Medical Equipment Supply Chain Management System at PFSA: warehouse layout design and system software development

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By: Zelalem Lemma Gebru, GSR/2989/06

Advisor: Masreshaw Demelash (PhD)

Center of Biomedical Engineering
Addis Ababa Institute of Technology
Addis Ababa University

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Addis Ababa University
School of Graduate Studies

Certificate of Examination

This is to certify that the thesis prepared by Zelalem Lemma Gebru entitled Assessment and Improvement of the Medical Equipment Supply Chain Management System of Ethiopia: a warehouse layout design and system software development for the PFSA submitted in partial fulfillment of the requirements for the degree of Master of Science in Biomedical Engineering complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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_____	_____	_____
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_____	_____	_____
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Chief of Department or Graduate program coordinator

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Lists of Acronyms

FDA	Food and Drug Administration
FMHACA	Food, Medicine and HealthCare Administration and Control Authority
FMOH	Federal Ministry of Health
GDP	Good Distribution Practices
GSP	Good Storage Practices
GUI	Graphical User Interface
HCMIS	Health Community Management Information System
ISO	International Organization for Standardization
MDGMP	Medical Device Good Manufacturing Practices
ME	Medical Equipment
MESCMS	Medical Equipment Supply Management System
MIS	Management Information System
MOH	Ministry of Health
NMESCMS	National Medical Equipment Supply Chain Management System
PFSA	Pharmaceuticals Fund and Supply Agency
PO	Purchas Order
QS	Quality System
RDF	Revolving Drug Fund
SC	Supply Chain
SCM	Supply Chain Management
SCS	Supply Chain System
SCOR	Supply Chain Operations Reference
SCPM	Supply Chain Performance Measures
WMS	Warehouse Management System
WHO	World Health Organization

Abstract

Improving the performance of medical equipment supply chain management system is crucial in the healthcare service delivery. The Pharmaceuticals Fund and Supply Agency (PFSA), the responsible body, has strived to systematize the medical equipment supply chain management system (MESCMS) since its establishment despite the fact it needs more improvement. The objective of this study is to investigate, analyze, design and develop an efficient MESCMS that can ensure the quality, safety, reliability of medical equipment through proper delivery, effective distribution, functional supervision and technical support for concerned health facilities (federal and regional hospitals, health center and health post).

Qualitative and quantitative methods were used for this case study of MESCMS. Data gathering techniques such as questionnaire, interview, and direct observation were applied for targeted personnel. The participants were selected by purposive sampling technique. In doing so, a total of 54 questionnaires were distributed in PFSA and facilities. From these, 43 questionnaires were filled out and returned back.

The survey data analysis result revealed that 88% and 78% of respondents agreed that the storage and distribution practices of medical equipment are not in line with the standard Good Storage Practices (GSP) and Good Distribution Practices (GDP) respectively. Moreover, the data also shows that 83% and 72% of the participants agreed that there is no proper delivery and inspection service of medical equipment at PFSA, respectively. Furthermore, 77.8% and 75.7% of the respondents agreed that PFSA is providing insufficient medical equipment functionality supervision and technical support for facilities, respectively. Finally, 84% of respondents agreed that the PFSA does not have an effective warehouse management system (software) used to keep and make available the required information about medical equipment within the transaction.

The regression analysis shows that GDP is dependent variable on independent variables such as Proper delivery, Tracking method, Automation, Storing practices, and Equipment inspection. The model's degree of explaining the variance in the dependent variable was R^2 =0.794. Therefore, the coefficient value tells about 79.4% of the variation in the GDP is explained by all other dependent variables. According to the ANOVA statistics $F = 14.659, p < 0.05$, therefoere, the five independent variables in the standared model are significantly predicative of

the dependent variable. PFSA need to have high attention to improve the GDP along with the other significant independent variables.

Currently, PFSA is working with computerized management system in order to conduit interaction between facilities and other stakeholders though it is not effective as required. In general, PFSA needs to apply best practices on inspection, storage, distribution, proper delivery, technical support and functionality supervision activities in the management of medical equipment in order to increase customer satisfaction.

The lack of proper management of medical equipment has affected the facilities not to deliver adequate healthcare services. Thus, in order to support PFSA to solve the identified problems, the research proposed a novel warehouse layout design and web-based management system. The management system can record and easily retrieve all the relevant information regarding the status of medical equipment both at FSA warehouse and at the facilities after delivery. Such computerized management system not only prevents mix-up in the warehouse and avoids order exchanges while distributing, but also helps trace the status of medical equipment after it leaves the warehouse. It can tell us the facility and the date where and when equipment is installed and commissioned.

Key Words: Medical equipment, Supply Chain System, warehouse layout design, Warehouse Management System

CHAPTER 1: Introduction

1.1. Background

Healthcare supply chain management is the process of interconnecting producers, suppliers and customers [1]. It helps for distributing the right quantities to the right place at the right time in order to satisfy the required services [2]. In this regard, a well-managed healthcare supply chain system can play vital roles in the provision of quality healthcare services.

The importance of pharmaceutical supply chain, as part of healthcare supply chain, is a focus for many researches. On the other hand, the medical equipment supply chain seemed to be given little attention [3, 4]. Different studies discussed that healthcare organization can apply different technologies to reduce constraints in all aspects of healthcare supply chain management [1, 2, 5]. These are:

- reducing waste/excess product
- capturing data for business requirements
- enabling automation within the organization and interregional healthcare network

In the healthcare supply chain system, warehouse is one of the indispensable component [6]. Particularly, it is instrumental for medical equipment supply chain system which helps for handle, store, and distribute the medical equipment properly. It can also help for preventing them from mix-up, damage, deterioration, contamination, or other adverse effects that affect the quality and performance of medical equipment [7].

The Ethiopian healthcare supply chain management system is mainly facilitated by Pharmaceuticals Fund and Supply Agency (PFSA) and Food Medicine and HealthCare Administration and Control Authority (FMHACA). PFSA was established in September 2007, by proclamation number 553/2007 to systematize the poor medicines supply management system in public sector [8]. On the other hand, the FMHACA was established in proclamation number 661/2009 for the regulation of medicines and healthcare products. In addition, stakeholders such as facilities and supplier have their own role in medical equipment supply chain system [9].

In this paper, we tried to assess the national medical equipment supply chain system in PFSA and propose warehouse layout design and develop warehouse management system.

1.2. Statement of the Problem

Ethiopian healthcare service has encountered inefficient supply chain management system of medical equipment facilitated by PFSA. The main challenge of PFSA is to establish efficient and effective medical equipment supply chain management system by implementing best practices. The current system does not have good practices such as proper handling, storage, and distribution process that cannot prevent medical equipment from mix-up, damage, deterioration, contamination, or other adverse effects. As a result of this, the quality, safety and reliability of medical equipment have been compromised.

In addition, warehouses of the PFSA do not have appropriate layout designs. This leads to create poor space management to perform activities such as inspection, receiving, storing and distribution. Moreover, PFSA also does not have efficient computerized system that can handle information about the medical equipment within the supply chain. The existing system (software) provides little or no information to communicate the PFSA and facilities about proper delivery, functionality supervision, and technical support services. The warehouse management system is a key component to manage the supply chain system [10]. To achieve better performance and efficient warehousing operations, there is a need for accurate and up to date information flow [11].

In this study, the existing supply chain management system of PFSA is assessed and warehouse layout design and computerized system are proposed in order to improve the performance of medical equipment supply chain management system.

1.3. Objective of the Research

1.3.1. General Objective

To assess the existing medical equipment supply chain management system (SCMS) at PFSA and to propose solutions that can improve its performance.

1.3.2. Specific Objectives:

- to assess the current practices of inspection, handling, storage and distribution of medical equipment at PFSA
- to investigate if FPSA provides proper delivery, technical support and functionality

supervision services to the facilities

- identify dependent and independent variables using multiple regression model
- to design medical equipment warehouse layout
- to develop a software that can automate the medical equipment supply chain management system

1.4. Literature Review

Several studies have been conducted on pharmaceutical supply chain. For instance, Eyob Lissanework (2013) studied that evaluation and improving pharmaceutical supply chain distribution network. He further explored that there was inadequate distribution network between suppliers and facilities [12]. Dessalegn Tesfaye (2015) tried to compare and contrast the Ethiopian public health supply chain management (SCM) before and after the establishment of the PFSA by assessing the strength, weakness and challenges. He showed the major strengths of the supply chain system such as the establishment of proxy and direct distribution system and improvement of infrastructure. He also identified weak supply chain technical capabilities (procurement, storage and distribution), unavailability of enterprise-wide business information system and lack of strong coordinating body [13].

Ashenafi Hussen (2014) conducted his research on reengineering the medical equipment management system. Particularly he presented general strategies in healthcare technology management system by reengineering the medical equipment management system from provider-regulator-purchaser aspect and developed desktop software application [14]. Based on the data he collected form healthcare providers such as hospitals, health centers and clinics he found out that there is problem in management of medical equipment provision, acquisition, utilization, donation and decommission.

In the above studies, little attentions have been given to the proper handling, storing and distributing of medical equipment and the warehouse layout in the PFSA. In addition, those studies give limited emphasis about the medical equipment management interactions between PFSA and the facilities to provide proper delivery, technical support and functionality supervision when and where necessary.

In this study, the researcher tried to assess the current medical equipment supply chain management system in PFSA and attempted to develop new web based warehouse management system (software) and warehouse layout design. More specifically, the research aims to propose improvements to the supply chain system in terms of the medical equipment safety, performance, reliability, as well as the research also recommends better practices like proper delivery, effective distribution, technical support and functionality supervision to the facilities.

1.5. Research Methodology

In this research, we intended to collect data and assess PFSA and facilities about the current medical equipment supply chain system. The study employed qualitative and quantitative multiple case study [15] to assess the medical equipment supply chain system focusing on PFSA. These quantitative and qualitative data were collected through (1) direct observation, (2) structured interviewing and (3) survey questionnaire. The quantitative data that obtained from questionnaire whereas the qualitative data are those obtained from interview and direct observation in order to obtain more relevant and comprehensive information. We used Microsoft application for preparing flowcharts and SPSS for data analysis. AutoCAD software was used for Layout design. HTML, PHP, JavaScript and MySQL tools were used to develop the system software. Detailed presentation of the research methodology is given in chapter 3.

1.6. Significance of the Study

Briefly, this study is significant because it will identify gaps on medical equipment supply chain system in general and propose solutions for PFSA and others. This research is also able to provide a conceptual framework for experts, decision-makers and other stakeholders. Furthermore, the study provides a means how PFSA and the facilities interact with one another for better utilization of the equipment and technical advice.

1.7. Scope and Limitation of the Study

This study is conducted on supply chain management system to assess the current practices of handling, storing, distributing of the medical equipment whether they ensure quality, safety, performance, reliability through proper delivery, technical support and functionality supervision. The study was delimited about to design warehouse layout and develop system software to

improve the medical equipment supply chain management system at PFSA.

There are various constraints that need to be addressed. The first limitation is shortage of enough reference materials with respect to medical equipment management in Ethiopia. This study is delimited to PFSA and some public hospitals found in Addis Ababa only to assess the medical equipment supply chain management system which is facilitated by the PFSA. This research did not include the private health system. The study did not include some of the stakeholders in the supply chain, such as manufacturer, local agents and donors.

1.8. Organization of the Manuscript

This manuscript is organized in 6 chapters. Chapter 1 includes Statement of the Problem, Objectives of the Study, Literature Review, Research Method, Significance of the Study, Scope and Limitation of the Study, and Organization of the Manuscript; Chapter 2 states that Theoretical and Conceptual Frameworks of the study. Chapter 3 describes Research Method of the study; Chapter 4 presents the Warehouse Layout Deign and System Software Development. And finally, Chapter 5 and Chapter 6 present Results and Discussions and the Conclusion and Recommendation, respectively.

CHAPTER 2: Theoretical and Conceptual Frameworks

In this chapter, theoretical and conceptual frameworks of the study are presented by reviewing different resources such as journals, reports, standards and internet.

2.1. Healthcare Supply Chain System

The Supply Chain Management (SCM) coordinates the upstream (production) and downstream (distribution) relationships with suppliers and customers [16, 17]. Healthcare supply chain system interconnects producers, suppliers and customers for the supply of medical products. It is a system that includes all the activities ranging from identification of demand of customers through product selection, negotiation, payment, storage, distribution and redistribution [16].

Particularly, medical equipment supply chain system is a system that integrates the manufacturer, distributor and customers. It helps for manage medical equipment based on their type and class t o store and distribute them to the right place at the right time to the right facilities [16, 17].

2.2. Medical Equipment

Medical equipment is defined as any instrument, apparatus, appliance, whether used alone or in combination, including the software, for the purpose of diagnosis, prevention, monitoring, and treatment, alleviation of disease or injury, compensation of handicap, disinfection of medical devices, disease investigations, replacement or modification of the anatomy or of a physiological process. They are indispensable part of healthcare technology that help to improve the quality of life of people in many ways [18].

2.3. Classification of Medical Devices

Medical devices can be classified based on the degree of invasiveness, duration of contact, the body system affected, and local versus systemic effects. An invasive medical device is devices that are penetrating or braking of the human skin or enter in to human body cavity. Whereas, non-invasive medical devices that do not break in the skin and contact with the mucous membrane and or internal body cavity. An invasive device is usually considered to have more hazardous than non-invasive device [19].

Medical devices are usually divided into different classes based on risk level. Some countries have different classification systems like general medical devices, active medical devices and in-vitro diagnostic devices. For instance, in the United States and European Union, medical devices are classified as class I (General Controls), class II (Special Controls) and class III (Pre-market Approval) devices where class III devices represent the highest risk, with slight difference [20, 21]. Figure 2.1 in the pyramid shows that European‘s risk-based medical device regulatory system.

