory management under uncertainty', *Business Systems & Economics*, 5(1), p. 26. Available at: https://doi.org/10.13165/vse-15-5-1-03.

Zwaida, T.A., Pham, C. and Beauregard, Y. (2021) 'Optimization of inventory management to prevent drug shortages in the hospital supply chain', *Applied Sciences (Switzerland)*, 11(6). Available at: https://doi.org/10.3390/app11062726.

Annexes

Annex I: Consent Form

Informed consent for research on Optimal Pharmaceutical Replenishment Policy: the case of Selected Health Centers in Addis Ababa, Ethiopia

Dear Respondent

You are invited to participate in an academic research study conducted by a researcher from the school of pharmacy, College of Health Sciences, Addis Ababa University, Ethiopia.

The study aims to determine the optimal replenishment policy for Health facilities in Addis Ababa.

All your answers will be treated as confidential, and you will not be identified in any of the research reports emanating from this research. Your participation in this study is essential to us. You may, however, choose not to participate and withdraw from the study without any negative consequences.

Your participation will be limited to cooperation while data are extracted or observed, which will take approximately 25 minutes of your time.

The results of the study will be used for academic purposes and may be published in an academic journal. The researcher will provide you with a summary of our findings upon request.

Please contact the researcher Bezawit Negash (bezawit.negash@aau.edu.et Tel; +251912439423) if you have any questions or comments regarding the study.

Please sign below to indicate your willingness to participate in the study.

Yours sincerely,

Bezawit Negash

I,______________________________ herewith give my consent to participate in the study. I have read the letter and understood my rights with regard to participating in the research.

-------------------------------------- ----------------------

Respondent's signature

Annex II: Data Collection Tools

Section A: Background

Addis Ababa University

College of Health sciences, school of pharmacy

Questionnaire/Data collection tool for Health Centers

Date:____________

Facility type:________________________________

Name of Organization: __________________________ Location____________

Storage Area in m^2_____________

Distance from Hub to health facilities_____________________

Time taken to deliver the products____________________

Expected (Target) service level ____________________

Please tick (✓) as appropriate

Responder:

1. Gender:
   Male ☐ Female ☐
2. Highest Educational Qualifications attained:

   Druggist ☐ pharmacist ☐ others (Please Specify) _________________________
3. Status of Respondent in the Organization: :

   Top Management ☐ Middle level Manager ☐ Lower level Manager ☐
4. Department:
   a. Human resource ☐ Store management ☐ pharmacy team leader ☐
5. How long have you worked in the current department:

   less than 2 years ☐ 2-5 years ☐ 6-9 years ☐ 10 years and above ☐

Description of products stored in the store

No.	Name of the product	SKU	Volume per treatment pack (m3)	packs stored in store	Total volume stored (m3)
1.					

Health Centers specifications

No.	Facility name	Woreda	Kebele	Type	Storage size	Distance to main road (m2)	Distance from hub
1.							
2.							
3.							
4.							
5.							

Section B: Data Extraction tool

Reporting period
From___________To__________
Minimum Lead time___________
Maximum Lead time_____________

Name of HC					Sub city				Addis Ababa
Year established					Woreda				
dd-mm-yy : Monthly consumption, DSO: Days of stock out, EXP: expiry or Damage									
Months	Aciciiovir-capsule-200mg	Addis Cure With Injection(Azithromycin 500mg + Ceftriaxone 250mg injection + Water for injection 5ml	Abacavir (ABC) - Tablet - 300mg	Amoxicillin + Clavulanic Acid - Oral Suspension - (125mg + 31.25mg)/5ml	Amoxicillin + Clavulanic Acid - Tablet (Film Coated) - (250mg +125mg)	Amoxicillin + Clavulanic Acid - Tablet (Film Coated) - (500mg + 125mg)	Amoxicillin - Tablet - 250mg	Amoxicillin - Table - 125mg	Amoxicillin - Capsule - 500mg
6-Aug-17									
DSO									
Exp									
5-Sep-17									
DSO									
Exp									
10-Oct-17									
DSO									
Exp									
9-Nov-17									
DSO									
Exp									

Section C: Health facility cost

Health facility utility cost to store commodities

The research will use two assumptions to focus on specific costs associated with each facility storage capabilities: 5% of health center and dispensary utilities are allocated to stock

Equipment cost of each health center

Five-year straight-line depreciation will be applied to shelves, and pallets

No.	Facility name	Maintenance (ETB)	Depreciated value (ETB)
1.			

No.	Facility name	Water	Electricity	Communication	Cost of Utilities	Cost attributed to stock room	cost of utilities	Cost attributed to stock room
1.								

Annual Store cost of each center

No.	Facility name	size-Storage + Dispensary(m^2)	Year built	initial cost (ETB)	Depreciated value (ETB)

Annual labor cost calculation of each health Center

Facility name	Number of staff	Staff title	Annual salary	Dedication to stock	Annual Labor cost (ET B)

Annual labor cost calculation of each health center

Facility name	Number of staff	Guards	Cost: Guard/Month (ETB)	Cost: Total Facility (ETB)	Cost Attributed to stock (ETB)

The research team will use two assumptions to focus on specific costs associated with each health facility storage capabilities. 50% of health center dispensary security costs are allocated to stock.

