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A Mobile and web application to track availability of essential medicines in pharmacies

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Master of Science in Mobile Telecommunications and Innovation

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A Mobile-based drugs and alcohol addiction self-assessment and management scheme

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A Mobile and Web Application to Track Availability of Essential Medicines in Pharmacies

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Declaration

I declare that this work is the author's original work and that content in this dissertation that is not the author's own has been acknowledged. I declare that this work has also not been previously submitted and approved for an award for the Master's Program in this University or any other University.

Mutua Jackline Katinda

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June 2017

Approval

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Abstract

Essential medicines are an imperative component in a country's health system and the need to ensure the availability of this class of drugs becomes apparent due to increased demand, given that this class of drug commodities is prone to stock-outs and unavailability. There are myriad challenges that come into play when there is limited or inaccurate information to guide the procurement of essential drugs and these include but are not limited to stock-outs and expiration of drugs. This is often due to over-stocking or poor procurement decisions based on inaccurate data related to dispensation patterns hence providing poor heuristics for accurate decision-making. It has been estimated that public facilities often experience stock outs of essential drugs about 46 days per year even though the health expenditure on medicines is about 66%.

This research proposes a mobile and web solution to address the challenge of gathering sufficient data and analysis of information regarding dispensation and loss patterns of essential medicines in pharmacies. This will be done by providing a mechanism to capture the dispensation information via mobile devices and visualizing available information such as stock data using graphs. The mobile application will utilize the Angular JavaScript framework and the Angular NVD3 graphing library to allow pharmacy practitioners to view stock and report data in the form of useful visualizations and summaries for decision-making on the fly. The application also provides an opportunity to share dispensation pattern and loss data with KEMSA by providing a share data feature. The information sharing will allow KEMSA to enhance their planning activities with regards to providing essential medicines in pharmaceutical outlets by collecting relevant information related to losses experienced in pharmacies as well as the pattern of dispensation of various commodities.

The outcomes of this research are beneficial to any public service bodies mandated with the task of availing essential medicines, so that they can consider ways to collaborate closely with pharmaceutical retailers to be able to achieve the goal of availing critical medicines for all and address the concern of unavailability of this class of drugs.

Keywords: Mobile, Web, Essential Medicines, Availability, Dispensation Patterns.

Dedication

I dedicate this work to all who have provided encouragement and support during this period.

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Acknowledgements

Many thanks to everyone who has been instrumental in aiding me to complete this work and most of all I thank God for guidance in the completion of this work.

My sincerest appreciation to my Supervisor Dr. Vitalis Ozianyi for his counsel and supervision as well as Dr. Sevilla for continuing to challenge us to use our knowledge and experiences gained in the programme to build technically sound solutions that address real world problems around us.

Finally, I thank my family, friends and colleagues for their encouragement as well as all who assisted in completion of this project.

Abbreviations/Acronyms

KEML	Kenya Essential Medicines List
ERP	Enterprise Resource Planning
ICT	Information Communications Technology
KEMSA	Kenya Medical Services Authority
LMIS	Logistics Management Information System
MEDS	Mission for Essential Drugs and Supplies
MMS	Ministry of Medical Services
MOH	Ministry of Health
MVC	Model View Controller
NoSQL	Non Structured Query Language
SCM	Supply Chain Management
UN	United Nations
UNFPA	United Nations Population Fund
UPC	Universal Product Code
USAID	United States Agency for International Development
USSD	Unstructured Supplementary Service Data
VM	Virtual Machine
VSAT	Very Small Aperture Terminal
WHO	World Health Organization

Chapter 1: Introduction

1.1. Background of the Study

The term '*essential drugs*' was coined around the late 1970's and the WHO (2004) defines them as that class of drugs that is crucial and vital to meet the healthcare needs of most of the population and thus, ought to be readily available always, in suitable dosage forms and at affordable prices. Access to essential medicines is described as ensuring that these drugs are constantly available and affordable at public or private health facilities or pharmaceutical retail outlets that are within an hour's walk from the residences of a given population (WHO, 2010). Access to medicines depends on four key factors as illustrated by the access framework shown below in Figure 1-1 that was developed by the WHO and one of the key pointers for policy makers in ensuring access, is to ensure that procurement, distribution and other supply activities are carried out in the most efficient manner (WHO, 2004).

Figure 1-1 The WHO Access Framework

(Source: WHO Policy Perspectives on Medicines, 2004)

In Kenya, the Kenya Medical Services Authority (KEMSA), which is a state corporation under the Ministry of Health, is charged with the mandate of establishing the Kenya Essential Medicines List (KEML), which is an indispensable guide to the medicines recommended for the treatment of common ailments in Kenya (MOH, 2016). The corporation is also involved in the availing of these essential drugs primarily to public health facilities although the procurement process has now been decentralised with the advent of the devolved government, which means county

governments now have a major part to play in the process of ensuring the availability of medical supplies in public facilities by selecting suitable suppliers (Gathura, 2013). Several counties have continued to work quite closely with KEMSA as their preferred supplier (KEMSA, 2013). Figure 1-2 shows an example of the supply flow of an essential drug from a manufacturer or donor via KEMSA all the way to the hands of patients in health centres or referral hospitals.

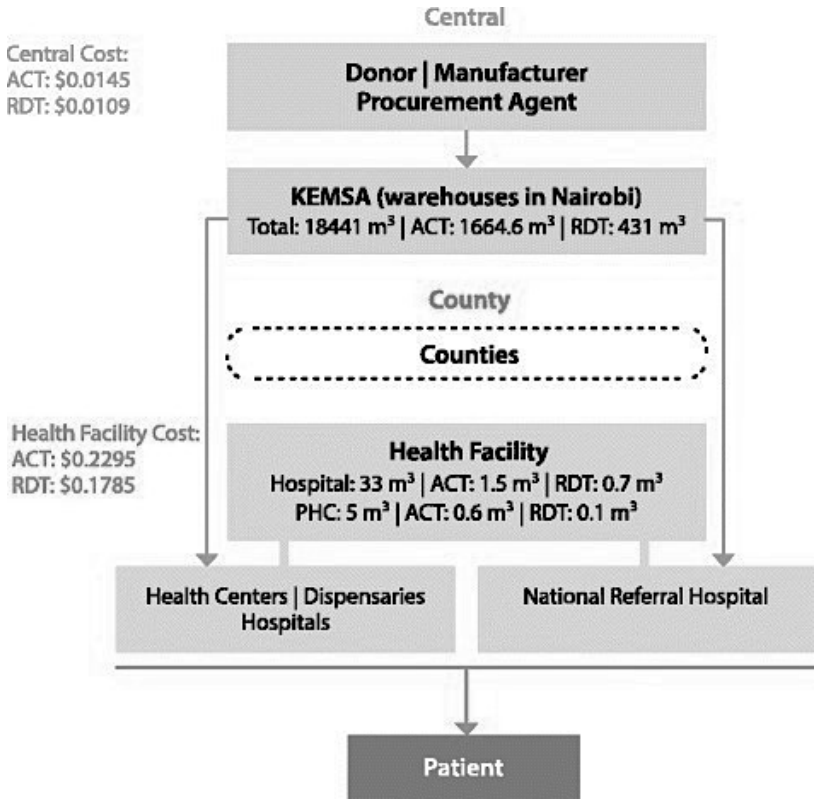

Figure 1-2 ACT Drug Supply in Kenya (Source: Shretta et al., 2015)