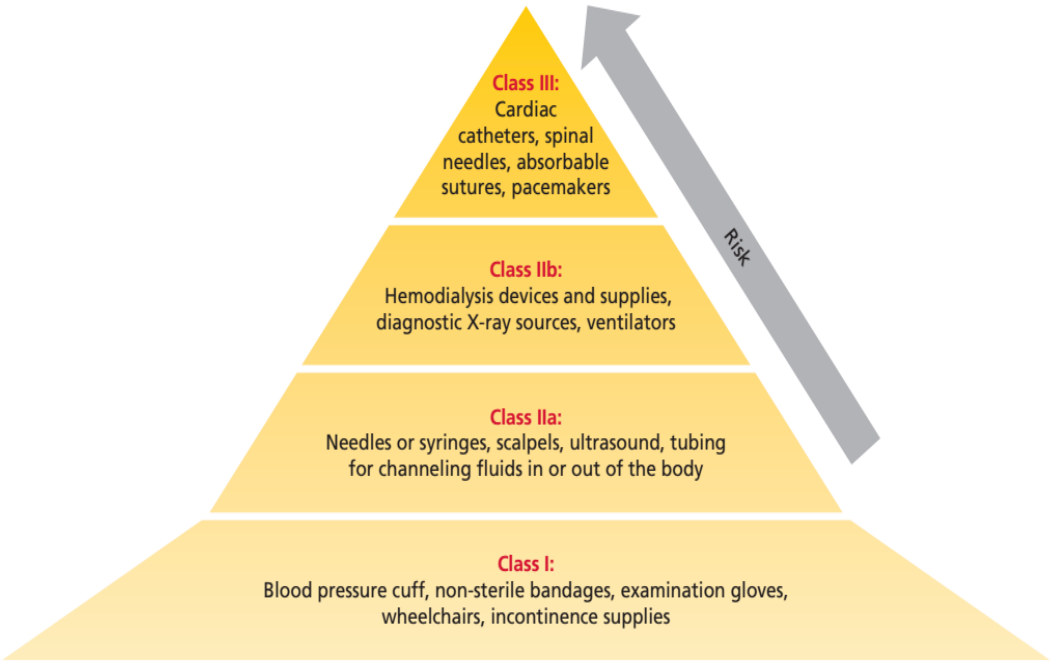


Figure 2. 1: European‘s risk-based medical device regulatory system[21]

The Global Harmonization Task Force is a voluntary group of representatives from medical device respective countries regulatory authorities. It was founded in 1993 by the governments and industry representatives of Australia, Canada, Japan, the European Union, and the United States of America [19]. It has classified medical device into class A, class B, class C and class D where class D represents the highest risk [22]. Ethiopia has adopted the Global Harmonization Task Force classification technique.

2.4. Medical Equipment Supply Chain Management

It is widely recognized that in medical device supply chain, there are numerous activities which are performed during handling, transportation, storage, distribution and tracking of the device. These activities should be managed and controlled to ensure safety and performance of medical device until being used.

Good Storage Practices for Medical device (GSPMD) and Good Distribution Practices for Medical Devices (GDPMD) are the International Quality Management Systems practices [7]. They assure quality of the medical devices through controlling numerous activities related to handling, transportation, storage, distribution and utilization. These practices could be applied by both suppliers and manufactures. Suppliers must maintain a quality system setting with responsibilities, processes and risk management measures in relation to their activities. These natures of risks are similar with those in the manufacturing environment. The lack of control over those activities may also affect the safety and performance of the device. The PFSA practices should comply with GSPMD and GDPMD standards.

ISO 13485:2003 specifies requirements for a quality management system that can be used by an organization for the design and development, production, installation, servicing of medical devices and provision of related services. The adoption of a quality management system should be a strategic decision of an organization. The design and implementation of an organization's quality management system is influenced by varying needs, particular objectives, the products provided, the processes employed and the size and structure of the organization [23].

The quality system regulations of FDA are discussed as follows:
Handling each manufacturer shall establish and maintain procedures to ensure that mix-ups, damage, deterioration, contamination, or other adverse effects to product do not occur during handling.

Storage (a) each manufacturer shall establish and maintain procedures for the control of storage areas and stock rooms for product to prevent mix-ups, damage, deterioration, contamination, or other adverse effects pending use or distribution and to ensure that no obsolete, rejected, or deteriorated product is used or distributed. When the quality of product deteriorates over time, it shall be stored in a manner to facilitate proper stock rotation, and its condition shall be assessed

as appropriate. (b) Each manufacturer shall establish and maintain procedures that describe the methods for authorizing receipt from and dispatch to storage areas and stock rooms.

Distribution (a) each manufacturer shall establish and maintain procedures for control and distribution of finished devices to ensure that only those devices approved for release are distributed and that purchase orders are reviewed to ensure that ambiguities and errors are resolved before devices are released for distribution. Where a device's fitness for use or quality deteriorates overtime, the procedures shall ensure that expired devices or devices deteriorated beyond acceptable fitness for use are not distributed. (b) Each manufacturer shall maintain distribution records which include or refer to the location of: (1) The name and address of the initial consignee; (2) The identification and quantity of devices shipped; (3) The date shipped; and (4) Any control number(s) used.

Installation (a) each manufacturer of a device requiring installation shall establish and maintain adequate installation and inspection instructions, and where appropriate test procedures. Instructions and procedures shall include directions for ensuring proper installation so that the device will perform as intended after installation. The manufacturer shall distribute the instructions and procedures with the device or otherwise make them available to the person(s) installing the device. (b) The person installing the device shall ensure that the installation, inspection, and any required testing are performed in accordance with the manufacturer's instructions and procedures and shall document the inspection and any test results to demonstrate proper installation.

Environmental control (a) where environmental conditions could reasonably be expected to have an adverse effect on product quality; the manufacturer shall establish and maintain procedures to adequately control these environmental conditions. Environmental control system(s) shall be periodically inspected to verify that the system, including necessary equipment, is adequate and functioning properly. These activities shall be documented and reviewed.

Contamination control (a) each manufacturer shall establish and maintain procedures to prevent contamination of equipment or product by substances that could reasonably be expected to have an adverse effect on product quality.

Buildings (a) Buildings shall be of suitable design and contain sufficient space to perform necessary operations, prevent mix-ups, and assure orderly handling.

It is, therefore, possible to conclude the supplier shall establish and maintain procedures that comply with the manufacturer's requirements for handling, storage, distribution, and installation of medical devices. Before and after the devices are imported, the supplier should implement and maintain those procedures. Medical devices are stored apart from other goods and under conditions complying with the instructions of the manufacturer. Concerning ambient humidity, temperature and light requirements, medical device should have a proper pack, handle and store.

During transportation, medical device should be transported via suitable vehicle and the manufacturers' instructions with respect to temperature, humidity, vibrations and the risk of physical damage should be taken into account. Understandably, factors that hinder the suppliers' quality system are properly monitored and there should be an appropriate quality system regulation in the organization.

For manufacturers and importers in the supply chain system, handling, storage, distribution, installation, and environmental control are the most important steps in their quality system. It is obvious that after a product is distributed, a manufacturer rarely has direct control over the product or how it is used. This quality system management should also be implemented at the supplier level in the supply chain system to ensure the quality of the device at the point of use to provide a quality healthcare service.

2.5. Warehousing

It is true that a warehouse of medical equipment is much more than a building that provides a space for storage. It must be designed in special way to receive, store, organize and distribution medical equipment efficiently. According to Rouwenhorst et al. (2000) warehousing can be described in three different angles: processes, resources and organizations [24].

Processes: there is a flow when products arrive to the warehouse and are taken through numbers of steps or activities until they are shipped out these are receiving, inspection, inventory control, storage, order-picking, accumulation and storing and shipping. These activities are

called processes [24, 25]. This means that processes are the overall activities that the supplier receive medical equipment and put it in appropriate place after inspection and then send the devices to different facilities

- **Receiving:** Goods that arrive in the receiving room are isolated, inspected, and if found to be acceptable, entered in to the stock-recording system. Receiving reports are prepared.
- **Inspection:** Draw sample from shipment and inspect (or arrange for inspection) to ensure compliance with specifications on purchase orders; report on status of inspection to purchasing and inventory control; count material and check against shipping invoice; report on status of count to inventory control. Note any discrepancies.
- **Inventory control:** Operate manual or automated inventory control system; provide directions for moving supplies to/from storage; provide information to management on receipts, issues, and stock balances; reconcile inventories to book or automated records; coordinate physical inventories.
- **Storing:** the task of moving usable commodities from the receiving area and placing them in predefined locations within the warehouse (either on the floor, shelf, or rack).
- **Retrieval:** is moving usable commodities from one or more locations (for example, the floor, shelves, or racks), and transporting them to the shipping area where they can be processed for shipment to customers.
- **Shipping:** includes the tasks that help prepare usable commodities for shipment to customers and the placement of those commodities on vehicles for transport to the customers.

Resources: all tools, equipment and human resources that are needed to operate in a warehouse system. Example of resources could be: the storage unit, the storage system, order picker auxiliaries, a computer system, personnel, and etc.

Organizations: all procedures and methods such as planning and control which are used in a warehouse system in order to control the flow of process are called organization. An example of this could be definition decisions of the process flow at the design stage [24].

Basically, there are three types of warehouses: Distribution warehouses, Production warehouses, Contract warehouses. A distribution warehouse is a warehouse in which products from different suppliers are collected (and sometimes assembled) for delivery to a number of customers. A

production warehouse is used for the storage of raw materials, semi-finished products and finished products in a production facility. A contract warehouse is a facility that performs the warehousing operation on behalf of one or more customers [26].

2.6. Steps of Warehouse Layout Designing

There are different ways in steps of designing a warehouse layout. Mohsen (2010) presented designing of warehouse layout in 14 steps [27]. Whereas, Jinxiang et al. (2010) warehouse design steps are in five major steps [28]. These are:

1. The overall warehouse structure determination
2. Sizing and dimensioning the warehouse and its departments
3. The detailed layout determination within each department
4. Warehouse equipment selection
5. Operational strategies selection

The most critical factor in warehousing is space. How an organization organizes and uses space has a profound effect on the efficiency of the personnel and their ability to improve service delivery for their customers. Layout planning is the discipline of allocating the space requirements of a warehouse and specifying how that space should be organized to facilitate identifiable warehouse activities [25].

The main objectives of layout planning are to

- use space efficiently
- promote the efficient handling of commodities
- provide economical storage
- provide flexibility to meet changing warehousing requirements

When a warehouse layout is designed, [25] one should take into consideration three steps:

1. Identify warehouse activities that require layout planning.
2. Determine the space requirements and ideal layout for each warehouse activity.
3. Develop a realistic layout by reconciling space requirements with existing constraints.

It is therefore possible to conclude that so as to design an effective warehouse one should employ the above proposed steps of warehouse design.

2.7. Criteria of Medical Equipment Warehouse Layout Design

The design of a Medical Equipment supplier warehouse layout should be in line with the manufacturer quality system regulation. It should consider adequate space for receiving, inspection, packaging, labeling, storage, etc. This is to minimize contaminants, assure orderly handling procedures, and prevent mix-ups.

The other variable that can significantly affect a warehouse layout design is the environment issues. Some environmental factors to be considered are lighting, ventilation, temperature, humidity, pressure and static electricity [7]. Appropriate racking systems and material handling equipment gives right focus for warehouse operations [25].

2.8. Warehouse Management Systems

In the supply chain, a warehouse management system is an essential component for linking the stakeholders. It is necessary to allocate medical equipment efficiently and effectively to enhance the productivity and reduce the operation costs of the warehouse. Therefore, WMSs have been developed for handling and monitoring of medical equipment in the warehouse[29].

A warehouse links the upstream and downstream entities. The performance of these operations affects not only the productivity and operation costs of a warehouse, but also the whole supply chain. Thus, information systems such as WMS is implemented for automation of a warehouse operation [29].

It is widely recognized that warehousing systems are classified into manual or/and computerized. A manual control system refers to physical, paper-based technology that is to attempt to streamline warehousing operations. Due to demands for accurate real-time information, expectations of next-day service and marketplace competition the use of manual systems is not preferable. Computerized WMS is a technology that integrates software, barcoding equipment, and radiofrequency communications to provide efficient medical equipment management services. The software component of a WMS is essential. The other two components: radio frequency communications equipment and bar coding equipment are optional [25, 30].

WMS, assisted by software, manage warehouse activities and monitor the product in the warehouse. A WMS supports all the tasks routinely performed within a warehouse: receiving, storing, packing and shipping products, and managing inventory. On the other hand, the major five benefits of implementation of WMS are zero information errors, reduced information lead times, increased storage capacity, optimal space utilization, increased labor productivity [29, 31].

The WMS software is the brain of the system. It stores data of products and customers profiles, and guide warehouse personnel to receive, store, and ship products to customers based on current inventory levels [25]. For the development of web based management system, the software part needs different tools. These are Web server, MySQL, HTML and PHP. Web server is software that delivers Web pages to the world. MySQL is a relational database management system that store information for the web database application. PHP is the scripting language that used to develop the application. It provides the dynamic functionality of the Web site. HTML is a markup language used to describing web pages. These tools are chosen because of their popularity for this application [32].

2.9. Supply Chain Performance Evaluation

Supply Chain Performance Measures (SCPM) serve as an indicator of how well the SC system is functioning. Measuring SC performance can facilitate a greater understanding of the SC. It helps to improve its overall performance [17]. The fundamental success of supply chain management involves the effective coordination and integration of all the entities among the various supply chain partners. Healthcare supply chain management system always seeks the effective value chain performance. Therefore, there are multitudes of factors to be considered so as to ensure on-time-delivery, protection and product integrity from origin to destination, etc. [33].

The Supply Chain Operations Reference (SCOR) – model integrates the concept of business process re-making, setting up benchmarks, and process measurement into a cross functional framework. This model specifies five supply chain performance metrics in two categories. First categories are customer-facing metrics that includes reliability, responsiveness and flexibility. Second categories are the internal facing metrics that include costs and assets [34] as shown in Table 2.1.

Table 2.1: Summary of the SCOR performance Metrics to evolution SCPM [35]

Attributes	Experienced Impact
Reliability	Coordinated action will reduce the potential for overall supply chain disruption and, therefore, provide a better ability to deliver product reliably through appropriate mitigation plans. The performance of the supply chain in delivering: the product to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.
Responsiveness	Coordination of mitigation and recovery activities can increase the speed of response as well as result in a more coordinated and faster supply chain. It can help in implementing faster response by reduce the lag between events and people awareness
Flexibility	Having coordinated response programs in place will speed general communication and coordination across the supply chain, improving the ability to coordinate reactions to surges or decreases in demand. It can help during planning activities providing the most valued information to decision makers within the whole supply chain
Costs	By sharing common activities within the supply chain and removing useless or ineffective process, this practice can contribute to cost reduction. By avoiding various negative outcomes, can avoid costs. If risk is discovered early, then is more potential to prevent it or at least minimize the impact of it on costs.
Asset Management	The variability of inventories in the supply chain is reduced. Designing for risk mitigation reduces the costs associated with a disruption by locating assets outside of high risk geographic areas.