Calculation of order costs

Step description	Duration (Minutes)	Hourly wage (ETB)
Validating orders		
Making orders		
Sending and storage of order		
Order confirmation		
Monitoring status		
Processing status and expediting		
Total cost		

Annex III: Product Characteristics

Health center 1										
Product	**Total Demand**	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
3TC+EFV+TDF Tab (300mg +600mg+300mg)	112280	3119	2746	2640.00	4710.00	0.96	0.32	25.16%	35.74%	102.54
Vit A - Cap - 100,0000IU	44403	1233	1176	1000.00	1950.00	1.02	0.67	9.95%	5.66%	40.55
Levonorgestrel+Ethinylestradiol + Ferrous Fumerate - Tab - 0.15mg+ 0.03mg+75mg	32575	905	1301	198.00	1638.00	1.93	4.36	7.30%	0.39%	29.75
Sulphamethoxazole + Trimethoprim - Tab - (800mg + 160mg)	31000	861	899	1000.00	1000.00	0.79	-0.15	6.95%	0.56%	28.31
Zinc Sulphate - Tab - 20mg	20312	564	1295	0.00	925.00	3.83	17.70	4.55%	0.31%	18.55
Sulphamethoxazole + Trimethoprim - Tab - (400mg + 800mg)	18000	500	1028	0.00	1000.00	3.01	10.57	4.03%	0.32%	16.44
3TC+NVP+AZT - Tab - (150mg + 200mg + 300mg)	17780	494	548	270.00	765.00	0.97	-0.22	3.98%	5.15%	16.24
Vit B6 - Tab - 25mg	15700	436	718	0.00	750.00	2.00	3.93	3.52%	0.08%	14.34
Albendazole - Tab 400mg	15100	419	524	200.00	600.00	1.51	1.69	3.38%	0.62%	13.79
Vit B6 - Tab - 50 mg	14500	403	1675	0.00	75.00	5.68	33.26	3.25%	1.48%	13.24
INH- Tab - 300mg	14112	392	871	0.00	672.00	3.77	17.36	3.16%	3.07%	12.89
3TC+NVP+AZT - Tab - (30mg +50mg +60mg)	12960	360	468	150.00	735.00	1.29	1.08	2.90%	0.89%	11.84

Levonorgestrel - Tab - 0.03mg	11282	313	567	43.00	441.00	2.06	3.43	2.53%	0.18%	10.30
3TC+TDF+DTG - Tab -(300 +300+50)mg	9300	258	1044	0.00	0.00	4.04	15.22	2.08%	3.32%	8.49
NVP- Tab - 200mg	9180	255	260	210.00	510.00	0.59	-1.06	2.06%	0.69%	8.38
Medroxyprogesterone Acetate - Injection 150mg/ml in 1ml vial	9176	255	165	264.00	360.50	0.14	-0.32	2.06%	6.14%	8.38
RUSF 100	8100	225	283	150.00	412.50	1.37	1.20	1.81%	2.69%	7.40
3TC+TDF- Tab - (300mg + 300mg)	5490	153	172	120.00	232.50	1.26	0.96	1.23%	0.55%	5.01
3TC+AZT- Tab - (150mg+300mg)	5220	145	295	0.00	210.00	2.98	10.39	1.17%	0.57%	4.77
INH- Tab - 100mg	4900	136	200	0.00	200.00	1.32	0.79	1.10%	0.08%	4.47
RUSF 10092gm	4350	121	245	0.00	112.50	1.82	1.69	0.97%	1.42%	3.97
Amoxicillin - Cap - 500mg	4000	111	274	0.00	0.00	2.48	5.22	0.90%	0.13%	3.65
EFV - Tab - 600mg	3930	109	159	30.00	120.00	1.68	1.72	0.88%	0.43%	3.59
Azithromycine 500mg + Ceftrazone 250mg + Water for injection 5ml	3235	90	453	0.00	16.00	5.95	35.53	0.72%	1.73%	2.95
Amoxicillin + Clavulanic Acid - Oral Suspension - (125mg + 31.25mg)/5ml	3115	130	554	0.00	19.00	4.85	23.68	0.70%	0.03%	2.84
Etonogestrel - Subdermal Implant Cap - 68mg	2011	56	34	60.50	78.25	-0.03	-0.54	0.45%	11.60%	1.84
ORS	2000	56	166	0.00	0.00	3.52	12.68	0.45%	0.19%	1.83
Mifeprostone + Misoprostol - Tab - 200mg + 200mcg	1690	47	106	0.00	0.00	2.49	5.74	0.38%	6.24%	1.54
Ethambutol - Tab - 100mg	1600	44	100	0.00	0.00	2.26	4.48	0.36%	0.06%	1.46
Levonorgestrel - Tab - 0.75mg	1164	32	125					0.26%	0.01%	1.06

Amoxicillin + Clavulanic Acid - Tab (Film Coated) - (500mg + 125mg)	1084	30	166	0.00	0.00	5.99	35.89	0.24%	0.22%	0.99
Aciclovir-Tab-200mg	901	25	94	0.00	0.00	4.31	19.93	0.20%	0.37%	0.82
Rifampicin + Isoniazid-(RH) - Tab - (75mg + 50mg)	672	19	54	0.00	0.00	2.58	4.95	0.15%	0.03%	0.61
Levonorget Subdermal - 75mg/Cap	670	19	33	10.00	20.00	3.06	9.70	0.15%	8.14%	0.61
3TC + AZT-Tab - (30mg + 60mg)	660	18	40	0.00	0.00	1.99	2.49	0.15%	0.02%	0.60
IUCD	650	18	40	0.00	0.00	2.09	3.25	0.15%	0.57%	0.59
EFV - Cap - 200mg	630	18	48	0.00	0.00	2.69	6.52	0.14%	0.04%	0.58
Chloroquine Phosphate - Tab - 250mg	600	17	70	0.00	0.00	4.05	15.26	0.13%	0.01%	0.55
EFV - Cap - 50mg	570	18	55	0.00	0.00	3.27	10.45	0.13%	0.04%	0.52
(RHZ) - Tab - (75mg + 50mg + 150mg)	504	14	43	0.00	0.00	3.09	8.82	0.11%	0.03%	0.46
Metoclopramide - Tab - 10mg	400	11	40	0.00	0.00	3.87	15.55	0.09%	0.01%	0.37
(RHZE) - Tab - (150mg+75mg+400mg+275mg)	207	6	5	4.50	10.00	0.54	-0.97	0.05%	0.03%	0.19
Magnesium Sulphate - Injection - 50% in 20ml Ampoule	125	3	19	0.00	0.00	5.97	35.71	0.03%	0.03%	0.11
Fluconazole - Cap - 200mg	90	3	11	0.00	0.00	4.71	22.88	0.02%	0.00%	0.08
NVP- Oral Suspension - 10mg/ml, 25ml	39	1	2	0.00	3.00	1.16	-0.16	0.01%	0.08%	0.04
Fluconazole - Cap - 100mg	0	0	1	0.00	0.00	6.00	36.00	0.00%	0.00%	0.01