As indicated in Figure 1-2 above, the various classes of drugs are provided either by a donor or procured straight from the manufacturer. Once procured, these are taken to the KEMSA warehouses. When a county places an order via KEMSA, the commodities are identified and delivered to the ordering facility, health centre or referral hospital. It is to be noted that when it comes to the distribution network for medicines is often perceived as ineffective when compared to other regular consumer supply chains particularly the beverage supply chain, which is incredibly efficient (Yadav *et al.*, 2010). The process of procuring essential drugs involves making sure that there is accurate historical data regarding consumption patterns in a facility and making sure there is a reasonable time lag between an order and fulfilment of a

delivery request. The deteriorating state of availability of essential medicines particularly in the lower levels of health facilities such as dispensaries and clinics in rural areas has time and time again been identified by the Ministry of Medical Services (MMS, 2009). An example of a prevailed state of unavailability of an essential drug can be found from a WHO (2009) study that sought to determine the availability of Artemisinin Combination Therapy (ACT), a first-line treatment for malaria that was found to be unavailable in recommended weight specific treatment packs for weeks after it had been introduced in Kenya.

The Ministry of Medical Services has also found that in a bid to ensure decision-making is well informed with regards to keeping track of essential medicine availability and facilitating access, it is crucial to maintain accurate records and make these available to key decision-makers and ensuring that it is easy for them to have a better overview of information on the fly as and when needed (MMS, 2009). As indicated on the access framework on Figure 1-1, this falls part of the reliable health and supply system component. It is to be noted that in Kenya, inaccuracy of information is not the only significant cause for unavailability but other concerns such as inadequate funding come into play and a study on unavailability of essential medicines in public hospitals indicated that funding was also a strongly cited (57.9%) factor that caused unavailability (Wangu & Osuga, 2014).

The above state of affairs warrants a need to investigate what mechanisms ought to be adopted to aid in streamlining processes and ensuring that access to essential medicine commodities is experienced by all facilities countrywide especially with the devolution of healthcare. This is also quite important because of the uneven distribution of health facilities in the various counties in Kenya (Wamai, 2009). A good starting point is to examine what technological solutions can be utilized to ensure that there is sufficient data collected that assist with proper planning and decision making so as to increase access. This research aims at documenting a mobile application as an intervention to tackle the problem of unavailability caused by stock outs or even losses. The researcher proposes a simple, convenient and efficient solution to the essential medicine availability challenge using a mobile application.

1.2. Problem Statement

The Ministry of Medical Services (2009) has over the years identified that Kenyan pharmaceutical retail vendors experience stock-out challenges as well as loss of medication (for example, due to expiration of drugs or even keeping too much stock) especially at the low end of the supply chain and this is a major problem that is experienced by public health facilities. This documented challenge arises due to poor and inadequate data to inform procurement decisions at various points, the lack of effective data analysis tools and inadequate information sharing with key bodies. A research on the key contributors to unavailability of essential drugs in Nakuru County indicates that the causative factor of poor distribution can be remedied through use of relevant information systems (Wangu & Osuga, 2014).

A study on the Kenyatta National Hospital's inventory management practices also established that as matter of fact, keeping accurate records has a positive effect on inventory management and inventory accuracy (Oballah *et al.,* 2015). The devising of applications accessible on mobile or web devices, would allow pharmacy practitioners to collect information on dispensation patterns, allow analysis of historic data as well as share this information with relevant bodies to improve the process of availing this class of drugs.

1.3. Purpose of the Study

This research aims at developing a system to facilitate the activities involved in the availing of essential medicines in pharmacies, which include collection of

dispensation information, effective data analysis and making timely procurement requests. Such enhancements will ensure availability of credible information to inform procurement of this class of drugs.

1.4. Research Objectives

The main objective of this study is to establish a mechanism to track the availability of essential medicines in pharmacies. The specific objectives of the study are identified as follows:

i) To investigate whether web and mobile technologies have been employed in tracking availability of essential medicines.

ii) To review existing architectures of mobile applications that have been implemented to track essential drug availability.

iii) To design and develop a mobile and web application that helps in tracking essential medicine drug supplies in pharmacies.

iv) To test and validate a mobile application that helps in tracking essential medicine drug supplies in pharmacies.

1.5. Research Questions

In line with this work's research objectives, the following research questions will be used to guide this study:

i) What web and mobile technologies can be employed in tracking availability of essential medicines?

ii) What are the existing architectures or systems that have been implemented to help with tracking essential medicines availability?

iii) What are the design requirements and desirable features that should be included in an application to aid in tracking availability of essential medicines?

iv) How well does the developed application aid in giving the desired outcome?

1.6. Scope and Limitations

This project involves the determination of how mobile technology can intervene in ensuring availability of essential medicines in pharmacies by facilitating tracking of commodities. This study will focus on information gathering, preparation, implementation and the evaluation of a mobile application to assist with ensuring availability of essential medicines in public pharmaceutical retail outlets or pharmacies in health facilities within Kenya and specifically within the Nairobi County. More emphasis will be given to public facilities during the course of the research as these are the main beneficiaries of some form of centralized funding for access to essential medicines at the county level and the fact that majority of these have continued to work with KEMSA.

The research also primarily focuses on KEMSA as a distribution agency as it had been the primary supplier of medical supplies to public facilities prior to devolution and that with devolution, counties have continued to engage its services. The study will only cover public pharmacies in public health facilities in the Nairobi County. The mobile application to be developed in the research also only affects users of mobile devices that have access to browser and Internet connectivity. A

responsive design approach will be taken so as not to depend heavily on mobile platform specific capabilities.

1.7. Assumptions

The following are the main assumptions of this study:

i. The development of a mobile application will aid in addressing the information gap challenges that cause unavailability and stock-outs.

ii. There is enough goodwill between KEMSA (the main supplier under study) and public health facilities to create an enabling environment to share information related to consumption and essential drug loss patterns.