Medical equipment supply chain system can be organized to achieve the quality system regulation of the equipment in a supply chain system. In the medical equipment supply chain system different stakeholders are involved under any condition who are working tends to ensure quality, integrity and safety of the equipment. In this case the manufactures have to develop supplier assessment policy to evaluate the performance of the supplier. Moreover, the qualities of the supplier also show ensuring the quality, safety and integrity of the equipment. It is therefore possible to say these are one of the criteria for performance of the medical equipment supply chain system [7].

Warehouse is obviously affecting the performance of the supply chain to meet customer expectations. Performance evaluation is an important action for both warehouse design and operation. It also provides warehouse design in areas such as cost, throughput, space utilization, and services which provide feedback and useful information about how specific design or operating activity performs in order to meet the requirements, and ways to improve it [28].

Table 2.2 present the seven important metrics that have been identified as measures of warehouse performance.

Table 2. 2: A brief outline for all warehouse performance management [36]

Criteria	Sub criteria	Performance measurements
Cost	Distribution cost	The transportation and handling cost, safety stock cost and duty.
	Inventory cost	The work-in-process and finished goods inventories.
	Warehouse cost	Associated with allocation from one tier to another.
	Intangible cost	Quality costs, product adaptation or performance costs and coordination.
	Overhead cost	Total current landed costs.
Resource Utilization	Labor, machine, capacity, energy	Investigate the percentage of excess or lack of that particular resource within a period.
Quality	Customer dissatisfaction	The number of customer complaints registered.
	Customer response time	The amount of time between an order and its corresponding delivery
	On-time delivery	The percentage of orders delivered on or before the due date
	Fill rate	The proportion of orders that can be filled immediately.
	Stock out probability	The instantaneous probability that a requested item is out of stock while number of backorders is the number of items backordered due to stock out
	Accuracy	Percentage of accurate goods delivered to clients.
Flexibility	Labor	The number of tasks a worker can perform.
	Material handling	The number of existing paths between processing centers and the variety of material which can be transported along those paths without incurring high transition penalties or large changes in performance outcomes.
	Operation	The number of products which have alternative sequencing plans without incurring high costs or large changes in performance outcome
	Delivery	The percentage of slack time by which the delivery time can be reduced.
Visibility	Time	Time required from when the designer changes his idea
Trust	Consistency	The percentage of late or wrong delivery to the next tier which led to an inconsistent supply. For late delivery, it is the percentage of time delayed whereas for wrong delivery, it is the percentage of returned goods.
Innovative -ness	New use of technology	The percentage decrease in time necessary for using a new technology

WMS is a key instrument in order to evaluate the performance of supply chain system. The WMS may also helpful to evaluate after the design process is accomplished. During the warehouse operation, WMS use to control the transaction process, reduce costs, improve the order-picking operation, faster inventory turns, increase the throughput capacity, enhance customer service and improve labor productivity [26].

2.10. An Overview of PFSA

PFAS was established in 2007 by Proclamation No. 553/2007, to systematize the poor medicines supply management system in public sector at an affordable price. The PFSA is responsible for the forecasting, procurement, storage and distribution of medicine and medical supplies to health facilities across the country. The objectives of PFSA are to:

- enable public health institutions supply quality assured essential pharmaceuticals at affordable price in sustainable manner to the public;
- play a complementary role in developmental efforts for health service expansion and strengthening by ensuring enhanced and sustainable supply of pharmaceuticals;
- create enabling conditions for enhancing the accumulation of fund in its revolving and cost recovery process and thereby ensure the realization of the objectives [8].

The overall strategic goal of PFSA is to ensure availability of pharmaceuticals at all levels of the public sector healthcare delivery system thorough an integrated supply chain. This structure is designed by giving mandates to each function. There are nine directorates directed by the General Director have a major responsibility. Some of them are the Procurement directorate, Storage and Distribution directorate, Forecasting and Capacity building directorate and Quality and Compliance Directorate works together FMHACA to assure the quality of pharmaceutical products by setting standards for the facilities [8, 12].

PFSA has established 21 different hubs at different regions and use HCMIS (Health community management information system) database system. Its purpose is to handle information for every transaction management within the PFSA. This reveals that there is an improvement on the supply chain of the national healthcare system. As stated on the proclamation, the FMOH is more focus on pharmaceutical products rather than medical equipment. Researches were done to improve quality of delivering and accessibility of pharmaceutical products to the facilities. However, little attention was given to the medical equipment as required.

Currently the PFAS established a new directorate named Medical equipment utilization and specification preparation directorate. The new directorate has biomedical engineers who are working in their respective responsibilities. This implies that the country gives emphasis on

managing medical equipment within supply chain system. However, as compared to the current level of health sector technology in the world, it is at its infant stage.

Procurement Process in the PFSA facilities present their inquiry by developing their own specific list of medical equipment, laboratory reagent and chemicals. Then PFSA set a purchase order agreement based on bid. The PSFA is also responsible to receive the orders according to specification, then store the equipment and finally distribute. As it can be seen in Figure 2.2, whenever the PFSA procures medical equipment for facilities, they interact with stakeholders and also with the facilities for different purpose like evaluating purchasing order by FMHACA for regulation, and they also interact with the agent who supply the equipment.

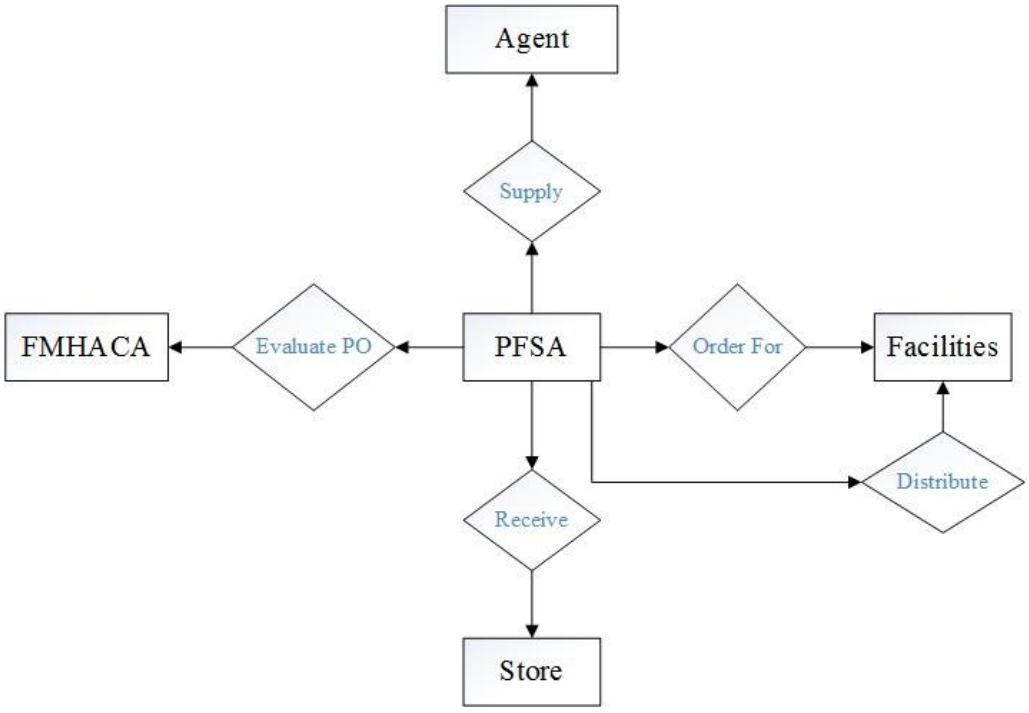


Figure 2. 2*: The flow chart shows the PFSA interact with other entities interaction*

The flow chart depicted in Figure 2.2 shows how the PFSA interacts with other stakeholders with in medical equipment supply chain management system.

CHAPTER 3: Research Methodology

This chapter explores the research design, methodology and procedures that were used for the research work. It also describes in detail the methods and materials used in the study such as the study area, sampling method, data collection and analysis methods as well as warehouse layout designing and software developing tools. In this research qualitative and quantitative multiple case study methods were employed to understand the medical equipment supply chain management system of PFSA.

3.1. Data Collection

Having spent sufficient time for about two months from August 4 – September 30, 2016, the researcher tried to grasp the working practices to understand about the current supply chain management system of PFSA. The study involved gathering information about the current medical equipment supply chain system from the perspective of safety, quality, and integrity proper delivery, technical support and functional supervision of the equipment at PFSA. The study employed qualitative and quantitative data collection method. The necessary information was collected through survey questionnaire, direct observation and structured interviewing. The quantitative data was obtained from questionnaire whereas the qualitative data that was obtained from interview and direct observation.

3.1.1. Survey Questionnaire

The survey questionnaire was developed to extract reliable information about the current medical equipment management supply chain system in PFSA and facilities. Questionnaire was prepared accordingly (Annex I and Annex III). The questionnaire was prepared for respondents who have been working at PFSA and facilities, especially administrative staff. The aims of the questionnaire were to assess the current practices of PFSA for the handling, storing and distributing, technical supports, functional supervision and proper delivery of the equipment.

3.1.2. Direct Observation

Since this study was carried out through a multiple case study method, direct observation of the PFSA and the facilities was important source for gathering data. Direct observation used as a

means to assess the techniques used in record keeping practices and system of operation within existing supply chain at PFSA through meeting, site-visit activities.

The researcher found direct observation a vital tool to generate facts about the current status of the supply chain management at PFSA. It helps for assessing the procedure of handling, storing, distributing and installation of the medical equipment. This is to ensure the safety, quality and integrity of the product. It provides for assessing the WMS, equipment loading and unloading procedures and equipment distribution procedure and process of picking equipment for distribution.

3.1.3. Structured Interview

Semi-structured interview was used to collect data at PFSA and facilities (see Annex II and Annex IV). The lists of issues deemed relevant in this study:

1) The PFSA managers, officers, experts
2) The employee who has a direct access on the warehouse management system
3) The employee who is responsible in receiving, inspecting, storing and distributing the equipment at the warehouse.

3.2. Sample Size Determination

3.2.1. The Study Area

The study mainly focuses on PFSA which is located in Addis Ababa Gulele sub-city. There are four reasons to select PFSA. Firstly, PFSA is the only responsible body established by proclamation to systematize the public healthcare supply chain system. Secondly, management of medical equipment is the priorities to provide quality healthcare service to create healthy community. Thirdly, while the researcher was carrying out practical attachment, he observed substantial problems in relation to medical equipment handling, storing, and distribution. Fourthly, there is also lack of system software that integrates PFSA with the facilities for better utilization.

3.2.2. Sample size

To get a picture about medical equipment supply chain management system at PFSA, the medical equipment expertise or equipment professionals and managers working at the main hub

were expected to provide the required information. By using purposive sampling technique, 30 professionals (the PFSA managers, officers, and expertise) were participated as key informants.

Even though the study was focused on PFSA, 24 professionals who have been working in managing medical equipment in 6 hospitals were involved. These are Tikur Anbessa Specialized Hospital, St. Paul Hospital millennium Medical College, St. Peter Specialized Hospital, Menelik II Referal Hospital, Yekatit 12 Hospital and Medical College, Ras Desta Damtew Memorial Hospital. The four personnel are department head in biomedical engineering, procurement, biomedical engineer and technician in each hospital. This is to ensure and obtain customer information about the PFSA proper delivery, technical support and functionality supervision of medical equipment.

A total of 54 respondents were participated; thirty questionnaires were distributed to the PFSA professionals at the main hub and the rest twenty four questionnaires were distributed to hospital professionals. However, 25 questionnaires from PFSA and 18 from hospitals were returned.

To analyze the data, we used SPSS software. First, the data will be analyzed for suitability of regression analysis. Then, availability of the lost data is checked through frequency analysis. To see whether or not there is any multiple ties between independent variables, the simple correlations, variance increase factors (VIFs), tolerance value and the condition index (CI) are examined. According to the Analysis of Variance (ANOVA) statistics, through the multiple regration analysis, it is check whether or not the independent variables in the standard model are signifiantly predictive of the dependent variable. We also measure the overall model fit using the coefficient determinations, R^2 and significance of the F-value. The absolute value of β (Beta) is used to indicate the order of importance of the independent variables.

3.3. Warehouse Layout and Software Development

For the warehouse layout designing process, I followed basic steps. These are identifying: (1) the purpose of the warehouse, (2) activities, process and resource, (3) required classes, (4) size and dimension, (5) equipment storage assignment policy and (6) develop the layout.

In the WMS software development section, the first phase is to identify the user groups that interact with the software. In second phase, system requirements are determined. In the third phase, functional and non-functional requirements are identified from the users requirement [37].

Microsoft applications are used for flowcharts. AutoCAD is used for layout design. HTML, PHP, JavaScript, MySQL and WampServer tools are used to develop the system software.

CHAPTER 4: Survey Result and Discussion

In this section, an attempt has been made to assess the current handling, storage and distribution practices at PFSA and to compare with FDA and WHO standards. Moreover, the current interaction and collaboration between stakeholders were evaluated based on quality of supply chain performance.

4. Results and Discussion

In order to assess the medical equipment supply chain management system at PFSA, 54 questionnaires were distributed for this assessment. 30 questionnaires were distributed to PFSA professionals and the rest 24 were distributed to 6 hospital professionals found in Addis Ababa. Out of 54 questionnaires, 25 and 18 from PFSA and hospitals were returned, respectively. The survey data parameters, extracted from the questionnaire (see the questionnaire in Annex I and III), results are presented.

Qualitative data obtained from interviews (3 officers were interviewed) and direct observations (stores in the main office were offices) were also used for the study. The qualitative data were compiled `to support the quantitative data as presented in the subsequent sections. Those respective results are valid, reliable and significant.