Health Center 2										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual demand %**	**Annual cost percentage**	**Consumption rate**
Etonogestrel Subdermal Implant Cap – 68mg	408	11.33	21.81	0	25	2.4786	7.0822	0.45%	36.09%	0.373
Vit A – Cap – 100,000 IU	14500	402.78	791.20	0	500	2.5836	7.0263	16.14%	28.32%	13.242
Sulphamethoxazole + Trimethoprim – Tab – (800mg + 160mg)	50000	1388.89	1315.35	1000	2000	0.6544	-0.4920	55.66%	13.80%	45.662
Oral Rehydration Salt – Powder -	6625	184.03	146.44	178	300	0.3511	-0.882	7.37%	9.42%	6.050
EFV – Tab – 600mg	3570	99.17	171.49	0	173	1.8094	2.5739	3.97%	5.95%	3.260
3TC+NVP+AZT – Tab – (30mg + 50mg + 60mg)	4020	167.50	185.55	120	300	0.5880	-0.6931	4.48%	4.25%	3.671
Levonorgestrel+Ethinylestradiol + Ferrous Fumerate – Tab – 0.15mg+ 0.03mg+75mg	6451	179.19	451.43	29	108	3.4483	11.8501	7.18%	1.17%	5.891
INH- Tab – 100mg	3000	83.33	210.44	0	0	3.0567	10.2178	3.34%	0.71%	2.740
Levonorgestrel – Tab – 0.03mg	406	11.28	35.11	0	0	4.7760	25.1876	0.45%	0.10%	0.371
Levonorgestrel -Tab – 0.75mg	672	19.20	52.32	0	0			0.75%	0.09%	0.614
3TC+AZT -Tab – (30mg + 60mg)	180	5.14	30.43	0	0	5.9160	35	0.20%	0.09%	0.164

Health Center 3										
Year	**Total Demand**	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual demand %**	**Annual cost percentage**	**Consumption rate**
3TC+EFV+TDF – Tab – (300mg +600mg+300mg)	416020	11572.78	12548.95	9120.00	20287.50	1.50	3.60	36.73%	46.50%	379.93
3TC+NVP+AZT – Tab – (150mg + 200mg + 300mg)	411380	11427.22	13086.14	5460.00	23470.00	1.01	0.13	36.32%	41.83%	375.69
NVP- Tab – 200mg	87540	2431.667	4367.536	0.00	3900.00	2.70	8.86	7.73%	2.31%	79.95
3TC+AZT- Tab – (150mg+300mg)	74580	2071.667	2127.783	1530.00	3495.00	0.77	-0.56	6.59%	2.88%	68.11
3TC+NVP+AZT – Tab – (30mg + 50mg + 60mg)	47820	1328.333	1755.809	630.00	2100.00	1.84	3.68	4.22%	1.16%	43.67
EFV – Tab – 600mg	42213	1172.583	1196.364	1020.00	1927.50	0.61	-0.81	3.73%	1.61%	38.55
Amoxicillin-capsuie-250mg	10100	280.5556	517.5875	0.00	750.00	1.67	2.03	0.89%	0.10%	9.22
Zinc Acetate – Tab 20mg	8600	238.8889	831.9608	0.00	200.00	5.66	33.11	0.76%	0.05%	7.85
Doxycycline – Cap – 100mg	7000	205.8824	557.5603	0.00	25.00	3.28	10.43	0.62%	0.40%	6.39
ORS	5550	152.6111	422.8995	50.00	187.50	1.70	2.00	0.49%	0.18%	5.07
Levonorgestrel Tab – 0.03mg	5494	141.6667	525.5609	0.00	25.50	3.07	8.76	0.49%	0.03%	5.02
Amoxicillin – Cap – 500mg	5100	130.5556	259.4714	0.00	0.00	4.99	26.65	0.45%	0.06%	4.66
Albendazole – Tab 400mg	4700	123.6111	182.2424	0.00	175.00	2.24	4.46	0.41%	0.07%	4.29
Medroxyprogesterone Acetate – Injection 150mg/ml in 1ml vial	2621	72.80556	78.34861	51.00	134.25	1.11	0.87	0.23%	0.62%	2.39

INH- Tab – 100mg	2300	63.88889	109.9423	0.00	175.00	1.33	0.11	0.20%	0.01%	2.10
Etonogestrel – Subdermal Implant Cap – 68mg	1011	28.08333	34.77468	11.00	50.00	1.08	0.26	0.09%	2.05%	0.92
IUCD	354	14.38889	22.40316	5.50	24.25	2.96	11.22	0.03%	0.11%	0.32
Azithromycine 500mg + Ceftrazone 250mg + Water for injection 5ml	71	1.972222	8.881718	0.00	0.00	5.03	26.30	0.01%	0.01%	0.06
Magnesium Sulphate – Injection – 50% in ampoule	49	1.361111	3.423889	0.00	0.00	2.64	6.36	0.00%	0.00%	0.04
NVP- Oral Suspension – 10mg/ml, 25ml	33	0.916667	1.518928	0.00	2.00	1.70	2.53	0.00%	0.02%	0.03