1.8. Justification

The problem statement reiterates that there is need to consider ways of ensuring that preventable diseases are kept at bay through making sure that essential medicines are available always. This can be done by making sure that there are means to inform decision making at all levels of the supply chain. Due to the abundance of mobile devices that can store and process more and more information faster than ever before, it is possible to allow individuals to manage essential medicines availability with cost-effective mobile devices. This research will aim at documenting how a mobile application can be utilized to address challenges in maintaining and analysing dispensation pattern data and using this data to address essential medicine unavailability while working closely with suppliers.

1.9. Significance of the Study

This study provides an opportunity to consider ways in which technological interventions can assist in improving the lives of individuals by providing access to critical medication through enhancements in information sharing between pharmacies and supplying bodies. It not only looks at leveraging the proliferation of smart phone and mobile devices in the Kenyan context, but also how to leverage the use of these devices to empower pharmacy practitioners to make decisions conveniently for the benefit of patients.

To the public bodies mandated with supplying this class of drugs, the research will allow them to consider ways in which they can collaborate closely with pharmaceutical retailers that they serve, to achieve their objectives.

To the pharmaceutical retailers, this research would empower them to keep track of stock loss rate levels and avoid issues such as late refills of stock due to late procurement requests or inability to keep track of stock rates effectively.

To county governments, this research presents an opportunity to continue exploring how to ensure that procurements functions in this area are cost-effective and that they do not lead to unnecessary losses.

To developers of mHealth applications, this research provides a starting point to design and implement mobile or web applications targeted at the pharmaceutical supply area. There has been an investigation of technologies used in mainstream supply chain management in the literature review section and this also provides suitable starting points to identify even more creative solutions to pharmaceutical supply chain issues in Kenya.

1.10. Summary

In summary, there is a need to ensure that essential medicines are available by considering how technology can be used to intervene and improve the current situation. The next chapter will explore the issues identified in this chapter in detail, as well as previous theoretical or practical work around different approaches for managing drug availability supplies in pharmacies.

Chapter 2: Literature Review

This chapter documents an overview of how technology has been used in enhancing the process of managing supply chains as well as logistics processes. It further takes an in-depth look at relevant literature on understanding the supply system for essential medicines in Kenya with a prime focus on the KEMSA supply process. The review then identifies ways in which mobile applications have been and can be used to solve key concerns that lead to unavailability at the lower level of the essential medicines supply chain in a bid to address key issues identified in the problem statement and justification sections in Chapter 1 of this report.

2.1 Essential Medicines Supply System and Challenges in Kenya

2.1.1 Understanding the Essential Drug Supply System in Kenya

Four main components characterize a good pharmaceutical procurement process and these components include procurement of the most cost-effective medicines in the right quantities, selection of reliable suppliers with high quality products, timely delivery of supplies and lastly, achieving the lowest possible best value-quality cost (WHO, 2010). In Kenya, an array of drugs is usually identified at the national level and these drugs are expected to be available in all public health facilities to treat prevalent diseases (KEMSA, 2006).

KEMSA, which is a specialised procurement and logistics corporation under the Ministry of Medical Services, was once solely responsible for the procurement and distribution of essential medicines and medical supplies in Kenya before the devolution of healthcare (Wangu & Osuga, 2014). It is to be noted that KEMSA primarily serves public health facilities and community based pharmaceutical retail outlets and majority of the private pharmaceutical vendors prefer to engage their own suppliers who meet their cost and budgetary expectations (Mwathi *et al.,* 2014). Figure 2-1 illustrates current order fulfilment process in the KEMSA supply system

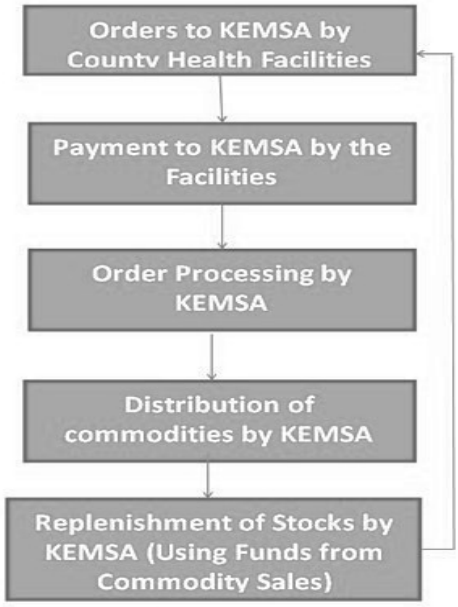

Figure 2-1 Order Fulfilment process by KEMSA (Source: KEMSA, 2013)

Following devolution of healthcare, the mandate to procure medicines fell on the County governments and all financing for medical commodities and decisions on where to procure medical supplies were devolved to the County governments (Mecca, 2013). Some counties opted to continue working with KEMSA as their main supplier, which is now operating under a new business model (KEMSA, 2013) while a few others opted for other private suppliers. Several counties entered partnerships with Mission for Essential Drugs and Supplies (MEDS). Table 2-1 indicates the changes in KEMSA's business model with the advent of devolution.

Table 2-1 Comparison of the KEMSA Old and New Business Model

(Source: KEMSA, 2013)

Old Model:	New Model:
Commodities Medical commodities and medical supplies bought by KEMSA with funds provided by the Ministry of Health	**Commodities** KEMSA will be responsible for procurement of medical commodities and supplies with its own funds
Commodity Order Management Ordering was done quarterly by the facilities on a PULL system (Demand Driven)	**Commodity Order Management** Ordering will be done by counties according to their needs
Payment Ministry of Health reimbursed for distribution costs and paid for warehousing costs	**Payment** The county governments will be meet the cost of distribution and commodities
Stock Replenishment Ministry of Health Replenished the stocks through procurement by KEMSA	**Stock Replenishment** KEMSA shall replenish its stocks from funds realized from sales of commodities to counties

In terms of technology adoption to enhance its SCM and logistics processes, KEMSA has made significant strides in infusing automation in their process since 2008 with the implementation of their ERP and LMIS systems as well as the KEMSA eMobile application (World Bank, 2014) although KEMSA still has myriad opportunities to consider how to enhance its supply and logistics processes through use of different technology interventions to be able to achieve its objectives. A self-assessment by KEMSA (2013), which led to the devising of the new business model necessitated by the devolution of healthcare in Kenya, identified that there was an urgent need to reposition itself to better serve counties directly and meet the needs of commercial facilities.

Figure 2-2 shows the different actors in the Kenya pharmaceutical supply system.