4.1. Result of Medical Equipment Storing Practices and Storing Method

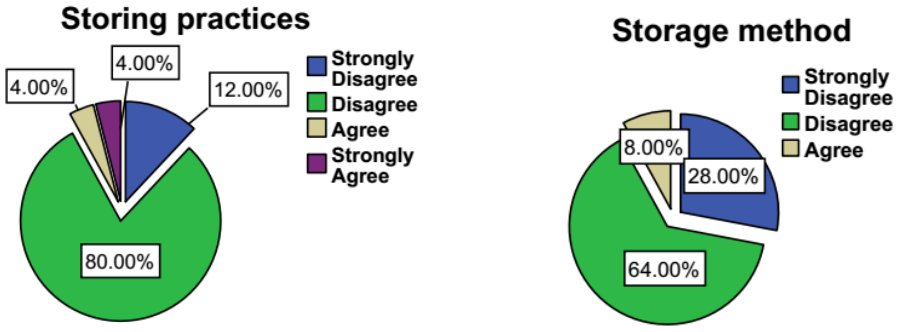
Frequency Tables and pie charts

Table 4. 1. Storage Practices

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	12.0	12.0	12.0
	Disagree	20	80.0	80.0	92.0
	Agree	1	4.0	4.0	96.0
	Strongly Agree	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

Table 4. 2. Storage method

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	7	28.0	28.0	28.0
	Disagree	16	64.0	64.0	92.0
	Agree	2	8.0	8.0	100.0
	Total	25	100.0	100.0	



(a) (b)

Figure 4. 1. Pie chart of (a) Storing Practices (b) Storing Method

4.2. Discussion of Storing Practices and Storing Method Results

Based on the results obtained from SPSS software, in Figure 4.1 80% and 12% of the respondents disagree and strongly disagree, respectively that the current storage practices are in line with Good Storage Practices (GSP) guidelines. However, only 4% and 4% of the respondents agree and strongly agree respectively that PFSA are applying good storage practices. This implies that PFSA is not practicing good storing guideline. FDA recommended good storage guideline in order to ensure the performance and quality of equipment within the supply chain [7]. We can conclude that there is lack of proper storage practices at PFSA and has a positive correlation with the statements of the problem.

Figure 4.1 also shows the result of the assessment on the storage method. Accordingly, 64% and 28% of the participant disagree and strongly disagree respectively that the storage condition of medical equipment in the warehouse is based on their type and class in zone. Only 8% of the participants agree that that medical equipment was stored with their type and class. In principle, to ensure the quality, performance and integrity of medical equipment medical equipment should be stored based on their type and class[7]. To verify this quantitative data, the researcher visited

a store found in the main office. It has been observed that medical equipment was mixed-up with other pharmaceutical products. And also PFSA is not following standard procedure to store the equipment based on manufacturer recommendation. Such poor storage practices will naturally lead to equipment mix-up, damage, deterioration, contamination, or other adverse effects.

4.3. Result of Warehouse Condition

Frequency Table and Pie Chart

Table 4. 3. Warehouse space

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	11	44.0	44.0	44.0
	Agree	13	52.0	52.0	96.0
	Strongly Agree	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

Table 4. 4. Tracking method

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	12.0	12.0	12.0
	Disagree	11	44.0	44.0	56.0
	Agree	10	40.0	40.0	96.0
	Strongly Agree	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

Table 4. 5. Environment condition

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	1	4.0	4.0	4.0
	Disagree	18	72.0	72.0	76.0
	Agree	6	24.0	24.0	100.0
	Total	25	100.0	100.0	

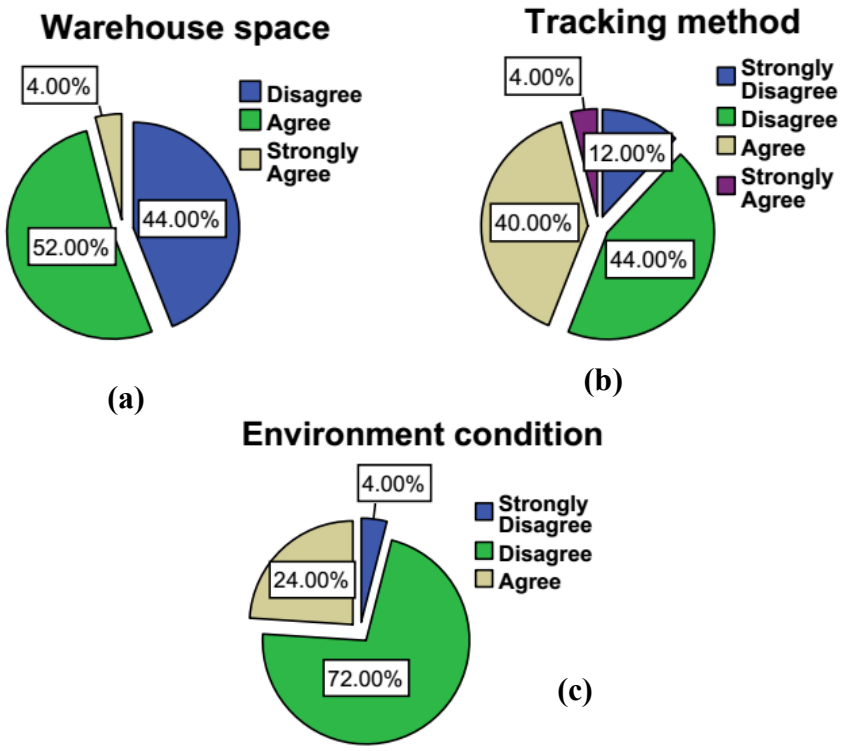


Figure 4. 2. (a)Warehouse space (b) Tracking method (c) Environment condition

4.4. Discussion of warehouse condition

As shown in Figure 4.2 about warehouse space, 52% of the respondents agree and 4% of strongly agree that PFSA has sufficient space to perform activities. This idea has been also raised during direct observation that warehouses space was not a major problem but the problem was ineffective space management to perform inspection and other activities. The presence of sufficient space in a warehouse management is critical to increase storage activities efficiency. The most critical factor in warehousing is space. How an organization organizes and uses space has a profound effect on the efficiency of the personnel and their ability to improve service delivery for their customers[25].

Figure 4.2 about tracking method shows that 40% and 4% of the participants strongly agree and agree respectively that the stock rotation system and pick and put-away accuracy procedure are exercised properly. Whereas, 44% and 12% of participants disagree and strongly disagree, respectively, that the stock rotation system and pick and put-away accuracy procedure are not exercised properly. This can be interpreted as that the current warehouse management system does not support effective stock rotation system. The data obtained from interview showed that PFSA usually distributes medical equipment when it is requested by the facilities. Other research

[12] also show that item tracking system at PFSA warehouse is semi advanced and manual 29.2% and 54.8%, respectively. A study [38] also discussed that a warehouse layout has a distinguished effect on picking travel distance. It proved that the layout design has an effect of more than 60% on the total travel distance, and also found the strong relationship between warehouse layout and picking travel distance. This affects the performance of warehousing and in advance the supply chain system.

Figure 4.2 shows warehouse environment. From the figure, 72% of the respondents disagree that there is a procedure to keep the environmental conditions in the warehouse. The interview and direct observation data also support the above analysis that there is lack of procedure to put medical equipment in environmentally safe condition. As per the GSP guideline, medical equipment should be kept away from humidity, dust, water, temperature and light. The environmental conditions could have an adverse effect on product quality. PSFA shall establish and maintain procedures to adequately control these environmental conditions [7]. However, our study shows that PFSA has not yet implemented the standard guideline.

4.5. Result of Inspection, Distributing Technique and Proper Delivery

Frequency Table and Pie Chart

Table 4. 6.Equipment inspection

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	8.0	8.0	8.0
	Disagree	16	64.0	64.0	72.0
	Agree	7	28.0	28.0	100.0
	Total	25	100.0	100.0	

Table 4. 7. Apply GDP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	12.0	12.0	12.0
	Disagree	18	72.0	72.0	84.0
	Agree	3	12.0	12.0	96.0
	Strongly Agree	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

Table 4. 8. Proper delivery

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	12.0	12.0	12.0
	Disagree	16	64.0	64.0	76.0
	Agree	6	24.0	24.0	100.0
	Total	25	100.0	100.0	

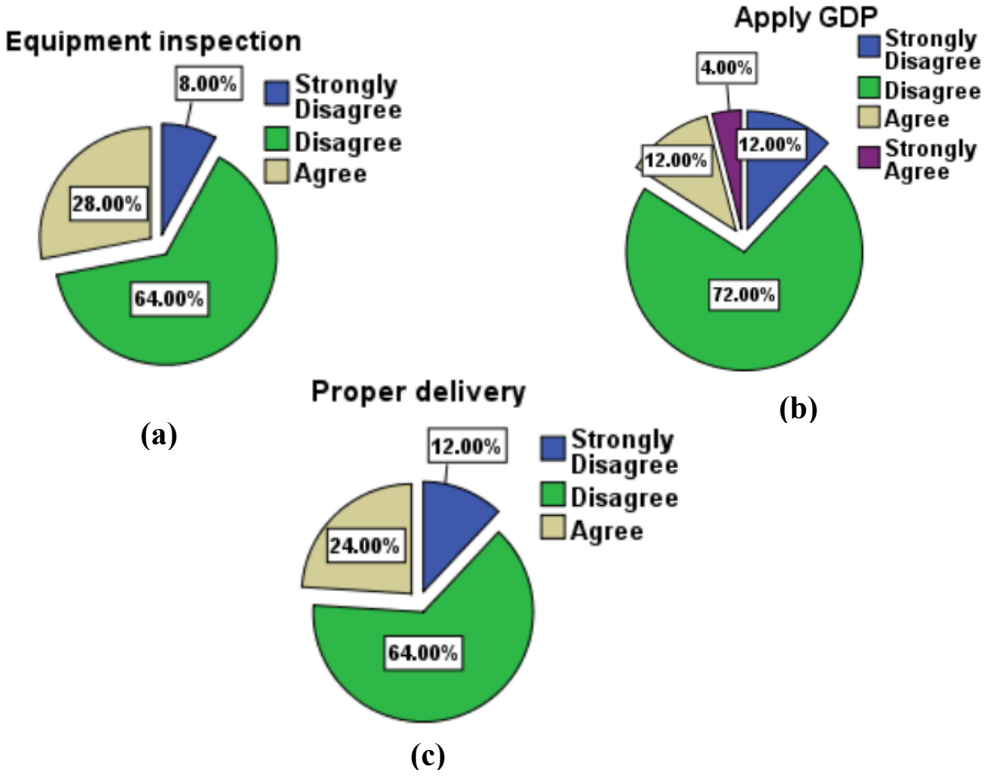


Figure 4. 3. (a) Inspection, (b) Distributing Technique and (c) Proper Delivery

4.6. Discussion of Inspection, Distributing Technique and Proper Delivery

Newly arrived medical equipment is supposed to be technically inspected according to the purchase order specification. This is to identify any of the missing parts/accessories, physically damage, non-functionalities, obsolete, deteriorated, contaminated equipment [7]. Regarding this, Figure 4.3 which present data about inspection shows that 64% of the participants disagree for the proper inspection practices and 8% of strongly disagrees. In contrast, the rest 28% agree that there is adequate inspection. This indicates that majority of the respondents revealed the current practice does not have adequate inspection. In relation to this, data analyzed from direct observation and interviewing scheme supported that there is lack of proper inspection. Due to

lack proper inspection, physically damaged, non-functional, obsolete, deteriorated, and contaminated equipment could be distributed.

Figure 4.3 presents data result about application of Good Distribution Practice (GDP). The result indicates that 72% of the respondents disagree and 12% strongly disagree that PFSA distribute equipment based on manufacturer recommendation while the rest 16% agree that PFSA follows the manufacturer recommendation. This indicates that PFSA has not been practicing the GDPs while distributing the medical equipment. In this regard, qualitative data also show that PFSA does not have GDP, interactive and automated system to control equipment at the time of distribution. This may cause unnecessary exchange of equipment and equipment specification between facilities. We have discussed that medical device should be transported via suitable vehicles to protect them from hazardous temperature, humidity, vibrations and any risk of physical damage [7].

Proper delivery is the measure the medical equipment delivery activities such as avoiding physical damage, on-time delivery and on-time installation. Figure 4.3 presents the result about proper delivery. It revealed that 64% of disagree and 12% of strongly disagree on the current practices that there is no medical equipment mix-ups, damages, deteriorations, contamination, and other adverse effects in PFSA during handling, storage, distribution and installation process. Only 24% of the respondents agree that there is a delivery. This shows that there is a late delivery and installation of medical equipment to the facilities. From this we can understand that the proper medical equipment delivery is not exercised as well.

In response to one of the open-ended items in the questionnaire, “If you have additional idea about the current warehousing approach for the medical equipment in PFSA …”, about 28% of the respondents said that medical equipment were stored along with pharmaceutical product wherever free space is available. They strongly recommended that the medical equipment storage should be separated from the pharmaceutical product.

For medical device handling, storage, distribution and installation practice, FDA recommends the manufacturer to develop standard procedure document for every device. This should be

applied throughout the supply chain to protect the device from adverse effects. But, the PFSA experience is far from the recommended standard procedures.

In general this case study shows that there is no proper practice towards applying standard procedures for medical equipment management. Currently most of the activities in PFSA are not performed based on FDA and manufacturer recommendations. This study reveals that the PFSA should give special attention to improve the medical equipment supply chain system.

4.7. Result of Equipment Functionality, Technical Support and Facilities' Satisfaction

Frequency Table and Pie Chart

Table 4. 9. Functionality

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	9	50.0	50.0	50.0
	Disagree	5	27.8	27.8	77.8
	Agree	3	16.7	16.7	94.4
	Strongly Agree	1	5.6	5.6	100.0
	Total	18	100.0	100.0	

Table 4. 10. Technical support

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	4	22.2	22.2	22.2
	Disagree	9	50.0	50.0	72.2
	Agree	4	22.2	22.2	94.4
	Strongly Agree	1	5.6	5.6	100.0
	Total	18	100.0	100.0	

Table 4. 11. Satisfaction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	4	22.2	22.2	22.2
	Disagree	11	61.1	61.1	83.3
	Agree	3	16.7	16.7	100.0
	Total	18	100.0	100.0	

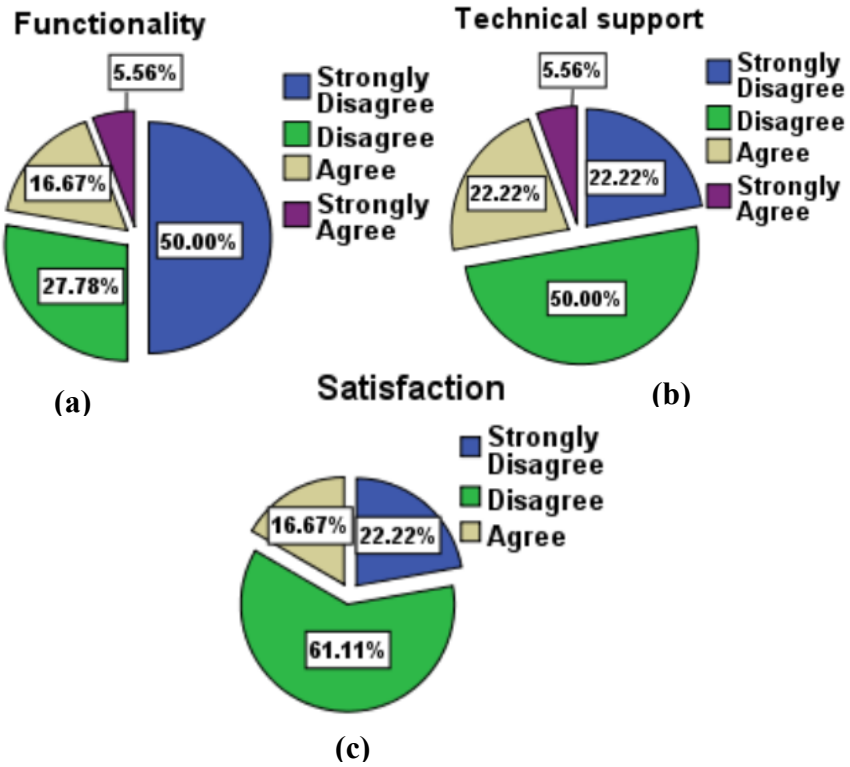


Figure 4. 4. (a)Functionality (b) Technical Support (C) Satisfaction

4.8. Discussion of Equipment Functionality, Technical Support and Facilities' Satisfaction

PFSA is supposed to carryout medical equipment functionality supervision for facilities. Figure 4.4 shows that 50.00% and 27.78% of the participants strongly disagree and disagree respectively for the frequent functionality follow up. The rest 16.67% and 5.56% of participants agree and strongly agree, respectively for regular follow up during utilization of the equipment. Dessalegn (2015) also identified on his research that most of the respondents suggested as PFSA need to meet regularly with health facilities, regions, and health programs. This implies that there is little regular follows up to the facilities during utilization of the equipment.