Health Center 4										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
INH- Tab – 300mg	108192	3005.333	5367.56	0.00	4704.00	2.90	10.48	24.74%	24.74%	98.81
EFV – Tab – 600mg	152042	4223.389	4774.226	2700.00	9000.00	0.59	-1.30	17.37%	42.11%	138.85
3TC+AZT- Tab – (150mg+300mg)	140740	3909.444	6005.459	600.00	6000.00	1.84	3.03	16.28%	58.39%	128.52
3TC+TDF- Tab – (300mg + 300mg)	127520	3442.222	5698.392	0.00	6000.00	2.23	5.03	13.36%	71.75%	116.45
Etonogestrel – Subdermal Implant Cap – 68mg	1097	29.91667	35.02356	20.00	50.00	0.97	-0.09	6.65%	78.40%	1.00
Sulphamethoxazole + Trimethoprim – Tab – (800mg + 160mg)	271100	7530.556	9678.041	3000.00	15000.00	1.17	0.60	5.13%	83.53%	247.57
3TC + ABC – Tab – (120mg + 60mg)	10200	283.3333	664.8308	0.00	0.00	2.63	7.33	4.34%	87.87%	9.31
Vitamin A – Tab	27600	766.6667	996.5655	500.00	1300.00	1.69	2.90	3.69%	91.56%	25.20
ATV+RTV- (300mg +100mg) – Tab	4050	112.5	227.8392	0.00	150.00	2.06	3.61	3.25%	94.81%	3.69
LPV+RTV- Cap – (40mg + 10mg)	6600	179.7222	199.8212	0.00	0.00	3.11	10.05	1.81%	96.62%	6.02
Amoxicillin – Cap – 250mg	44200	1227.778	6172.455	0.00	0.00	5.85	34.44	1.29%	97.91%	40.36
Dolutegavir-Tab-50mg	6450	179.1667	370.5932	0.00	0.00	1.95	2.68	1.28%	99.18%	5.89
ORS	7370	183.3333	510.3164	100.00	300.00	1.57	3.44	0.72%	99.90%	6.73
Ethambutol – Tab – 100mg	2600	72.22222	203.696	0.00	0.00	3.25	9.55	0.10%	100.00%	2.37

Health Center 5										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
Etonogestrel – Subdermal Implant Cap – 68mg	18423	8002.75	9744.812	21.50	400.00	2.70	8.15	2.30%	47.66%	16.82
3TC+NVP+AZT – Tab – (150mg + 200mg + 300mg)	242340	8975.556	9133.279	6600.00	11520.00	1.51	2.26	30.29%	31.48%	221.31
EFV – Tab – 600mg	288099	2220	2959.579	3810.00	15855.00	1.08	0.20	36.01%	14.05%	263.10
3TC + NVP+ AZT- Tab – (30mg +50mg +60mg)	68400	1900	1837.943	1530.00	3345.00	0.61	-0.70	8.55%	2.11%	62.47
INH- Tab – 300mg	16500	980.5556	1318.402	100.00	700.00	2.06	3.64	2.06%	1.61%	15.06
Medroxyprogesterone Acetae – Injection (Aqueous suspension) – 150mg/ml in 1ml vial	2074	611.1111	3331.904	10.00	156.00	1.16	0.12	0.26%	0.62%	1.89
(RHZE) – Tab – (150mg+75mg+400mg+275mg)	7980	511.75	1044.097	180.00	360.00	0.98	0.74	1.00%	0.55%	7.28
Dolutegavir-Tab-50mg	5790	458.3333	756.4485	0.00	495.00	1.47	1.59	0.72%	0.49%	15.07
Levonorgestrel +Ethinylestradiol + Ferrous Fumerate – Tab – 0.15mg+ 0.03mg+75mg	79920	261.1111	458.119	720.00	4455.00	1.22	0.28	9.99%	0.42%	72.98
Amoxicillin + Clavulanic Acid – Tab (Film Coated) – (250mg +125mg)	22000	221.6667	223.4982	0.00	0.00	5.96	35.62	2.75%	0.35%	20.09
Levonorget Subdermal – 75mg/Cap Subdermal – 75mg/Cap	41	231.6	352.5819	0.05	2.00	2.88	10.79	0.01%	0.22%	72.98
IUCD	348	90	253.5463	0.00	14.00	1.84	2.64	0.04%	0.14%	0.31

Amoxicilin – Tab – 250mg	9400	86.41667	116.5608	0.00	375.00	2.50	6.62	1.17%	0.12%	1.89
NVP- Oral Suspension – 10mg/ml, 240ml	132	9.666667	17.52712	2.50	6.75	1.17	0.96	0.02%	0.12%	0.12
Zidovudine/Azidothymidine (AZT) 10mg/ml- Oral Solution	44	3.666667	4.20204	0.00	0.00	3.73	14.65	0.01%	0.05%	0.04
3TC -Tab- (15mg)	3240	1.222222	4.007929	0.00	0.00	3.18	10.66	0.40%	0.00%	2.95
Vit B6 – Tab – 50mg	35300	1.158333	1.976198	350.00	1575.00	1.65	2.21	4.41%	0.00%	32.23