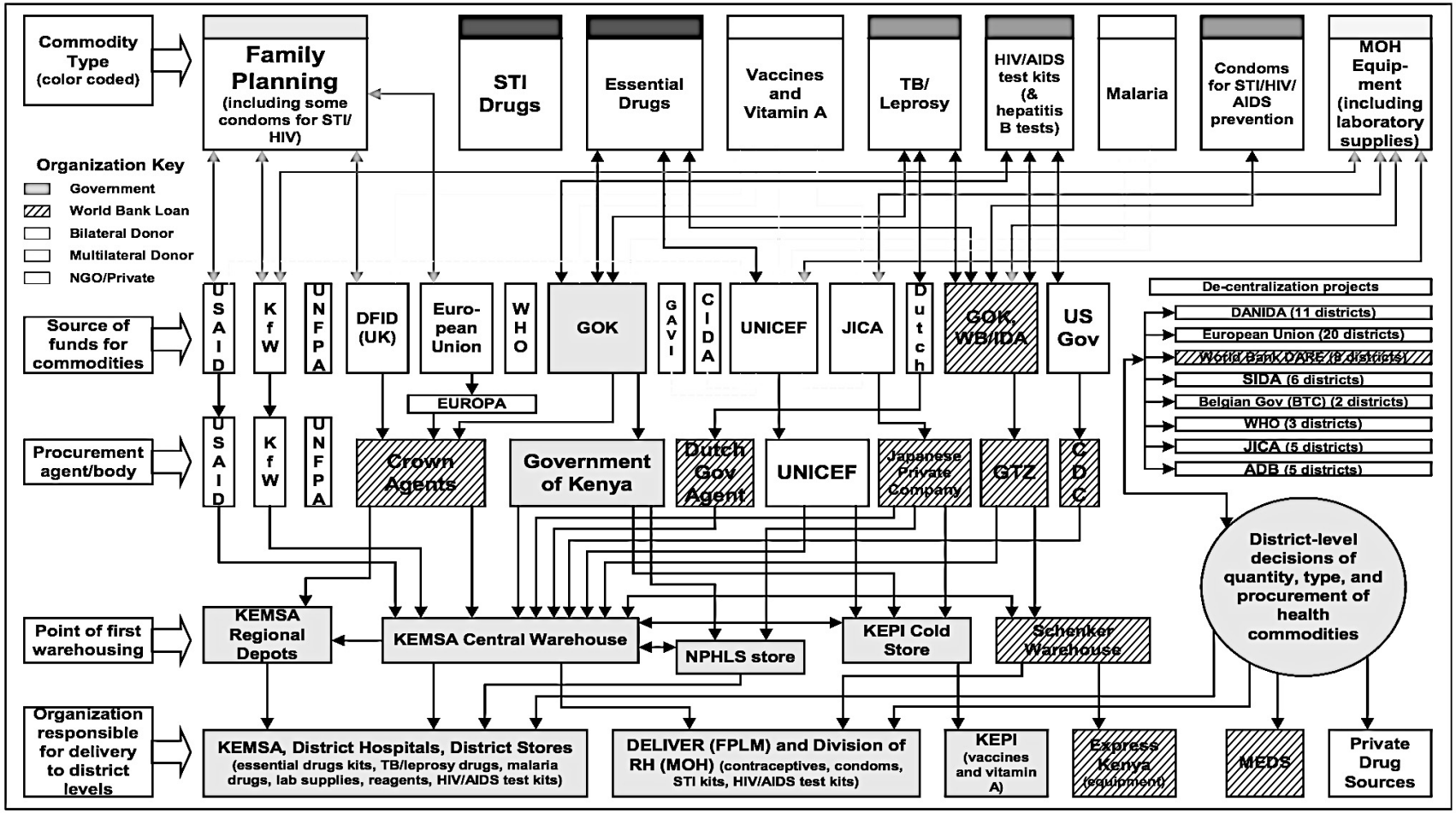

Figure 2-2 Elaborate Breakdown of Kenya Pharmaceutical Supply System (Source: Aronovich & Kinzett, 2001)

The monitoring of the availability of drugs and their prices, remains the duty of the Kenyan Department of Pharmacy in the Ministry of Medical Services which has in the past been carried out in collaboration with the WHO and Health International Africa since 2006 (KEMSA, 2009). This process is often meant to revisit and adjust if necessary, the specific products to be procured, which are derived from the Kenya Essential Medicine's List and/other relevant treatment protocols (KEMSA, 2009). The Kenya supply chain system is a complex system involving different actors as shown in Figure 2-2, who aid in the procurement of different drug types but for the purposes of this study the focus will mainly be on essential drugs through KEMSA rather than exploring all the agencies and all the different classes of drugs that they fund.

The quarterly data collection exercise is conducted in different districts/counties from different health facilities comprising of public FBHS facilities to adjust the KEML. This data is usually collected from pharmaceutical personnel based in the survey area (KEMSA, 2009). The frequency of data is collected using manual standardized forms, which are sent for analysis using a standardized Excel workbook to the KEMSA headquarters (KEMSA, 2009).

2.1.2 The Reality and Challenges of Ensuring Availability of Essential Medicines in Kenya

There have been various studies to identify whether progress is being made with regards to ensuring availability of essential medicines in facilities. Majority of these studies have showed continued stock-out problems in health facilities and with the advent of the devolved government, the devolution of healthcare still presents challenges for individual facilities. A study on availability of essential drugs in Webuye county (Mecca, 2014), indicates that stock-outs were still experienced at the District hospital although there were a bulk of concerns related to financing. Mwathi and Osuga (2014) also identify that the key issues affecting availability of essential medicines especially in Kenyan public hospitals include inappropriate selection, poor distribution, inadequate funding and irrational use. To address the poor distribution problem, the researchers proposed that an elaborate information management system to enhance communication between KEMSA and hospitals needs to be considered (Wangu & Osuga, 2014).

In a study on the application of ICTs in pharmaceutical data and information management in public facilities in Nairobi County, it was found that this was low even though all facilities except one had computers, accessories and data management software for use in stock record management and inventory control (Chuchu *et al.,* 2015). This study identified that out of the 30 facilities with data management software, only 6(20%) were using it to manage stock records. In a study by the Ministry of Medical Services (2009), it was determined that the health sector in general seemed to face a critical shortage of qualified pharmaceutical personnel to manage medicines supply, dispensation and use. With about two thirds of public and FBHS facilities lacking qualified personnel, pharmaceutical services were found to be deficient and were characterized by regular stock-outs and inadequate records. The inadequate data would often lead to losses of drugs, which would expire, on shelves due to overstocking thus leading to losses (MMS, 2009).

Overall, the findings of various studies indicate that there has been a stagnating or deteriorating performance particularly within the public sector since 2003 and with respect to essential medicines, whose availability has not changed significantly, stock outs in facilities are still experienced and the process of maintaining stock records and labelling of medicines has not improved either. These studies reveal that private facilities seemed to be doing better in managing their procurement as opposed to public health facilities for the obvious reason that a private facility would take much more precaution to ensure that the facility does not incur unnecessary loss due to a personal investment by the owner of the facility.