The other information parameter is about technical support which is about a service that comprises: (1) training support, (2) technical follow up, (3) commissioning and decommissioning, (4) order and specification preparation, (5) maintenance, (6) identification of nonfunctioning equipment. These duties are provided by the PFSA to facilities. The results presented in Figure 4.4 shows that about 50.00% and 22.22% of the participant disagree and strongly disagree respectively that facilities get the necessary technical support from PFSA. The

rest 22.22% of the participants agree and 5.56% of the participants strongly agree that they get regular technical support during utilization of the equipment. The majority of the participant agreed PFSA does not give technical support whenever and wherever in need. In other words, the data reveals that the cooperation among PFSA and facilities are not enough in order to well manage the equipment. In this point, Ashenafi (2014) also discussed that installation and proper use of medical instruments was found to be the main problem. He identified that most hospitals (75.0%) do not get assistance and support from PFSA to properly install and use medical instruments. He said that Hospitals reported as they have no established system on how and when decommissioning should take place.

Figure 4.4 presented the result about facilities satisfaction which indicates that 61.11% and 22.22% of the participants disagree and strongly disagree, respectively for regular supervision and support provided by PFSA to the facilities. The rest 16.67% are satisfied by the service. This implies that the PFSA has not achieved the objectives it was established for. In order to achieve the objective of PFSA, the supply chain management system need to be improved so as to satisfy the facilities as well as to improve healthcare system. Regarding to this, Eyob (2013) identified that there is about 78.1% of facilities are not satisfied.

4.9. Result of Efficiency of the Current Medical Equipment WMS

In order to support PFSA in its effort of improving the supply chain system, we have conducted a preliminary study on the efficacy and challenge of the existing warehouse management system and on equipment functionality and the level of technical support facilities get from PFSA as described below.

Frequency Table and Pie Chart

Table 4. 12. Automation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	8	32.0	32.0	32.0
	Disagree	13	52.0	52.0	84.0
	Agree	3	12.0	12.0	96.0
	Strongly Agree	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

Table 4. 13. Informative

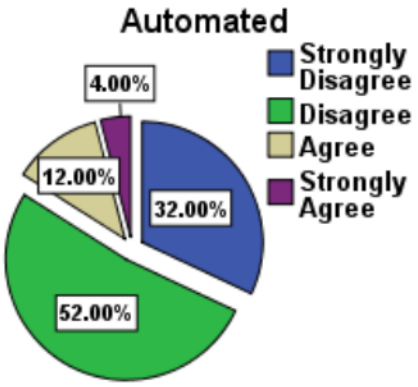
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	12.0	12.0	12.0
	Disagree	18	72.0	72.0	84.0
	Agree	3	12.0	12.0	96.0
	Strongly Agree	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

Table 4. 14. Inventory

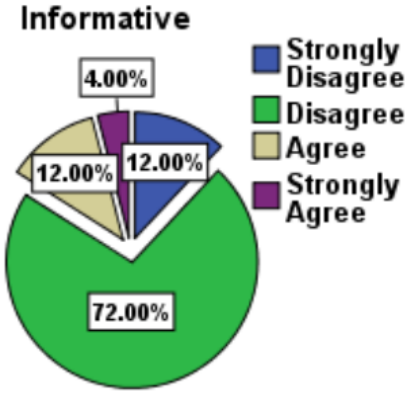
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	13	52.0	52.0	52.0
	Agree	11	44.0	44.0	96.0
	Strongly Agree	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

Table 4. 15. Improvement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	1	4.0	4.0	4.0
	Agree	6	24.0	24.0	28.0
	Strongly Agree	18	72.0	72.0	100.0
	Total	25	100.0	100.0	



(a)



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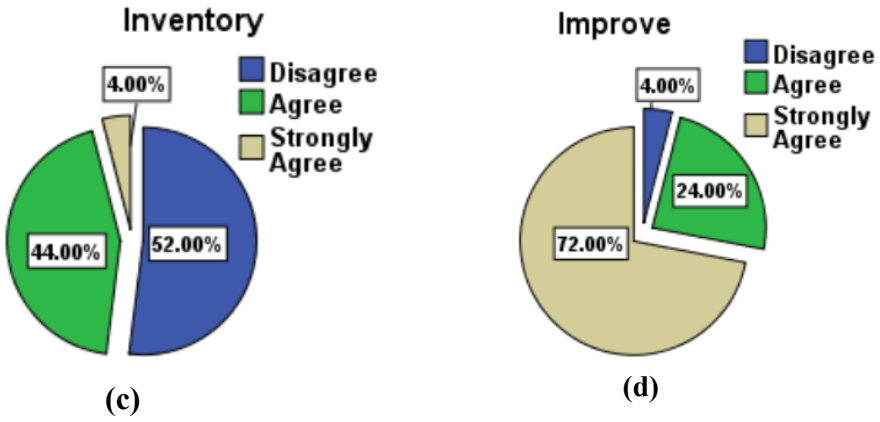


(c) (d)

Figure 4. 5. (a) Automated (b) Informative (c) Inventory (d) Improve

4.10. Discussion of Efficiency and Challenges of the Current Medical Equipment WMS

As seen in the Figure 4.5 which is about automation system, 52% of the respondents disagree and 32% strongly disagree that the current management system is efficient and automated to support activities within the warehouse and the supply chain in advance. This means that the current WMS is inefficient and ineffective. A research, [12] also showed that 61.1% of the warehouse facilities at PFSA are manual. Due to the large size of activities performed at the PFSA, working on papers creates burden to the workers and causes inaccuracy and ineffectiveness in their services.

On the other hand, as it is indicated in Figure 4.5, about 72% and 12% of participants disagree and strongly disagree that the current system (the software) is informative about the equipment. The interview data also indicates that the pharmaceutical product management system (software) is more effective than medical equipment management system software. This shows that the current medical equipment warehouse management system is not customized to manage the medical equipment related activities at PFSA. In addition, in a research [12], about 79.1% of the respondents responded that the usage of management information system (MIS) is weak and the researcher concluded that MIS is not in practice within PFSA and health facilities. Informative system software can create conducive work environment and better efficiency for medical equipment management within the transaction.

The other study parameter is medical equipment inventory. It should consist of required information related to the equipment like quantity, name of manufacturer, date of manufacture,

local agent, name of client, life-time, warranty agreement, storage condition, date of calibration, history of preventive maintenance and other information [39]. Figure 4.5 present the result about inventory which shows that 52% of the participants disagree that the existing system has appropriate inventory. This idea also discussed during interview with the warehouse officer; the inventory is only convenient for pharmaceutical product but not for medical equipment. From this one can conclude that the current management system does not handle required inventory information to manage the medical equipment within the supply chain.

Finally, to know whether there would be a need to improve warehouse management system or not, (as presented in Figure 4.5) about 72% and 24% of the respondents agree and strongly agree, respectively that there is a need to improve and/or develop a new management system.

From the open-ended items of data which intends to let respondents give their opinion on whether the existing system is appropriate or need new system, 20% of participants suggest that PFSA does not have efficient system that helps for managing medical equipment within the supply chain. The respondents also argued that the communication between PFSA and the facilities are very limited. They strongly recommended that PFSA should create a means to give proper services to the facilities.

Most of the activities in PFSA are not performed based on FDA and manufacturer recommendations. Currently, PFSA is working with computerized management system in order to conduit interaction in between facilities and other stakeholders though it was not effective as required. Therefore, In general, PFSA needs to apply best practices on inspection, storage, distribution, proper delivery, technical support and functionality supervision activities in the management of medical equipment in order to increase customer satisfaction.

4.11. Result and Discusion Parameter Dependency Analysis

To see whether or not there are multiple relations between variables simple correlations, variance increase facors (VIFs), tolerace value and the condition index (CI) were examind. When level of significance α =0.05, there exists enough evidence to conclude that at least one of the predictor is useful for predicting; therefore the model is useful [40, 41].

The collected data were categorized in to the following 12 variables, such as Storing practices, Storage method, Warehouse space, Tracking method, Environment condition, Equipment inspection, GDP, Proper delivery, Automation, Informative, Inventory, Improvement. From these variables, only Storing practices, Tracking methode, Equipment inspection, GDP, Proper delivery, and Automation are significantly correlated variables for the model. Out of those correleted variables GDP are selected as dependent variable. The rest five, Storing practices, Tracking method, Equipment inspection, Proper delivery and Automation are independent variables.

Table 4. 16. The multiple relation coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-.357	.358		-.995	.332					
	Tracking methode	.300	.103	.355	2.922	.009	.626	.557	.304	.734	1.362
	Equipment inspection	-.233	.155	-.210	-1.506	.149	.293	-.327	-.157	.557	1.796
	Proper delivery	.578	.151	.542	3.823	.001	.625	.659	.398	.539	1.854
	Automation	.238	.094	.291	2.544	.020	.520	.504	.265	.829	1.206
	Storing practices	.283	.135	.256	2.096	.050	.564	.433	.218	.728	1.373

a. Dependent Variable: GDP

Table 4. 17. The Collinearity Diagnostics

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions					
				(Constant)	Tracking methode	Equipment inspection	Proper delivery	Automation	Storing practices
1	1	5.706	1.000	.00	.00	.00	.00	.00	.00
	2	.119	6.918	.00	.04	.03	.03	.67	.02
	3	.079	8.484	.00	.20	.08	.07	.13	.23
	4	.047	11.065	.13	.72	.00	.00	.18	.27
	5	.028	14.198	.44	.04	.06	.57	.01	.27
	6	.020	16.758	.42	.00	.82	.33	.00	.21

a. Dependent Variable: GDP

Table 4. 18. The model summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.891[a]	.794	.740	.327

a. Predictors: (Constant), Storing practices, Equipment inspection, Automation, Tracking methode, Proper delivery

b. Dependent Variable: GDP

Table 4. 19. ANOVA [a]

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.814	5	1.563	14.659	.000[b]
	Residual	2.026	19	.107		
	Total	9.840	24			

a. Dependent Variable: GDP

b. Predictors: (Constant), Storing practices, Equipment inspection, Automation, Tracking methode, Proper delivery

The simple corelation in Table 4.16 shows that none of the correlations coefficents are higher than 0.8. This means there is not any multiple relation between variables. If variance increase factors (VIFs) in Table 4.16 is equal or higher than 10, there is a multiple relations between variables. Table 4.16 presents VIF values for all variables and each are smaller than 10. In addition to these, if tolerance values are higher than .01, no multiple relation between variables is observed. When the CI is bigger than 30, there are multiple relations between variables [40, 41]. From Table 4.17, all of the calculated CI values are smaller than 30. Thus, we concluded that there were no multiple relations between variables.

We assessed the overall model fit using the coefficient determinations, R^2 and significance of the F-value. From the coefficient of determinations, as presented in Table 4.18, the model's degree of predicting the dependent variables was found to be R=0.891. The model's degree of explaining the variance in the dependent variable was R^2 =0.794. These coefficient values tell us that the model predicts the dependent variable well. Therefore, about 79.4% of the variation in the GDP is explained by all other dependent variables. The regression equation appears to be very useful for making predictions since the value of R^2 is close to 1.

The multiple linear regression analysis result is discused with the ANOVA (Analysis of variance) statistics, we use ANOVA statistics to check how well the model fits the data. An examination of Table 4.19 make it clear that the five independent variables in the standared model are significantly predicative of the dependent variable according to the ANOVA statistics $F = 14.659,\ p < 0.05.$ The result in Table 4.19 indicates that the regression model is significant. If the significance value of p is larger than say 0.05 then the independent variables do not explain the variation in the dependent variable, and the null hypothesis that all the population values for the regression coefficients are 0 is accepted [40, 41].

The absolute value of β(Beta) in Table 4.16 indicates the order of importance of the independent variables. The variable with the highest β value is relatively most important independent variable. On examining the contributions made by the independent variables in the model, proper delivery has the biggest contribution with the value of (β=0.542). It was followed by Tracking method, Automation, Storing practices, and Equipment inspection, respectively. Based on the regression analysis result, the regression equation was obtained:

$$\mathbf{GDP} = -\mathbf{0.357} + \mathbf{0.578} * \mathbf{proper\ delivery} + \mathbf{0.300} * \mathbf{Tracking\ method} + \mathbf{0.238} * \mathbf{Automation} + \mathbf{0.283} * \mathbf{Storing\ practices} - \mathbf{0.233} * \mathbf{Equipment\ inspection}$$

Our purpose, Proper delivery, Tracking method, Automation, Storing practices, and Equipment inspection were analyzed for the power of dependency of the GDP. This means that the dependent variable which is GDP is the core activity, in PFSA, that controls effectiveness of all other activities. Therefore, PFSA need to have high attention to improve the GDP along with the other significant independent variables that are Proper delivery, Tracking method, Automation, Storing practices, and Equipment inspection.