Health Center 6										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
3TC+EFV+TDF – Tab – (300mg +600mg+300mg)	565710.00	15714.17	11817.10	18435.0000	26317.5000	-0.031	-1.136	22.71%	49.29%	516.6
3TC+AZT- Tab – (150mg+300mg)	738180.00	20505.00	10792.08	18780.0000	28245.0000	0.422	1.057	29.64%	22.24%	674.13
EFV – Tab – 600mg	340860.00	9468.33	6097.52	10335.0000	13980.0000	0.174	0.533	13.69%	10.15%	311.2
Etonogestrel – Subdermal Implant Cap – 68mg	2186.00	60.72	36.95	58.0000	80.0000	0.179	-0.672	0.09%	3.45%	1.99
3TC+TDF- Tab – (300mg + 300mg)	106020.00	2945.00	2362.21	2865.0000	4185.0000	1.958	7.138	4.26%	2.89%	96.82
RUSF 10092gm	24000.00	666.67	713.04	450.0000	1200.0000	0.756	-0.728	0.96%	2.15%	21.91
Sulphamethoxazole + Trimethoprim – Tab – (800mg + 160mg)	419000.00	11638.89	7175.96	10000.0000	16000.0000	0.708	0.930	16.82%	2.06%	382.64
INH- Tab – 300mg	26208.00	728.00	707.08	672.0000	1344.0000	0.916	0.422	1.05%	1.56%	23.93
Levonorget Subdermal – 75mg/Cap -	430.00	12.29	11.28	10.0000	20.0000	0.599	-0.514	0.02%	1.43%	0.39
Mifeprostone + Misoprostol – Tab – 200mg + 200mcg	1175.00	33.57	36.13	25.0000	50.0000	0.796	-0.564	0.05%	1.19%	1.07
EFV – Cap – 50mg	39030.00	1115.14	1223.73	930.0000	1410.0000	3.348	15.249	1.57%	0.83%	35.64
(3TC) + NVP+ (AZT) – Tab – (30mg + 50mg 60mg)	32580.00	905.00	744.91	870.0000	1425.0000	0.667	0.612	1.31%	0.61%	29.75
EFV – Cap – 200mg	33300.00	925.00	488.52	900.0000	1237.5000	0.147	0.334	1.34%	0.55%	30.41
3TC+AZT – Tab – (30mg + 60mg)	34320.00	953.33	876.64	810.0000	1545.0000	1.715	4.864	1.38%	0.30%	31.34
ORS	8863.00	246.19	246.23	198.0000	321.5000	1.752	3.746	0.36%	0.22%	8.09
Albendazole – Tab 400mg	18660.00	518.33	368.39	550.0000	800.0000	0.513	-0.019	0.75%	0.21%	17.04
Medroxyprogesterone Acetae– Inj.150mg/ml in 1ml vial	964.00	27.54	24.64	25.0000	48.0000	0.776	0.065	0.04%	0.18%	0.88

IUCD	735.00	20.42	20.28	16.0000	27.7500	1.624	3.423	0.03%	0.18%	0.67
Amoxicillin-capsuie-250mg	22000.00	611.11	1478.95	0.0000	1000.0000	4.091	18.817	0.88%	0.17%	20.09
Levonorgestrel+Ethinylestradiol + Ferrous Fumerate – Tab – 0.15mg+ 0.03mg+75mg	43245.00	1201.25	2031.69	197.0000	1623.0000	1.975	3.137	1.74%	0.14%	39.49
Amoxicillin – Cap – 500mg	6000.00	166.67	529.15	0.0000	75.0000	3.841	14.456	0.24%	0.05%	5.47
Levonorgestrel- Tab – 0.03mg	8002.00	222.28	378.61	30.0000	371.0000	2.295	5.917	0.32%	0.03%	7.30
Ethambutol – Tab – 100mg	3000.00	85.71	338.80	0.0000	0.0000	5.617	32.489	0.12%	0.03%	2.73
INH- Tab – 100mg	5900.00	163.89	248.60	0.0000	275.0000	1.632	1.936	0.24%	0.02%	5.38
Cloxacilin Sodium – Capsul – 250mg	4500.00	128.57	305.41	0.0000	0.0000	2.275	3.956	0.18%	0.02%	4.10
(RHZE) – Tab – (150mg+75mg+400mg+275mg)	356.00	9.89	6.65	8.0000	14.5000	0.819	0.347	0.01%	0.01%	0.32
Ceftriaxone – Injection – 1 g	97.00	2.77	4.95	0.0000	3.0000	1.440	0.346	0.00%	0.01%	0.08
Paracetamol – Tab – 500mg	5000.00	138.89	350.74	0.0000	0.0000	2.180	2.913	0.20%	0.00%	4.56
Levonorgestrel – Tab – 0.75mg	216.00	6.17	9.18					0.01%	0.00%	0.19

Health center 7										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
3TC+EFV+TDF – Tab – (300mg +600mg+300mg)	722700	20075	15887.75	17670	29865.0000	0.596	-0.501	51.79%	76.42%	660.00
3TC+AZT- Tab – (150mg+300mg)	254040	7056.667	6765.219	6690.0000	12600.0000	0.433	-1.165	18.21%	9.29%	232.00
EFV – Tab – 600mg	121290	3369.167	4117.878	1140.0000	6352.5000	1.096	0.319	8.69%	4.38%	110.77
INH- Tab – 300mg	51072	1418.667	1899.194	672.0000	1344.0000	1.770	2.337	3.66%	3.69%	46.64
3TC+TDF- Tab – (300mg + 300mg)	82170	2282.5	3997.584	615.0000	3120.0000	3.517	14.945	5.89%	2.72%	75.04