2.2 Proliferation of Mobile Technology Interventions to Solve Health Sector Challenges

A study conducted to determine the usage of mobile devices by Ericsson in Sub-Sahara Africa (2014), revealed that by the end of 2014 there would be over 635 million mobile subscriptions in Sub-Saharan Africa alone and the same study also predicts that the number will further rise to around 930 million by the end of 2019 as majority of mobile users now seem to carry out quite a broad number of tasks on mobile devices that are normally preferred to be carried out on laptops and desktops. With regards to the use of mobile technology in the health sector, the WHO (2011) defines mHealth or mobile health as medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital

assistants (PDAs), and other wireless devices.

Like other developing countries, mHealth in Kenya primarily focuses on two core areas and these are data collection, where mobile devices are used to replace traditional paper-based methods, and lastly on behavioural change where devices are used to disseminate key messages and good practices among communities (Pratyaya, 2014). It is important to note the continued growth of the mHealth ecosystem in a bid to recognize that these current focus areas could be further expanded to lead to more innovations in this space. Subramanian (2012), indicates that with increased adoption and usage of mobile devices and increased participation of software developers in the creation of mobile applications for different contexts, there is a slow but significant change in the way business transactions are carried out with various innovations spanning payment solutions to management of supply chains.

There are various pressing problems in the pharmaceutical supply chain and this shift is making its way into this sector as seen from various technological innovations in the field that attempt to solve pressing inefficiencies in the pharmaceutical supply chain (USAID, 2011). For instance, health facility users can now routinely manage certain aspects in the supply chain using their mobile devices. It is evident that several healthcare facilities in Kenya face tremendous challenges such as frequently updated regulations, unknown health reform, changing funding policies and different economic ordeals. The focus for most facilities now is to ensure that costs are kept at a minimum and waste in clinical operations is reduced but one key area of waste that is more often or not neglected, is in the health supply chain (Subramanian, 2012).

There is a need to consider ways to allow better management of certain aspects of the supply chain at low or high points of the supply value chain. There are different points of intervention for mobile application in the supply system and these could be in allowing facilities to create forecasts for orders, dispense medication and determine stock availability based on dispensed commodities create orders among other applications. (UNFPA, 2011). The challenge remains with software developers to think innovatively and liaise with relevant organizations to create an even smother system from procurement to dispensation of commodities to ordinary individuals.

2.3 Technological Attempts to Solve the Essential Medicine Availability Problem

Applications targeted at the pharmaceutical industry often have more applications targeted at the consumer of medical and pharmaceutical retail supplies as rather than those in the supply chain. Various functionalities are provided various by these applications such as managing prescriptions, finding pharmacies, purchasing prescriptions, maintaining history of medication among other features. However, there is a need to continuously find more ways to use mobile devices to create efficiency in the supply chain at different levels particularly in ensuring the availability of essential drugs.

In a study (Aungst, 2013) that involved ninety pharmacists from eight different hospitals to evaluate the impact of smartphone integration into clinical pharmacy practice, it was found that smartphones have been accepted in clinical pharmacy practice with a positive perception about their use and that they have improved pharmacists' efficiency in their response to drug information inquiries, and their appropriate incorporation in clinical pharmacy practice will represent significant part of daily pharmacists' practice routine. (Elnaem & Jamshed, 2107). However, there is still a little focus on applications that are generally beneficial for pharmacists (Aungst, 2013). There do indeed exist applications that have been developed try and improve the process of ensuring the availability of quality medical supplies. The existing applications are mostly USSD, android, web-based or standalone applications and a few of these are discussed in the following sections.

2.3.1 KEMSA eMobile Application in Kenya

In a bid to ensure the availability of general medical supplies, KEMSA introduced the KEMSA eMobile application which is a commodity tracking suite of applications accessible through mobile phones that allows monitoring, ordering, tracking and evaluation of medicines for health facilities and programs in the country that are supported by the Ministries of Medical Services and Public Health. The system is interoperable with KEMSA’s Logistics Management Information System and provides information for decision-makers at the health facility level and other stakeholders (KEMSA, 2015). Figure 2-3 shows how the KEMSA eMobile application integrates with the overall KEMSA system, which includes ERPs, and LMIS systems (KEMSA, 2015).

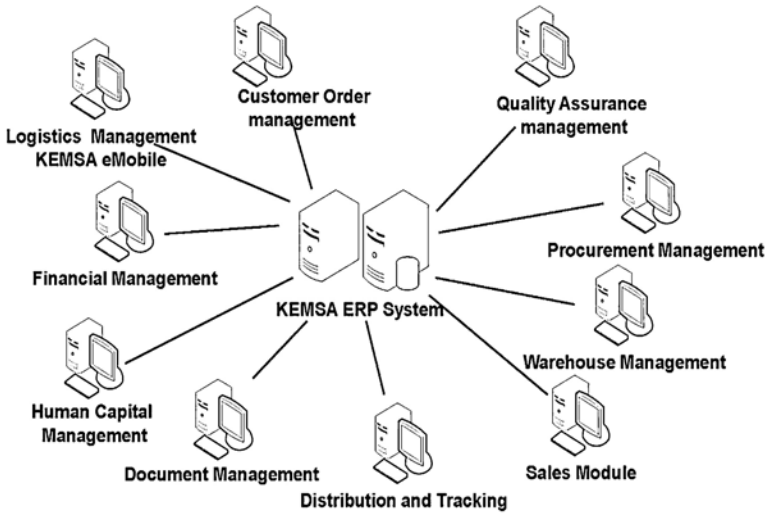

Figure 2-3 KEMSA's Systems Integration

(Source: KEMSA, 2015)

The KEMSA e-Mobile helps to give real time information to the clients on the status of their orders, processing time of the orders and the customer balances (Aging Balances). The application provides real time information to clients about the status of any orders made to KEMSA and the service delivery from the S.S.D: Supplementary Service Division. Figures 2-4 and 2-5 show some of the features on the mobile application.

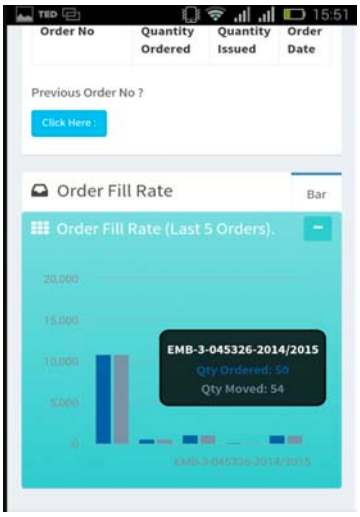

Figure 2-4 View KEMSA eMobile Application

(Source: Google Play)

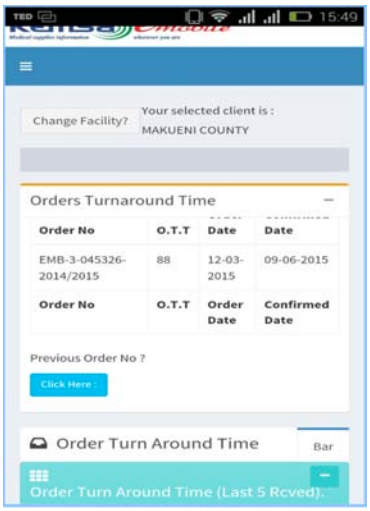

Figure 2-5 View Order Turn-around Time on the KEMSA eMobile Application

(Source: Google Play)

Through the application, the users can be able to carry out the following functions:

i) Check on the order status of their commodities

ii) Check on their customer balances sitting within KEMSA

iii) Check on the Order Turn Around Time

iv) Check on the Order Fill Rate

There are four focus areas of the mobile application and these are shown below in Figure 2-6.