The survey result discussion leads us to develop the warehouse layout design and the system software. To improve the service of PFSA, the layout design and system software development are based on GDP, Proper delivery, Tracking method, Automation, Storing practices, and Equipment inspection elements. From the regression analysis result, GDP as dependent variable and Proper delivery, tracking method, Automation, Storing practices, and Equipment inspection

as independent variables are focus points in the warehouse layout design and system software development process.

As a conclusion of the survey result and discussion, we believe that if a proper warehouse layout and automated management system (software) is implemented, most of the problems in PFSA activities regarding medical equipment management could be addressed. Hence as part of this research, we have proposed (1) a novel warehouse layout design that can create effective space management and (2) a web based management system that can record and easily retrieve all the relevant information regarding the status of medical equipment. Such reengineered medical equipment management system not only prevents mix-up in the warehouse and avoids order exchanges while distributing but also helps trace the status of medical equipment after it leaves the warehouse for installation.

Therefore, from the above explanation we forward the WMS should (1) automate the full transaction of the medical equipment, (2) be able to have traceability capacity, and (3) have the means to access feedback from facilities as well as (4) bridge with FMHCA. The warehouse layout design and the system software development section will be present in the next chapter.

CHAPTER 5: Warehouse Layout Design and Software Development

This chapter discusses the warehouse layout design and the warehouse management system (software) development. The warehouses layout and warehouse management system are the main input in making the warehouse to be efficient [42]. The researcher tried to improve the PFSA supply chain system by designing a layout of the warehouse and developing a computerized warehouse management system.

Warehouse is a key part in the healthcare supply chain system. Warehousing is an important activity in the supply chain system. It helps provide healthcare service in reasonable time, cost and quality. An ineffective warehouse can be renovated for higher speed, throughput rate and productivity to enhance the performance of the supply chain system. We give special emphasize on the layout of warehouse and computerized management system since they are dominant factors in the medical equipment supply chain system.

The PFSA needs to improve performance of the warehouse by deploying efficient warehouse management system. Medical equipment identification in the warehouse is major factor anchored for unnecessary operational costs [38]; in such a way that the average travel distance for the order-pickers should be minimized by redesigning the layout of warehouse and automating it with a software.

Warehouse management system (software) helps for upgrade the performance of the warehouse. It (1) reduces warehousing cost, (2) improves efficiency, (3) speeds up inventory turns, (4) increases the throughput capacity, (5) provides available space, (6) enhances customer service and (7) improves labor productivity [26].

5.1. Design of Warehouse Layout

In designing layout of a warehouse, the first step is identifying the purpose of the warehouse. Warehouse in PFSA is a distribution warehouse where equipment is stored temporarily until it is distributed to the facilities. The warehousing activities in the PFSA can be described in three

different angles: process, resources and organization. Process activities include receiving, inspection, inventory control, storing, retrieving, and distribution. Resources are storage unit, the storage system, order picker auxiliaries, a computer system, man power and etc. Organizations includes all procedures and methods such as plan and control in the warehouse system [24].

Designing warehouse layout is better to consider basic features such as efficiency, reliability, integrity and flexibility in order to control and reduce wastes of resources, money, labor, time, and it prevents equipment from mix-up, contamination, deterioration and damage [7].

Warehouse layout design considers how to handle and store capital equipment especially x-ray machines, computed tomography (CT) scanners, magnetic resonance imaging (MRI), analytical device, and medical dispensing equipment because of their size, sensitivity, and indispensability. We aim a properly designed warehouse layout that helps to maintain the quality and integrity of equipment by preventing them from shock, vibration, rolling, corrosion, oxidization, dirt, dust, and other contaminant [43].

The designing process of the warehouse layout can be discussed as in the following steps:

Step1: Identifying purposes of the warehouse.

Step2: Identify the activities, process and resource in the warehouse

Major activities at PFSA can be depicted in the following process diagram.

Figure 5. 1. The flows of activities in the medical equipment warehouse at PFSA

Step3: Forming classes

The class formation is based on class-based storage methodologies.

***Product characteristic methodology*:** some commodities have certain characteristics that dictate how and where they should be stored within the warehouse. Temperature, humidity, ambient light and electrical shocks are some of the most important of these characteristics. Each commodity should be analyzed closely to determine its appropriate placement, given its temperature requirements [44].

Size methodology: states that heavy and bulky item, which might include heavy furniture and equipment, should be stored close to the point of shipping to minimize the effort and cost of

handling them. This also suggests that these items should be stored as close to the floor as possible [44].

Demand-based: It is advisable that high demand equipment should be stored near to the distribution point [44].

Step4: Sizing and dimensioning

The area of medical equipment storage can be from 60 to 90 percent of the warehouse's total space. When the area is from 60% to 70% , such design is a called a low desired inventory level and when it is in the range from 70% to 80%, is a medium desired inventory level, and when it is in between 80% to 90% it is for high desired inventory level [25].

To perform any activities in the warehouse there should be proper space for inspection, handling and movement. These points are considered during assign sizing and dimensioning of every department within the layout of the warehouse. The dimension of each department is based on the equipment size, demand and sensitivity. We allot 40% of the total area is for large equipment, 20% for medium equipment and 10% for small equipment. The rest 30% of the total area is open for passageway access, staging, space for inspection, not inspected and warehouse clerk console. Sensitive equipment needs special attention regarding with the temperature, humidity, ambient light, and electrical shocks.

Step5: layout design

To achieve an efficient flow of goods in and out of the warehouse, space is most critical thing. In PFSA, order-picking is the most labor-intensive and costly activity in traditional warehouses operations. The order picking consumes above 50% of the total warehouse operating expense [38]. We intended to reduce travel distance to store or pick equipment by developing an effective warehouse layout designs.

Product characteristic and size methods are used to assign storage department for different equipment that are different in characteristics and size. As we know, medical equipment can be large, medium and small in size and even some of them may be heavy and sensitive. The passageway should be designed properly for very large equipment. Also, enough staging area is important for inspection, receiving and distributing the equipment. In addition to this, design

formation of the layout should include space for equipment that is not inspected. Other than the medical equipment, we need to assign proper place for warehouse clerk console.

A ‘U flow layout’ model Layout design is used.

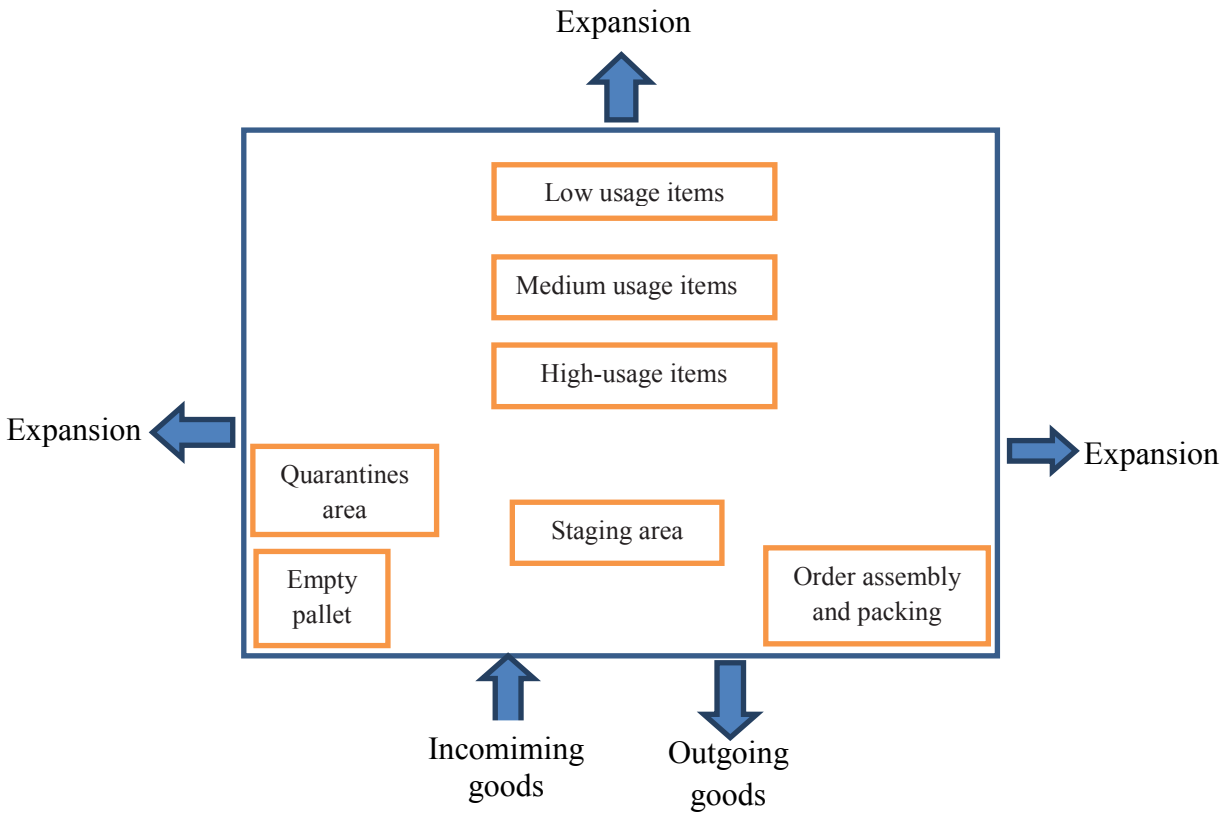


Figure 5. 2. U-flow warehouse [11]

Advantages of 'U’ flow model layout:

- Good utilization of dock resources because the receiving and shipping processes can share dock doors.
- Facilitates cross-docking because the receiving and dispatch areas are next to one another and can operate together.
- Excellent lift truck utilization because put away and retrieval trips are easily combined and storage locations closest to the receiving and dispatch docks are natural locations to house fast moving large rated items.
- Provides excellent security because only one side of the building is used for entry and exit.
- Allows scope for expansion in three directions.

The disadvantage of the 'U' flow warehouse layout is that congestion can occur if there is heavy incoming and outgoing traffic at the same time. Medical equipment reception and distribution are located on the same side of the building and products are taken into warehouse in accordance with their product characteristic and size designation, with the largest size and heavy equipment nearest the loading bays [11].

Our designed layout of the warehouse has nine zones (department) based on the equipment size and sensitivity. Demand of medical equipment is assumed to be constant.

Table 5. 1: Layout Department Formation Matrix

Sensitivity / Size	High(H)	Medium (M)	Low (L)
Large (L)	**LH**	**LM**	**LL**
Medium (M)	**MH**	**MM**	**ML**
Small (S)	**SH**	**SM**	**SL**

Table 5.1 describes that the layout zone (department) formation. This formation is based on the equipment size and sensitivity. The layout design in Figure 5.3 is based on the matrix table of Table 5.1. The warehouse layout design focuses only on how the equipment storage is organized and met the objectives of warehouse layout planning.

The displayed layout design in depicted in Figure 5.3 is based on the space effectiveness, material handling and flexibility. The design could be implemented for any-size warehouse based on the preferred percentage of size and sensitivity.

Step 6: Storage assignment policy

For storage assignment policy, class-based storage is used: each class is assigned to dedicate area [6]. Storage within the area is assigned by both fixed and fluid location method. Most bulk supplies should be stored on pallets and loose items stored on shelves. Fixed-location method is for items that are stored on shelves and fluid-location method is for items stored on the pallet rack [25].

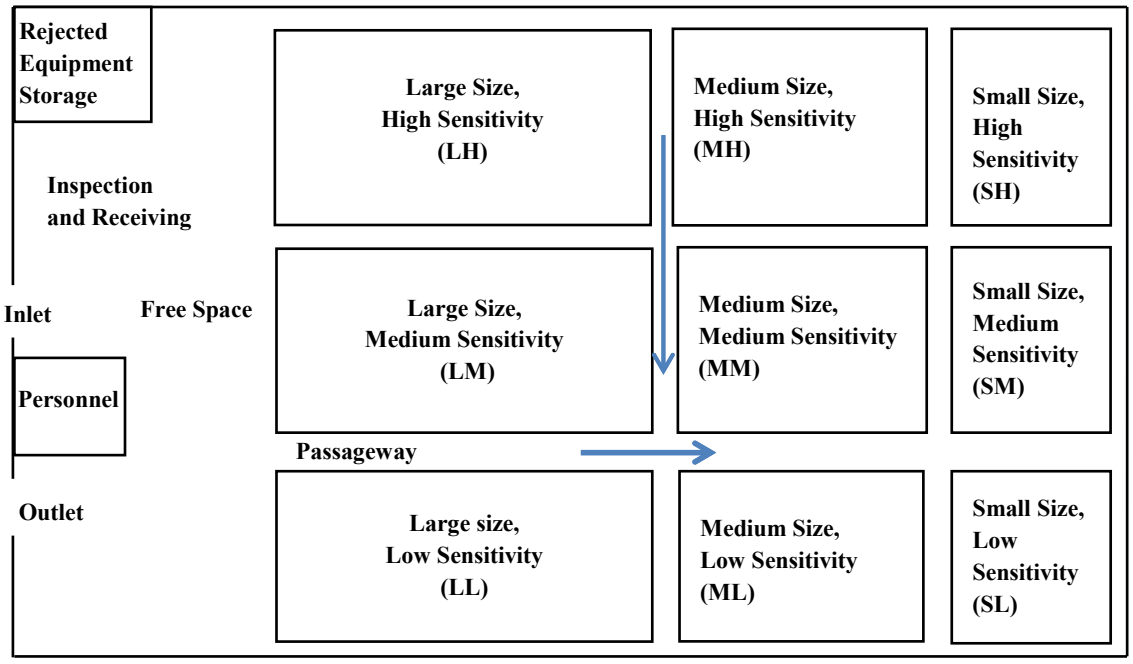


Figure 5. 3. The warehouse layout department formation based on size and sensitivity of the medical equipment

Some equipment like X-ray, CT, MRI, analytical device and medical dispensing equipment are often large, heavy, and sensitive [43]. Other equipment like pacemaker needs high level of control, because it directly implant to the patient [19]. Some device such as optical device is sensitive to ambient light, so we need to protect the equipment from direct sun light during storage [7].

Our proposed layout design let the PFSA to establish and maintain control on storage areas and stock rooms proper management to prevent mix-ups, damage, deterioration, contamination, or other adverse effects of medical equipment. The proposed warehouse layout design will facilitate proper stock rotation and easy retrieval approach using First in First out (FIFO) or First expire First out (FEFO) principle.

5.2. Development of Computerized WMS

This sub-topic intends to discuss a computerized WMS (software) development. The WMS is expected to include required information in relation to the medical equipment within the supply chain (see Annex V). In the WMS development process, the main requirements are classified in three phases; the first phase is to identify the user groups that interact with the WMS. In second phase, we try to determine the requirements gathered from beneficiary during the case study. In

the third phase, functional and non-functional requirements are identified from the users requirement [37].