Medroxyprogesterone Acetae – Injection – 150mg/ml in 1ml vial	5700	158.3333	123.5621	121.0000	257.0000	0.773	0.468	0.41%	1.27%	5.20
Abacavir (ABC) – Tab – 300mg	13800	383.3333	456.5586	270.0000	510.0000	1.768	3.220	0.99%	1.05%	12.60
Lamivuduine(3TC) – Tab – 150mg	19380	538.3333	792.6862	300.0000	525.0000	2.048	3.268	1.39%	0.36%	17.69
ORS	9400	261.1111	299.7883	200.0000	400.0000	1.349	1.298	0.67%	0.29%	8.58
Albendazole – Tab 400mg	11600	322.2222	364.9745	200.0000	500.0000	0.950	-0.134	0.83%	0.16%	10.59
Vit B6 – Tab – 25 mg	66800	1855.556	2114.095	1000.0000	2875.0000	1.363	0.878	4.79%	0.11%	61.00
IUCD	381	10.58333	13.81174	6.5000	20.0000	2.046	5.897	0.03%	0.11%	0.34
Amoxicillin-capsuie-250mg	7000	194.4444	624.2456	0.0000	0.0000	3.579	13.136	0.50%	0.06%	6.39
INH- Tab – 100mg	3600	100	170.7128	0.0000	200.0000	1.678	1.829	0.26%	0.02%	3.28
(RHZE) – Tab – (150mg+75mg+400mg+275mg)	353	9.805556	10.91217	6.5000	17.0000	1.107	0.363	0.03%	0.02%	0.32
Ethambutol – Tab – 100mg	1500	41.66667	115.5731	0.0000	0.0000	2.860	7.674	0.11%	0.02%	1.36
Ceftriaxone – Injection – 1 g	83	2.305556	7.708324	0.0000	0.0000	4.379	21.107	0.01%	0.01%	0.07
Water For Injection – Injection – in 10ml Vial	1300	36.11111	72.31984	0.0000	50.0000	2.857	9.833	0.09%	0.01%	1.18
Magnesium Sulphate – Injection – 500mg/ml (50%) in 10 ml ampoule	69	1.916667	3.556684	0.0000	3.0000	1.533	0.725	0.00%	0.00%	0.06
Vit A – Cap – 100,000 IU	23200	644.4444	1197.961	0.0000	500.0000	1.968	2.786	1.66%	0.00%	21.18

Health Center 8										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
3TC+EFV+TDF – Tab – (300mg +600mg+300mg)	531690	14769	27080	6525.0000	13725.0000	3.553	15.632	55.34%	0.73	485.56
Medroxyprogesterone Acetae – Injection (Aqueous suspention) – 150mg/ml in 1ml viol	37623	1045	5062	12.5000	128.5000	5.682	33.065	3.92%	0.11	34.36
3TC+AZT- Tab – (150mg+300mg)	137580	3822	10033	0.0000	780.0000	3.139	9.564	14.32%	0.07	125.64
Levonorget Subdermal – 75mg/Cap Subdermal – 75mg/Cap -Implant Cap(Subdermal) - 75mg/Cap Pack of 2 Cap(Jadelle)	790	22	60	0.0000	7.5000	3.729	14.648	0.08%	0.04	0.72
Efavirenz - Tab - 600mg	52740	1465	3824	0.0000	1102.5000	3.903	16.286	5.49%	0.02	48.16
Sulphamethoxazole + Trimethoprim - Tab - (800mg + 160mg)	144000	4000	5806	0.0000	7000.0000	1.707	2.990	14.99%	0.01	131.51
3TC+TDF- Tab - (300mg + 300mg)	25410	726	1795	0.0000	450.0000	3.743	16.063	2.64%	0.01	23.21
Albendazole - Tab 400mg	20280	563	1203	0.0000	850.0000	3.140	11.715	2.11%	0.00	18.52
IUCD	500	14	34	0.0000	0.0000	2.388	4.733	0.05%	0.00	0.46
Amoxicillin + Clavulanic Acid - Tab (Film Coated) - (500mg + 125mg)	1350	38	105	0.0000	0.0000	2.627	5.390	0.14%	0.00	1.23
Amoxicillin - Cap - 500mg	5000	139	672	0.0000	0.0000	5.739	33.699	0.52%	0.00	4.57
Efavirenz - Cap - 200mg	2580	74	207	0.0000	0.0000	3.402	11.341	0.27%	0.00	2.36
Water For Injection - Injection - in 10ml Vial	1200	33	74	0.0000	37.5000	2.546	6.076	0.12%	0.00	1.10

Health Center 9										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
INH- Tab - 300mg	26891	768.3143	1199.059	2.0000	1344.00	2.111	5.299	5.56%	18.97%	24.55
Etonogestrel - Subdermal Implant Cap - 68mg	762	21.16667	37.01235	0.0000	41.25	1.646	1.693	0.16%	14.25%	0.69
Sulphamethoxazole + Trimethoprim - Tab - (800mg + 160mg)	189000	5250	7647.128	3000.0000	7000.00	3.014	11.790	39.07%	11.03%	172.60
RUSF 10092gm	9150	254.1667	435.9513	0.0000	300.00	2.163	4.499	1.89%	9.71%	8.35
Levonorget Subdermal - 75mg/Cap - Implant Cap(Subdermal) - 75mg/Cap Pack of 2 Cap(Jadelle)with Sterile	240	6.666667	19.12366	0.0000	0.00	3.907	16.969	0.05%	9.46%	0.21
Etonogestrel Subdermal Implant Cap - 68mg	449	12.47222	28.22409	0.0000	0.0000	2.317	4.390	0.09%	8.40%	0.41
3TC+TDF- Tab - (300mg + 300mg)	17841	495.5833	660.2021	255.0000	690.00	1.394	1.037	3.69%	5.77%	16.29
3TC+AZT- Tab - (150mg+300mg)	13920	386.6667	601.1037	0.0000	600.00	1.698	1.954	2.88%	4.97%	12.42
ORS	13600	377.7778	866.8864	0.0000	500.00	4.362	22.031	2.81%	4.09%	11.89
EFV - Tab - 600mg	11190	310.8333	851.1047	0.0000	82.50	3.491	12.293	2.31%	3.95%	10.21
Ferrous Sulphate + Folic Acid - Tab (Enteric Coated) - (150mg + 0.5mg)	120303	3341.75	4922.158	50.0000	6300.00	1.429	1.296	24.87%	3.09%	109.86
(3TC) + NVP+ (AZT) - Tab - (30mg + 50mg +60mg)	13440	384	643.132	0.0000	840.00	1.406	0.681	2.78%	3.00%	12.27
Gentamicin - Injection - 40mg/ml in 2ml Ampoule	350	10	37.96283	0.0000	0.00	4.345	19.893	0.07%	1.08%	0.31