Figure 2-6 KEMSA eMobile Application Focus Areas
(Source: KEMSA, 2013)

In summary, the application is basically a commodity tracking system that tracks health commodities from the time they are ordered from the facility level to the time they are delivered. The application was built with the intention of improving access to collecting medical commodities consumption data from approximately 3000 health facilities nationally. In a study to assess the use of mobile applications to gain sustainable competitive advantage at KEMSA (Ngumi, 2013), it was revealed that 40% of the respondents of the study indicated that there was no improvement in the quality of service because of the mobile application, and were also found to have indicated that efficiency in distribution was the factor that influenced their choice of drug supplier the most. The study further indicates that only 15% indicated that ease of ordering was a factor that influenced their decision the most, which was a proposed benefit of the mobile application.

2.3.2 Stock out Visibility Solution (SVS) by the South African National Department of Health and Vodacom

In 2013, the South African National Department of Health (NDoH) partnered with Telecommunications Company Vodacom South Africa with a third-party developer and deployed a custom-built mobile application in about 3126 clinics across South Africa. The application was primarily aimed at monitoring drug stock levels and reducing stock-out levels in facilities across the country. The application

dubbed *'Stock Visibility Solution (SVS)'* developed by Vodacom via a third-party vendor through its long-standing partnership with NDoH is now fully deployed and fully functional in all urban and rural South African clinics across eight provinces (Vodacom Business, 2016).

The technology was launched with the intention of increasing access to critical medicines by allowing the Department of Health to track critical supply chains in health facilities at any given time. The Department of Health can now monitor real-time visibility of stock levels in clinics to ensure that citizens have access to the healthcare they need, particularly for those patients who rely on chronic medication (Mezzanine Ware, 2016). Figure 2-7 illustrates a summary of how the SVS application works.

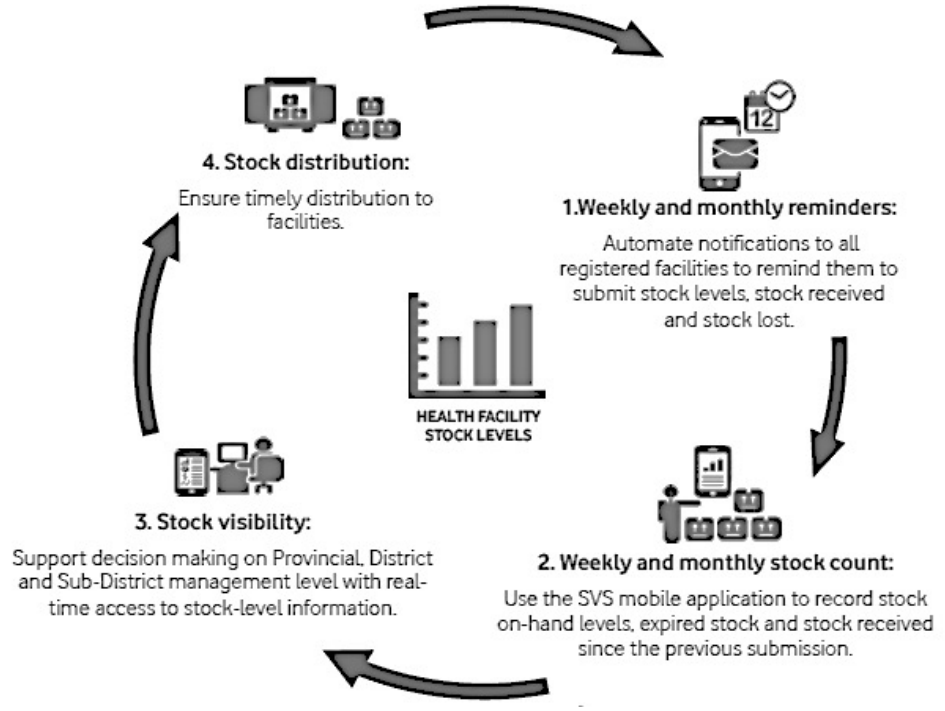

Figure 2-7 How SVS Works
(Source: Vodacom Business, 2016)

NDoH for the most part relied on manual processes to manage drug stock levels in South Africa's primary healthcare system prior to the development of the application, as not all clinics were equipped with ICT systems. The basic functionalities of the SVS application are shown below in Table 2-2.

Table 2-2 Key Functionalities of the SVS Application (Source: Mezzanine Ware, 2016)

Functionality	Description
Medical Catalogue Management	▪ Enable mid-level managers to control items per facility ▪ Add and remove items centrally and synchronize to facility level in real time ▪ Upload full description, bar code and supplier details.
Clinic profile and registration	▪ Complete clinic profile with staff and GPS Coordinates for geospatial mapping which includes the geographic location and characteristics of the clinic
Mobile stock level capturing	▪ Identify stock by scanning a bar code or selecting from an approved list ▪ Capture stock out levels per facility thought a lightweight android application
Data Security and Access	▪ Application synchronize in real time to cloud based data warehousing to ensure data is always available and secure
Stock out report Analysis	▪ Instantly compare the number of facilities that stock an item with the number of facilities that are out of stock of an item
Reporting	▪ Schedule SMS notifications and SMS alerts for low and no stock levels ▪ Download reports in any format and configure automated email reports to key stakeholders

During the period when manual processes were being utilized, stock-outs of critical medicines in clinics arose largely because of the inability to visibly monitor myriad stock levels across the country. This was also complicated by delays in stock order deliveries to pharmaceutical depots and inadequate notice periods pertaining to low stock levels. The mobile technology provides a solution to these challenges and so far, has reported some improvements. To some extent there exists some similarity between the KEMSA application and the SVS application although there is a more deliberate focus on trying to keep track of how facilities are faring beyond the order

and delivery stages. There is also a clear attempt to share reports with key stakeholders.