5.2.1. User Groups

The warehouse management system divides the user into administration user and registered users. Registered user groups are PFSA staffs, facilities' representatives and regulatory bodies' representatives. Different user groups have different access permission. The access level depends on the permission given during registration.

5.2.2. Requirements Analysis

We defined and described system requirements specifications in details. The software enables the administrator to change the system contents with a full access. The user requirements specify the different roles and permissions for the two groups. Staffs of PFSA who are administrative staff of the medical equipment are the first registered groups with a specific privilege like registering ordered equipment, received equipment, distributed equipment and status of supplier. Facilities are second registered group that the system allows them to communicate with the PFSA in reporting ongoing working condition of the medical equipment, informing any challenges beyond their staff and to trace the ordered equipment where it is. The third registered group is regulatory bodies. It let them access the system to trace the working condition of the equipment and the status of local supplier as well the distribution of equipment in the country.

User requirements should describe functional and non-functional requirements so that they can understand who do not have detailed technical knowledge. The user requirement specification provides an abstract description for both functional and non-functional requirements, which is easily understandable by non-technical end-users. For the effectiveness of the management system a dedicated server computer is required [37].

User groups are categorized into registered user and administrative user. The registered user has limited access than the administration team. The administrators have, in fact, unlimited access to WMS and are responsible for the contents of the WMS. The following sub-sections describe the summary of high-level requirements of registered users and administrative users' role expected from the system.

Administrative Role

The system administrator is responsible for managing the warehouse management system. The administrator should have access to any activities and be responsible for registering the staff, the hospital representative and the regulatory bodies. The administrative user requirements are first, access to the administrative section, second, manage the whole transaction of the system, and finally, administer members and create new users.

Registered User Requirement

Registered users are whose credentials are usually in the form of username and password, authenticated by the system. The registered user can access the PFSA database based on their level of access that allowed to their activities. The registered user requirements are summarized here after.

PFSA Staffs' access requirements are (1) creating order equipment, (2) recording information about arrived equipment, (3) confirming distributed equipment, (4) registering supplier status, (5) accessing distributed equipment status (6) generating reports.

Facilities users' access requirements are (1) informing status of equipment, (2) informing the equipment maintenance status, (3) checking equipment arrival.

Whereas, the regulatory bodies' access requirements are (1) tracking the equipment in the country, (2) checking equipment maintenance status, (3) checking equipment functionalities, and (4) generating reports.

5.2.3. System Requirements

The system requirements are detailed description of the functionality to be provided [37].These activities are directly related to the equipment which is under the control of PFSA. The WMS is expected to include (1) owner of the order, (2) the equipment specification, (3) price, (4) date, (5) inspection status, (6) traceability (in warehouse and facilities), and (7) distribution status.

The following features are included in the software to use the software as communication platform with the facilities. These include (1) arrival, (2) installation, (3) maintenance, (4) functionalities. On the other hand, the software has accesses for the regulatory bodies that

include medical equipment (1) availability status, (2) maintenance status, and (3) functionality status.

5.2.4. Architecture of the Software

Software architecture is defined as a high-level view of the system that can show the relationships among the sub-components and their properties. We chose a 3-tier architecture design model which divides in terms of presentation, business logic and data access. The system's presentation layer is the user interfaces (web page). A business logic layer (BLL) defines the functional part of the system and acts as link between the presentation layers. And the data access layer (DAL) is in charge of retrieving and storing the data. Figure 5.4 shows the 3-tier architecture while Figure 5.5 shows a high-level view of the system and the user-system interaction [45].

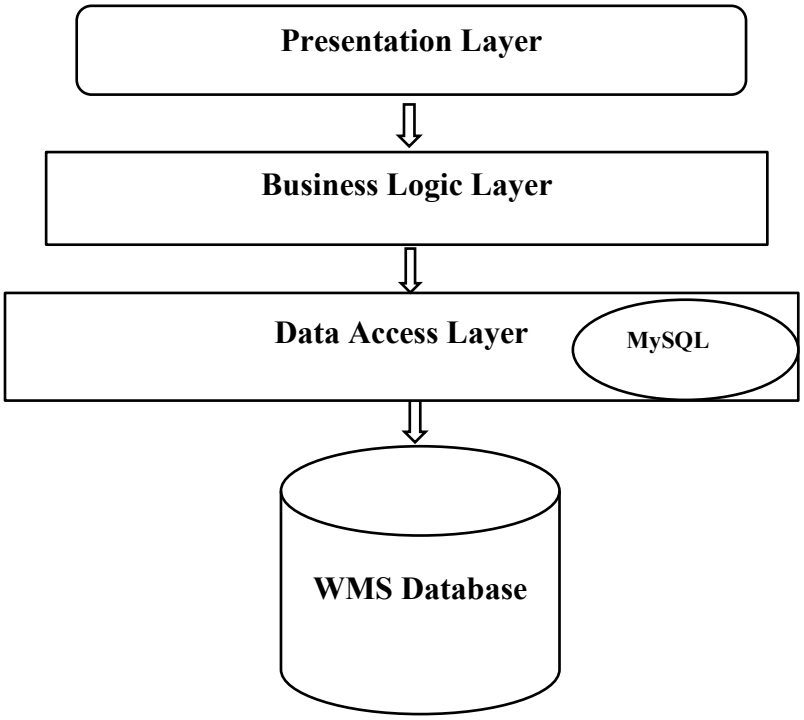


Figure 5. 4. Software Architecture

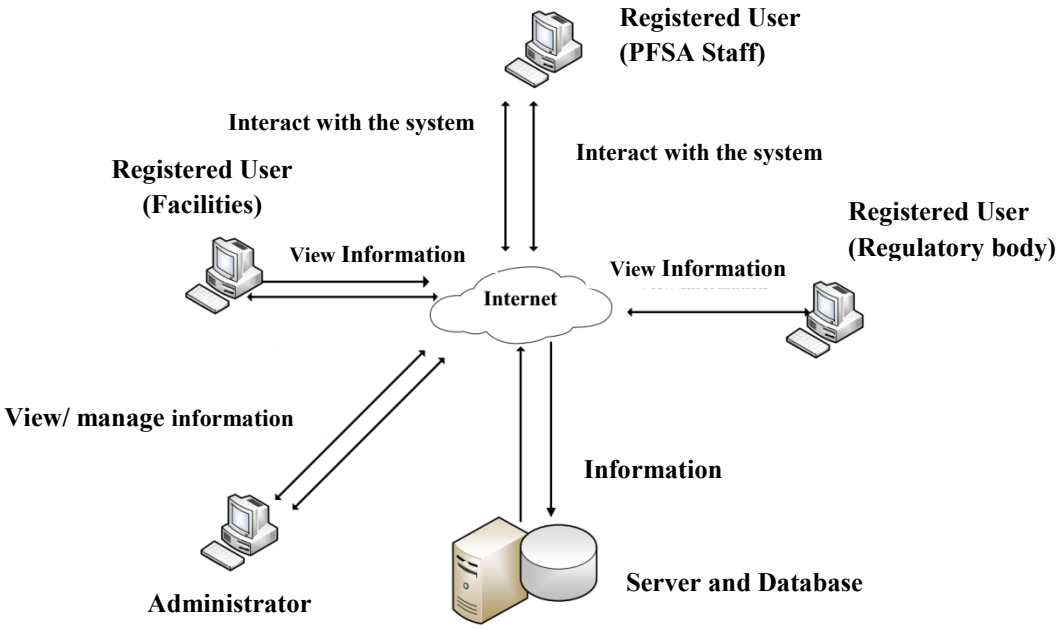


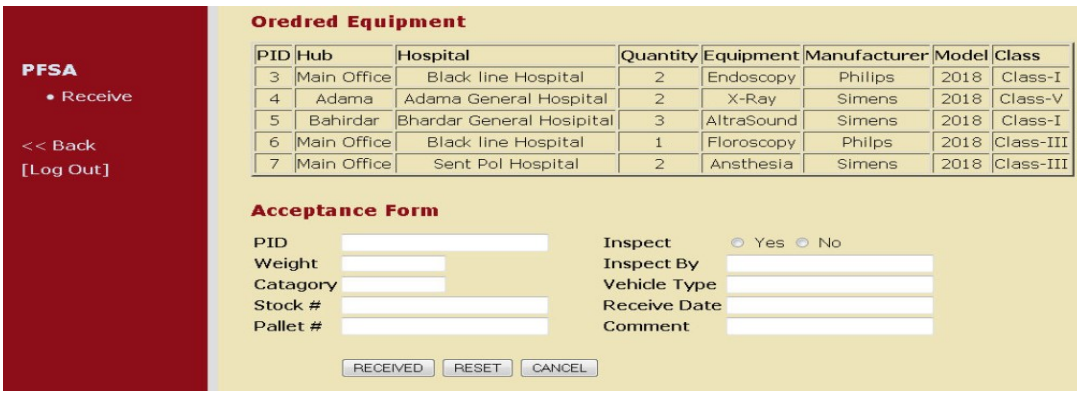
Figure 5. 5. User-system interaction

5.2.5. Graphical user interfaces(GUIs)

Graphical user interfaces that give privileges for the three sectors, as user groups, PFSA Staff, facilities and the regulatory bodies are presented hereunder.

(a)

(b)



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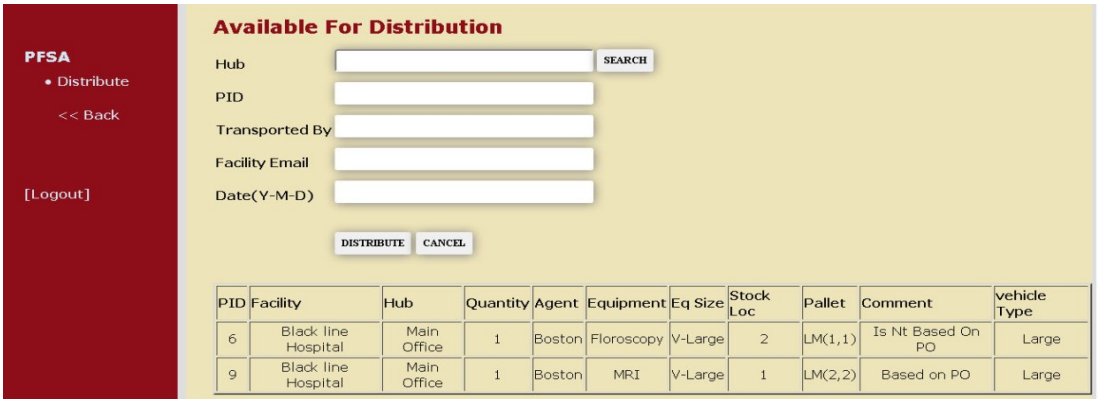

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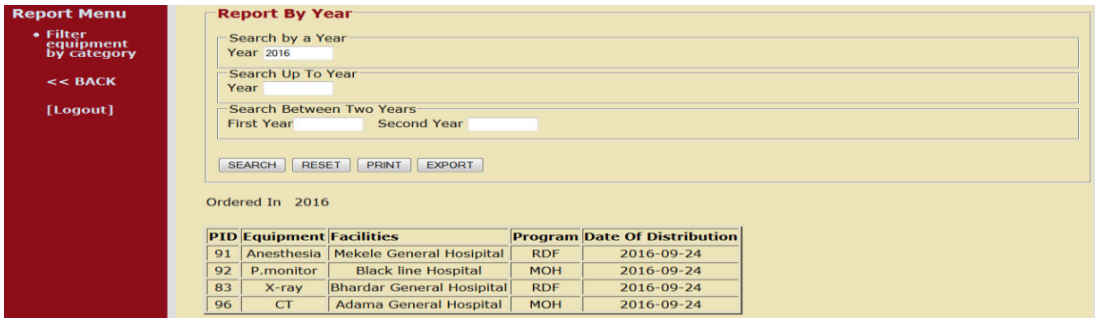
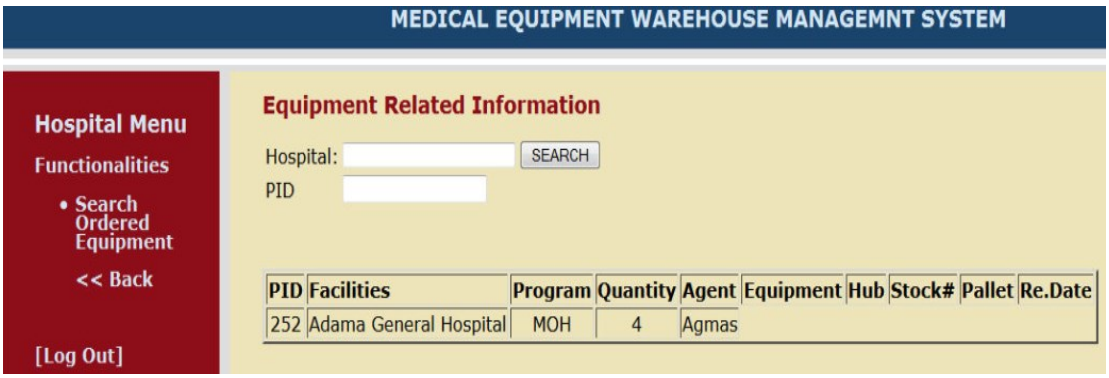


Figure 5. 6. The developed WMS software guide user interface (GUI). GUI that gives privilege for PFSA Staff to (a) order (b) receive, (c) distribute and (d) report of medical equipment.