Vit B6- Tab - 25 mg	44200	1227.778	2108.84	0.0000	1800.00	1.843	2.383	9.14%	0.73%	40.36
Amoxicillin - Cap - 500mg	5100	141.6667	289.2107	0.0000	0.00	1.951	2.855	1.05%	0.55%	4.65
Levonorgestrel+Ethinylestradiol + Ferrous Fumerate - Tab - 0.15mg+ 0.03mg+75mg	13020	361.6667	813.1253	8.0000	103.50	2.657	6.657	2.69%	0.50%	0.32
Levonorgestrel - Tab - 0.03mg	3837	106.5833	356.6707	0.0000	30.00	4.820	24.977	0.79%	0.20%	3.50
NVP- Oral Suspension - 10mg/ml, 240ml	24	0.666667	1.309307	0.0000	1.00	2.525	7.220	0.00%	0.15%	0.021
(RHZE) - Tab - (150mg+75mg+400mg+275mg)	198	5.5	5.764423	4.5000	10.00	0.683	-0.392	0.04%	0.10%	0.18
Levonorgestrel- Tab - 0.75mg	181	5.027778	10.79546					0.04%	0.01%	0.16

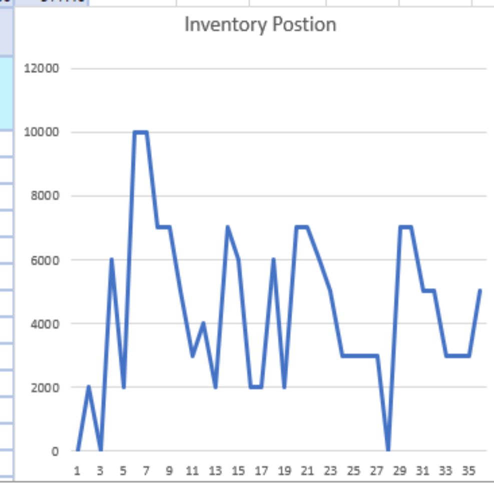
Health Center 10										
	Total Demand	**Average Demand**	**STD**	**50% Percentile (Median)**	**75% Percentile**	**Skewness**	**Kurtosis**	**Annual Demand %**	**Annual Cost Percentage**	**Consumption Rate**
NVP- Tab - 200mg	320360	8898.889	14791.11	0.00	17195.0	1.514	1.134	34.42%	34.14%	292.57
EFV - Tab - 600mg	119460	3318.333	7081.642	0.00	2940.00	2.722	8.030	12.84%	18.41%	109.09
INH- Tab - 300mg	56776	1577.111	3222.659	0.00	1848.00	2.316	4.420	6.10%	17.51%	51.85
Levonorget Subdermal - 75mg/Cap -Implant Cap(Subdermal) - 75mg/Cap Pack of 2	800	22.22222	48.46861	0.00	0.00	2.158	4.257	0.09%	13.78%	0.73
Sulphamethoxazole + Trimethoprim - Tab - (800mg + 160mg)	290000	8055.556	8912.093	5500.00	15000.00	1.014	0.661	31.16%	7.40%	264.84
Vit A - Cap - 100,000 IU	18715	519.8611	997.1534	0.00	600.00	2.407	6.107	2.01%	3.38%	17.09
LPV+RTV- Tab - (200mg + 50mg)	5280	146.6667	684.9234	0.00	0.00	5.730	33.625	0.57%	1.81%	4.82
LPV+RTV- Cap - (40mg + 10mg)	2400	66.66667	313.5055	0.00	0.00	5.252	28.706	0.26%	0.89%	2.19
Zinc Acetate - Tab- 20mg	33500	930.5556	1828.32	0.00	1000.00	2.371	4.978	3.60%	0.75%	30.59
ORS	4401	122.25	303.5548	0.00	0.00	2.665	6.402	0.47%	0.58%	4.01
Ceftriaxone - Injection - 1 g	790	21.94444	71.86573	0.00	0.00	4.519	22.879	0.08%	0.43%	0.72
Vit B6 - Tab - 25 mg	59950	1665.278	3960.083	0.00	1800.00	4.230	20.622	6.44%	0.43%	54.74
Sulphamethoxazole + Trimethoprim - Tab - (400mg + 80mg)	14000	388.8889	1128.28	0.00	0.00	3.199	10.046	1.50%	12.78	12.78
Ethambutol - Tab - 100mg	1800	51.42857	191.5439	0.00	0.00	4.238	18.984	0.19%	0.09%	1.64
Levonorgestrel+Ethinylestradiol + Ferrous Fumerate - Tab - 0.15mg+ 0.03mg+75mg	2074	57.61111	129.0677	0.00	27.00	2.636	6.763	0.22%	0.03%	0.72
Water For Injection - Injection - in 10ml Vial	300	8.333333	30.47247	0.00	0.00	3.920	15.472	0.03%	0.01%	0.27