2.3.3 Technological Interventions from the Developer Community to Solve the Drug Availability Concern

There are several solutions that have been developed to enhance the collection of information related to the managing of drug inventory whether essential or non-essential and two sample solutions are discussed in Table 2-3.

Table 2-3 Applications to Address Pharmaceutical Inventory Concern (Source: Google Play)

Application	Platform	Key Features
TradeLinks Pharmacy Billing & Inventory A mobile application developed by UK based company Softflow systems for pharmaceutical Stores.	Android	▪ The application is useful for billing and inventory control. ▪ Provides stock keeping and debtor/credit management facilities. ▪ The ability to integrate the application with common accounting systems for better record keeping and allow leveraging of existing accounting products to manage the
Logistimo This is a proprietary web application hosted web service by a company known as Logistimo.	Web	▪ Includes features inventory tracking, monitoring, workflow handling, demand forecasting replenishing optimization, quality monitoring as well as scheduling. ▪ The mobile version of the application is also agnostic to network context as it transmits over any wireless carrier network, and its opportunistic multi-channel support lets users work seamlessly between Internet, SMS, and Offline modes Logistimo cloud engine is accessible via common mobile phones and web browsers, uniquely positioning customers to penetrate resource-poor settings of emerging markets.

2.4 Gaps in Assessed Solutions to Address Unavailability of Essential Drugs

From the literature review, it has been identified that inappropriate selection of medicines, irrational use of medicines, poor inventory keeping, poor forecasting and quantification methods, poor distribution practices are some of the factors that

are known to reduce availability of medicines (Wangu & Osuga, 2014). The reports reviewed above particularly form the Ministry of Medical Services indicate that there is an on-going concern about the need to ensure the availability of essential medicines and that technological attempts do in fact create a successful approach to managing stock outs as evidenced from the SVS application deployed in South African clinical facilities. It is also clear that the use of mobile device technology to solve health care problems has also increased especially due to the proliferation of smart devices. With regards to the Kenyan context, the deployment of the KEMSA application was primarily aimed at easing the ordering process but inefficiencies remain in the supply system.

The applications described in this Chapter, in a way address challenges faced by facilities somewhat in isolation and seek to improve availability in individual medical facilities rather than considering ways to empower clinics and pharmacies to be active participants in ensuring availability of essential medicines. The solution by Vodacom and the South African Department of Health is a crucial motivation for this study as it has proven to have a level of succes and that the main functionalities seem to partially address the crux of this study. A key gap in the applications assessed include a focus on enhancing the order process but there is not significant attention given to getting information regarding usage and dispensation patterns.

Building an application that allows KEMSA as a supply body to get more information regarding dispensation and loss patterns from pharmacies that they serve is a way of enhacing the services they provide to these facilities. In terms of the development approach from most developers and software vendors, there have been more attempts to build responsive applications that are accessible on any device rather than committing to always build native applications although this approach has the benefit of taking full advantage of platform specific support for certain features rather than extensive use of external libraries to build an application.

2.5 Conceptual Framework

In light of this literature review a proposal for a mobile application with the following properties is made to address concerns of ensuring essential medicines availability particularly in the Kenyan context:

- Run on mobile or web platforms.
- Use three-tier server architecture.
- Use relevant graphing libraries for ease of information consumption.
- Allow sharing information on inventory levels for essential medicines to the body responsible for supplying essential medicines.
- Allow sharing of dispensation pattern information that can reveal information such loss rates and expiry rates.

Chapter 3: Research Methodology

This Chapter discusses the methodology utilised in this research and its subsequent design to enable a possible replication of this work or assist with future research aimed at extending its findings by determining a suitable starting point.

3.1. Research Design

The research design ideally guides one's data collection and data analysis and it allowed the researcher to address the research problem logically and as unambiguously as possible. The main data collection method was primarily from analysing previously documented literature concerning the research problem area. The key concerns when selecting material to be used were the credibility of the author, intention of the work, the audience, quality of references as well as how recent the work is in relation to advancements made in the problem area. The quality of the literature analysed will be key in ensuring that the data analysed speaks relevantly to addressing the key research objectives and the research questions as well as the problem statement.

3.2. System Development Methodology

The development methodology adopted was the Agile Development Methodology. This is because it allows an iterative approach to development and facilitates quick prototyping of solutions that can be continuously improved as more and more relevant requirements are identified. Due to the constraint of time and budget this methodology seemed as the most appropriate as opposed to adopting the waterfall model, which in a sense assumes the existence of unlimited adequate resources and eventual success of a project. Figure 3-1 shows the Agile development methodology process, which was used in the development of the proposed solution.

Figure 3-1 Agile Development Methodologies (Source: DotSquares)

The use of the agile methodology allowed easy building and testing of application features and quickly adopting feedback to enhance the features being built over time. This aided in better outcomes as opposed to building the application and testing it later in the development cycle and finding out gaps in delivered solution.

3.2.1. System Modelling and Design

The research involved the identification of system architecture for the proposed system through use of different modelling tools such as class diagrams, entity relational models and use case diagrams. The modelling tools were used to solidify the requirements of the system identified during the requirements analysis phase and these were further used to inform the design phase in-order to express the general overview of the proposed application. The development phase also used the results of the design phase to carry out the actual implementation of the application.

User testing was also conducted to validate the usefulness of the application and this was carried out after the development process.

3.2.2. System Testing

The three main kinds of testing that were done included unit tests, functional tests and user acceptance tests.

i) Unit Tests

Unit tests focus on a small part of the software system and they guide development. Unit testing makes use of various testing frameworks based on the chosen implementation technology and it can be concluded that unit tests are technology-facing tests and support the team. Examples of unit testing frameworks include JUnit for java applications, PyUnit for python among others. The unit-testing framework used for testing during development will be the karma-testing framework. Figure 3-2 below shows a simple user test at the unit level.

```
describe('Users factory', function() {
  var Users;

  // Before each test load our api.users module
  beforeEach(angular.mock.module('api.users'));

  // Before each test set our injected Users factory (_Users_) to our local Users variable
  beforeEach(inject(function(_Users_) {
    Users = _Users_;
  }));

  // A simple test to verify the Users factory exists
  it('should exist', function() {
    expect(Users).toBeDefined();
  });
});
```

Figure 3-2 Sample unit tests from

ii) Functional Tests

This class of tests focuses on a grouped number of functionality to complete a certain workflow and they are generally business facing tests that support the team to confirm the set business rules of applications. Various frameworks can also be used for feature test such as Cucumber, Capybara among others. Functional tests can either be manual or automated.

iii) User Acceptance Tests

These tests are manual in nature and involve testing users' perceptions and experiences of using an application.

3.3. Guidelines to Building the Application

There are various techniques to developing mobile applications and they range from building native applications that take advantage of platform feature support without the need to use external libraries to responsive design or the mobile

web approach. Based on the key features of the proposed solution the main concerns to be considered will be ensuring that it possible to easily access information, have a good user experience and connectivity.