(a)



(b)

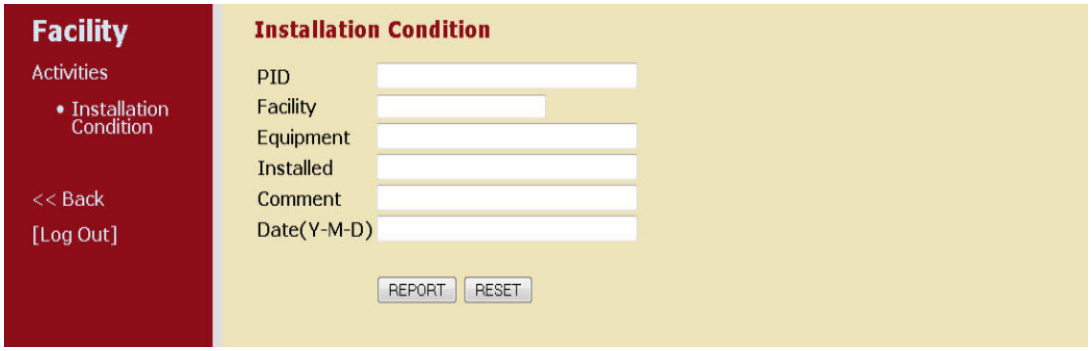


Figure 5. 7. The developed WMS software user guide interface (GUI) that give privilege for facilities' Staffs (a) to check the arrival of ordered equipment (b) to inform the equipment condition

(a)

(b)

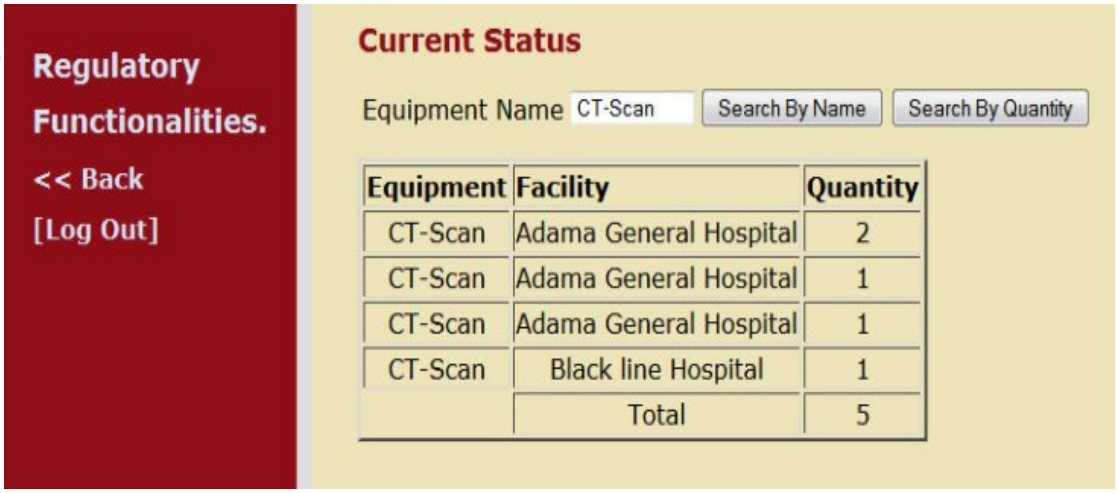


Figure 5. 8. The developed WMS software user guide interface (GUI) that give privilege for regulatory Staff to (a) check functionalities (b) number of equipment

CHAPTER 6: Conclusion and Recommendations

6.1. Conclusion

The assessment mainly focuses on major activities of PFSA in the medical equipment SCMS such as inspection, storage, distribution, proper delivery, technical support and functionality supervision activities in the management of medical equipment in order to increase customer satisfaction.

This research showed that that 88% and 78% of respondents agreed that the storage and distribution practices of medical equipment are not efficient and based on the manufacturers recommendation, respectively. In addition, about 72% and 83% of the participants from the facilities disagree that there is proper inspection and proper delivery service provision of medical equipment by PFSA, respectively. Therefore, the researcher concludes that there is improper delivery and inspection of medical equipment which constrains the healthcare service of the facilities.

Furthermore, 77.8% and 75.7% of the respondents forwarded that PFSA is providing insufficient functionality supervision and technical support of medical equipment, respectively. This implies that, PFSA has no effective management system to communicate with the facilities and other stakeholders. Informants stated that they had sometimes gotten follow-up during utilization of the medical equipment.

Lastly, the case study revealed that 84% of respondents agree that the PFSA has no reliable warehouse management system (software) used to keep and make available the required information about medical equipment within the transaction. This implies that PFSA has no comprehensive, effective and efficient warehouse management system.

The regression analysis shows that GDP is dependent variable on independent variables such as Proper delivery, Tracking method, Automation, Storing practices, and Equipment inspection. The model's degree of explaining the variance in the dependent variable was R^2 =0.794. Therefore, the coefficient value tells about 79.4% of the variation in the GDP is explained by all other dependent variables. According to the ANOVA statistics $F = 14.659, p < 0.05$, therefoere, the five independent variables in the standared model are significantly predicative of

the dependent variable. PFSA need to have high attention to improve the GDP along with the other significant independent variables.

In order to support PFSA address the identified challenges aforementioned above, a new warehouse layout and a web-based WMS (software) development is considered in this thesis. The layout design is supposed to help improve the current practice in handling, storing and distribution of medical equipment. The web-based management system also helps keep required information throughout the process of ordering, inspecting, receiving, inventory controlling, storing, retrieving, distributing and installing of medical equipment.

We believe that the designed layout and the developed software will help PFSA improve its overall services and supervisions provided to the facilities such as technical supports, equipment functionality supervisions. The implementation of the warehouse layout and the software will certainly improve the current medical equipment management practices within the supply chain in the country.

6.2. Recommendations

Based on the findings, the researcher recommends that managing medical equipment needs special attention to utilize the equipment properly throughout their life time. Our recommendation includes:

1. PFSA should give proper attention to manage the medical equipment throughout specification development, ordering, inspecting, storing, distributing, installation and utilization. The PFSA should give involve required professionals with regular training at every stage of medical equipment management.
2. The warehouses layout design should consider the medical equipment quality, safety, integrity and performance during delivering, storing and distribution. Appropriate procedures, standards and practices need to be developed and applied for every activity in the warehouse to improve the warehouse performance.
3. The PFSA should use or develop computerized WMS to improve the services.
4. The PFSA need to be well prepared and build its technical and management staff capacity in order to provide required technical support, supervision services and proper delivery for facilities. We highly recommend its staffs to take adequate training on SCM of

medical equipment.

5. In order to have a holistic medical equipment management policy, we recommend further studies to be conducted to assess the medical equipment SCMS of the private sector. The researcher also recommends implementing an innovative remote controlling system using wireless technology to control medical equipment functionality.

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Annex

Annex I: Questionnaire for the assessment of PFSA staffs

Addis Ababa University

School of Graduate Studies

Centre of Biomedical Engineering

Dear Participants;

The researcher has been conducting a research in the area of Medical Equipment Supply Chain Management System as part of his MSc thesis in Biomedical Engineering in AAU. With sincerity, he would like to extend his deep appreciation to your staff for the willingness and enthusiasm in participating in this research. Thank you in advance for your kind cooperation in answering the questions as truthfully as possible. Your response will be highly confidential. For any question pertaining to this study, please contact Dr. Masreshaw Demelash at the Centre of Biomedical Engineering via his email *masreshaw.demelash@aau.edu.et*.

Objectives of the study:

- ***To improve the current supply chain management system for the medical equipment in our country***
- ***To improve the current utilization of medical equipment in public healthcare facilities***
- ***To ensure the quality, safety and on time delivery of the medical equipment***

Personal data

Current position_____

Qualification_____

Service year in the current profession _____

This questionnaire is a total of three pages. Please mark √ for your appropriate choice (rate) for objective questionnaire.

Questionnaire Related to Medical Equipment Handling, Storage and Distribution Practices

1. Assessment on the current handling, storage and distribution practice

No	Questions	Strongly agree	Agree	Disagree	Strongly disagree	No idea
1.1	The storage conditions are consistent with Good Storage Practices guidelines					
1.2	The distribution conditions are consistent with Good Distribution Practices guidelines					
1.3	Maintain the equipment integrity, safety, performance, reliability and effectiveness until delivery to end users					
1.4	The current practices prevents mix-ups, damage, deterioration, contamination, or other adverse effects to equipment during handling, storage, distribution and installation					
1.5	The current practices have adequate control to ensure obsolete, rejected, deteriorated, or contaminated equipment is distributed					
1.6	The environmental conditions such as humidity, dust, water, temperature and light in the warehouse are controlled to ensure the quality of medical equipment					
1.7	There is a means to protect medical equipment from physical damage under any condition					
1.8	The equipment distribution /transportation is as per the manual recommended by the manufacturer					
1.9	The warehouse has sufficient space for inspection					
1.10	The storage of medical equipment in the warehouse based on their type, class or any category in zone					
1.11	In the warehouse there is first expiry /first out (FEFO) or first in /first out (FIFO) principle					
1.12	We can easily find the equipment's exact storage place in the warehouse while in distribution					

If you have additional idea about the current warehousing approach for the medical equipment in your agency, please describe it_____

Questionnaire for Medical Equipment WMS (the software)

1. Assessment on medical equipment warehouse management system

No	Questions	Strongly agree	Agree	Disagree	Strongly disagree	No idea
1.1	The agency has an efficient computerized medical equipment warehouse management system					
1.2	I can get any required information about the equipment from the existing management system whenever needed					
1.3	There are challenges that does not support by the existing management system					
1.4	The management system support to deliver the equipment on time to the facilities					
1.5	The existing system indicates the level of inventory appropriately					
1.6	The existing system forces you to use more paper work					
1.7	The existing management system is efficient to manage the medical equipment in the supply chain system					
1.8	The agency may need to develop a new management system that handle the full transaction of the medical equipment					

2. Assessment of the current management system related to distributed equipment

No	Questions	Yes	No	Remark
2.1	Is the current management system helps to check whether the equipment is calibrated?			
2.2	Do you think the system is helpful to check the equipment's service based on warranty?			
2.3	Does it handle information whether the equipment is properly working after distribution?			
2.4	Is the current management system helps to trace the distributed equipment?			
2.5	Helps to take required measure during transportation of the capital equipment like MRI, CT, X-ray and analytical devices etc.… against from shock, vibration, rolling, pitching			

2. Assessment of the current management system within the supply chain

No	Questions	Yes	No	Remark
3.1	Does it support activities from the facilities side?			
3.2	Do you think it provide information for the regulatory body?			

If you have additional idea about the existing system and the new system, please describe it

_____

Annex II: Questionnaire for PFSA warehouse managers, experts and officers during field visit and semi-structure interview

1. Is there any regular training taking how to handle, store, distribute and install medical equipment?
2. Are the all warehouses built by considering the ME condition criteria?
3. Does the agency use warehouse by rent which is appropriate for ME?
4. Is there any layout design for the warehouse before?
5. What kind of equipment is frequently needed by the facilities?
6. Does the current management system give required information to manage medical equipment and pharmaceutical products?
7. What are the detailed functionalities of the HCMIS?
8. How the agency communicates with the facilities?
9. Is the management system is web based or desktop application?
10. How the agency communicates with the hubs and the facilities?
11. How many biomedical engineer staff is working in the agency?
12. Does the agency give attention to store healthcare products?

Annex III: **Questionnaire for the assessment of facilities staffs**

Addis Ababa University

School of Graduate Studies

Centre of Biomedical Engineering

Dear Participants;

The researcher has been conducting a research in the area of Medical Equipment Supply Chain Management System as part of his MSc thesis in Biomedical Engineering in AAU. With sincerity, he would like to extend his deep appreciation to your Hospital and staff for the willingness and enthusiasm in participating in this research. Thank you in advance for your kind cooperation in answering the questions as truthfully as possible. Your response will be highly confidential. For any question pertaining to this study, please contact Dr. Masreshaw Demelash at the Centre of Biomedical Engineering via his email *masreshaw.demelash@aau.edu.et*.

Objectives of the study:

- ***To improve the current supply chain management system for the medical equipment in our country***
- ***To improve the current utilization of medical equipment in public healthcare facilities***
- ***To ensure the quality, safety and on time delivery of the medical equipment***

Personal data

Current position_____

Qualification_____

Service year in the current profession _____

This questionnaire is a total of three pages. Please mark √ for your appropriate choice (rate) for objective questionnaire.

Questionnaire for the healthcare facilities

1. Assessment of on-time delivery of equipment and services

No	Questions	Always	Often	Sometimes	Rarely
1.1	The ordered medical equipment delivered on time as per specification				
1.2	The ordered medical equipment has been installed on time				
1.3	The ordered medical equipment has been commissioned based on your time frame				

2. Assessment on technical support by the agency (PFSA)

No	Questions	Always	Often	Sometimes	Rarely
2.1	We get appropriate support during ordering of the equipment				
2.2	We get regular follow up during utilization of the equipment				
2.3	We get technical support from agency whenever necessary				
2.4	The agency is taking required measure whenever the equipment stops working with the lack of accessories, consumables and spare parts				
2.5	The agency makes sure that the supplier to gives on time training on the equipment				
2.6	The agency gives proper support during equipment decommissioning				

3. Assessment on received equipment

No	Questions	Always	Often	Sometimes	Rarely / Never
3.1	Have you ever received any medical equipment that is physically damaged?				
3.2	Have you ever received any medical equipment that is not functioning?				
3.3	Have you ever received any medical equipment that you did not order/want?				
3.4	Have you ever received any medical equipment that does not meet your original specification?				
3.5	Have you ever received any medical equipment that has missing parts or accessories?				
3.6	Have you ever received any medical equipment that is not in line with the service that you provide?				

4. Assessment on utilization of the equipment

No	Questions	Always	Often	Sometimes	Rarely /Never
4.1	We face equipment failing within a few days/months of functioning after installation				
4.2	The equipment is maintained based on the warranty with in few days when it was stops working				
4.3	Preventive maintenance is done based on the manufacturer recommendation				
4.4	The medical equipment stops working for long period of time				

5. Assessment on facilities satisfaction

No	Questions	Always	Often	Sometimes	Rarely
5.1	We are satisfied by the service/support provided by the agency on medical equipment				
5.2	There is a standard feedback exchange platform between your hospital and the agency				

If you have any additional comments about the services given by the agency (PFSA), especially related to medical equipment, please describe it_____

Annex IV: Questionnaire for facilities technical staffs during field visit and Structure interview

1. How and where do you store medical equipment ready for installation?
2. Is there any regular training held how to handling, storage, and installation medical equipment?
3. Do you have any training related to organized equipment, parts and accessories in the warehouse?

Annex V: Features of the developed software

We presented hereunder some of the major code of functions or methods that can perform specific action in the development of the warehouse management system and main parts of its Graphical User Interface (GUI).

```
function find_users_for_login(){
}
function insertorder(){
}
function insertorder_with_new_po(){
}
function insertorder_ingroup(){
}

function find_ordered_equipment_instock(){
}
function search_update_user(){
}
function hospital_equipment_status(){
}
function find_hospita_info_distribute(){
}
function find_hospita_info_receive($pid){
}
function Find_Agent(){
}
function Find_facilities(){
}
function Find_equipment_name(){
}
function hospital_equipment_status(){
}
function Register_facilities(){
}
function Receive_Equipment(){
}
function Distributed_Equipment(){
}
function find_equipment_currentlly_avalibel(){
}
```