Annex IV: Spread Sheet Simulation Optimization

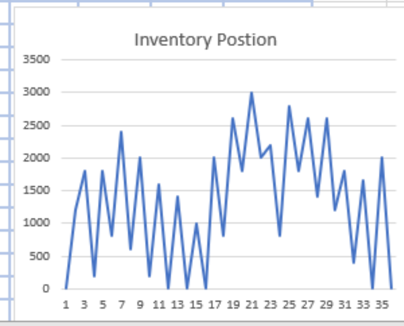
The first section of the simulation model consists (A2:B2) of drug information, including product name, pack size, and unit price. The third row of the simulation model consists of the decision variable: the order up to level (H3) and total cost cell (I3). Onwards from columns A5 and B5 are the months of demand which is the time bucket. Column C shows whether to order or not based on the review period on G3. Column D represents the beginning inventor for the single period; for the start of the model beginning inventory is used as half of the initial month's demand. Column F shows stock on hand, and column G shows the demand filled. Column K represents the decision to order (coded as 1) or not. If the inventory position is less than or equal to s, or if the day is a review period, then an order, rounded to a multiple of the package size defined in cell B3, is issued to reach S. This order is up to the level found on the H3. The dates and quantities of order arrivals, shown in column N, are calculated based on the drug's lead time. Columns I and J indicate the ending inventory and the number of drugs out-of-stock each month. The graphic section s gives a clear picture of the performance of the inventory policy defined by (R, S). The total number of orders, the average inventory, and the total number of stockout encounters are calculated in cells B4, K3, and R3, respectively. The spreadsheet model then runs a solver to minimize the total relevant cost.

Spreadsheet model that shows the current replenishment policy (IPLS)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Product Description	Sulphamethoxazole + Trimethoprim - Tablet - (800mg + 160mg)		CSL	TC	Stock out	Total no . Orders	Unit price	Average Inv.	Unit holding cost	Unit Ordering cost	Unit Shortage cost	HC	SC	OC
Pack size	1000		98.000%	377.5	3	19	$ 0.41	4,389	1.7210E-05	19.87	19.87	0.076	59.60	377.46
Avg demand	1389													
Month	Monthly Demand	Monthly Order	Beginning inv	Unit recevied	SOH	Demand filled	End inv	Stock out	Stock out unit	Adjusted AMC	Place order?	Order quantity	Lead Time	
1	1000	1	1000	0	1000	1000	0	0	0	1000	1	4000	14	
2	2000	0	0	4000	4000	2000	2000	1	0	1500	0	0	13	
3	2000	1	2000	0	2000	2000	0	0	0	1667	1	7000	14	
4	1000	0	0	7000	7000	1000	6000	0	0	1667	0	0	17	
5	4000	1	6000	0	6000	4000	2000	0	0	2333	1	8000	17	
6	0	0	2000	8000	10000	0	10000	0	0	1667	0	0	16	
7	0	1	10000	0	10000	0	10000	0	0	1333	1	0	15	
8	3000	0	10000	0	10000	3000	7000	0	0	1000	0	0	15	
9	0	1	7000	0	7000	0	7000	0	0	1000	1	0	14	
10	2000	0	7000	0	7000	2000	5000	0	0	1667	0	0	13	
11	2000	1	5000	0	5000	2000	3000	0	0	1333	1	3000	17	
12	2000	0	3000	3000	6000	2000	4000	0	0	2000	0	0	17	
13	2000	1	4000	0	4000	2000	2000	0	0	2000	1	6000	16	



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
2	Product description	Sulphamethoxazole + Trimethoprim - Tablet - (800mg +			CSL	SS	Review Period	Order Up to level	TC	K	Avg. Inventory	Unit price	Unit holding cost	Unit Ordering cost	Unit Shortage cost	Annual demand	Lead time	Stock out	Avg Demand	SD Demand	SD of DL
3	Pack size	1000			96.43%	252.8721239	2	2848.4	**154.0144928**	1.64	1345.8333	$ 0.21	0.00488	6.09195	6.09195	50216.67	6	5	1395	377.68761	154.1903195
4	Total no. orde	19															Min L	**13**			
5	Month	Monthly Demand	Monthly Order	Beginning inv	Unit recevied	SOH	Demand filled	End inv	Stock out	Inv Postion	Place order?	Order quantity	Lead time	Arrive on			Max L	**17**			
6	1	2000	0	1424	0	1424	1424.2	0	0	0	1	3000	14	2			THC	8			
7	2	1800	1	0	3000	3000	1800	1200	1	1200	1	2000	13	3			TSC	30			
8	3	1400	0	1200	2000	3200	1400	1800	0	1800	0	0	14	0			TOC	116			
9	4	1600	1	1800	0	1800	1600	200	0	200	1	3000	17	5							
10	5	1400	0	200	3000	3200	1400	1800	0	1800	0	0	17	0							
11	6	1000	1	1800	0	1800	1000	800	0	800	1	3000	16	7							
12	7	1400	0	800	3000	3800	1400	2400	0	2400	0	0	15	0							
13	8	1800	1	2400	0	2400	1800	600	0	600	1	3000	15	9							
14	9	1600	0	600	3000	3600	1600	2000	0	2000	0	0	14	0							
15	10	1800	1	2000	0	2000	1800	200	0	200	1	3000	13	11							
16	11	1600	0	200	3000	3200	1600	1600	0	1600	0	0	17	0							
17	12	2000	1	1600	0	1600	1600	0	0	0	1	3000	17	13							
18	13	1600	0	0	3000	3000	1600	1400	1	1400	0	0	16	0							
19	14	1400	1	1400	0	1400	1400	0	0	0	1	3000	14	15							
20	15	2000	0	0	3000	3000	2000	1000	1	1000	0	0	14	0							
21	16	1800	1	1000	0	1000	1000	0	0	0	1	3000	16	17							
22	17	1000	0	0	3000	3000	1000	2000	1	2000	0	0	14	0							



Reorder period 2, 95% target service level, proposed model