3.3.1. Architecture

One of the most popular architecture for building applications is the three-tier architecture comprising of a presentation layer, data layer and an application layer. For the purposes of this report the MVC (Model View Controller) architecture was also considered and the key components are illustrated in Figure 3-3.

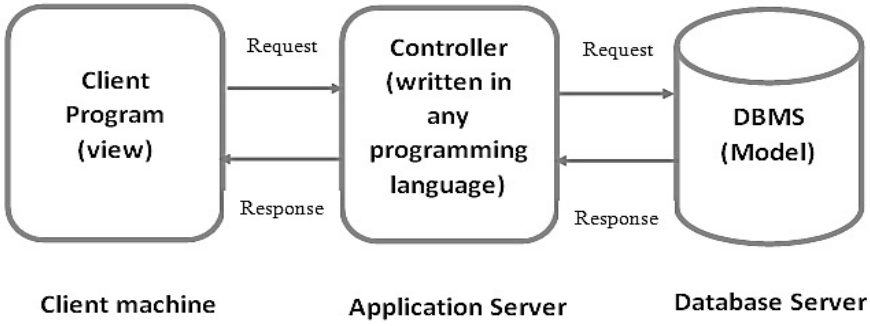

Figure 3-3 Three-tier MVC Architecture (Source: Wideskills, 2017)

With regards to client types a client can either handle a bulk of the processing login (fat client) or have majority of the work done on the server-side done by the server (thin client).

3.3.2. Reproducible Development Environment

The application will need to be developed in an easily reproducible development environment in order to mimic a production level environment where the application would essentially be deployed in hence Vagrant will be used as it is free to use and publicly available Ubuntu boxes can be obtained form Vagrant's main portal. Other advantages of using vagrant is the availability of features such as folder syncing that allow changes to be made on the host machine a well on the vagrant box. The use of tunnelling applications such as Ngrok will be used in order to demonstrate the workings of the application on mobile devices or desktop computers by proving an address that can be accessible anywhere in the world.

3.3.3. Graphing Technologies, Development Frameworks and Scaffolding

In order to take advantage of advanced graphing techniques that could be difficult to use if a native approach to building this application was taken, the AngularJS JavaScript framework is a proposed framework to be used. Since the Agile methodology will be utilised, there is a need to make use of technologies that allow quick bootstrapping of applications and the fact that it is easy to use scaffolding libraries such as the Yeoman generator to generate seed applications it becomes possible to put more focus on building the core functional of the application rather than on setting up the application from scratch. The AngularJs framework also has a great graphing library (Angular NVD3), which is based on D3js.

D3js works well because of its flexibility as it works seamlessly with existing web technologies therefore it is possible to manipulate any part of the document object model. Its flexibility on the client side web technology stack also gives it an advantage over other tools because it can look like anything you want, and it isn't limited to small regions of a webpage like SVG-only based libraries. It also takes advantage of built in functionality that the browser has, simplifying the developer's job, especially for mouse interaction therefore allowing for sleek and interactive visualizations.

3.3.4. Workflow Management

The Agile methodology is recommended for the research project hence there needs to be an easily manage the various feature development phases and inherent tasks in each phase. The Trello board tool will be used to manage the workflow as it is possible to break down tasks in a kanban fashion and group these as backlog items, in progress items and completed items.

3.3.5. Use of Responsive Design

Applications designed to be accessed over the web can either be implemented as applications with separate codebases, building mobile web applications or using an approach referred to as Responsive Design which has become popular over the years. The premise of responsive design is that when designing and building an application, it should respond to the user's behaviour and environment based on the device screen size, platform and orientation. Typically, a mix of flexible grids and layouts, images and an intelligent use of CSS media queries is utilised to achieve

this. When a user moves from one device to another whether it is switching from their laptop or tablet device, the application should automatically adapt to accommodate for resolution, image size and scripting abilities. In other words, the application should have the technology to automatically respond to the user's preferences. This eliminates the need for having different design and development phases for every single new gadget that is added to the market.

New devices with new screen sizes are being developed every day, and each of these devices may be able to handle variations in size, functionality and even colour. Some are in landscape, others in portrait, still others even completely square. Figure 3-3 illustrates the concept of responsive design.

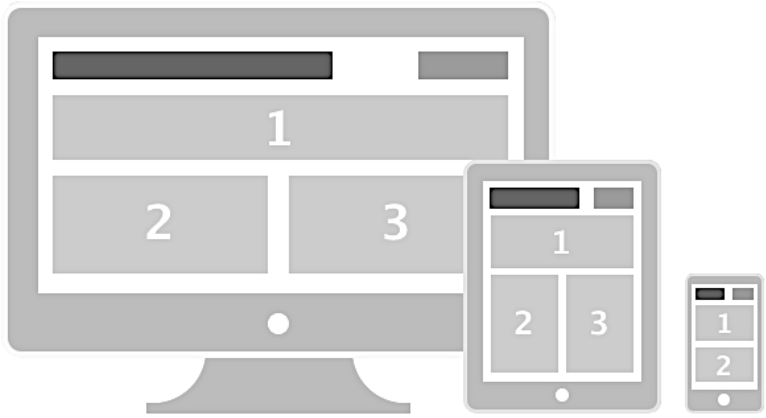

Figure 3-4 Responsive design across different devices

(Source: Boston College Libraries, 2017)

There are quite several advantages of building applications using responsive design such as the following

i) Single code base where the developer builds once and runs an application across all devices
ii) The application built can render across any screen size and this design paradigm considers device differences in widths and heights as well as orientations.
iii) This approach also gives better Search Engine Optimization (SEO) since one version of an application improves page ranking instead of having two versions of the same application, which could affect page ranking.
iv) Once the application is deployed, there is a reduction in maintenance costs

and effort as a single link as opposed to multiple versions of the application.

v) There is also control and flexibility provided to the maintainer of the application as changes can be made at one central code base.

Table 3-1 identifies the key differences between using a responsive design approach and a mobile web approach, which were the two main application design paradigms to choose from.

Table 3-1 Comparing Responsive Design Approach and the Mobile Web Approach

Criteria	**Responsive Design**	**Mobile Web Application**
Versions	Only one version of the application is built that is optimized across mobile devices.	Two separate versions need to be built, one for pc devices and another for mobile devices.
Development Cost	The relative costs increase with increase in number of elements in the website.	The cost can be defined as medium.
Implementation Time	The development cycle is a bit lengthier and the complexity increases, as the site map gets more and more complex.	The development cycle does not take as long as when working with responsive design.
Design Approach	This approach requires specialized knowledge.	The design approach is quite simple and straightforward.
User Experience	Slightly lower user experience since the app is designed for a website and optimized across mobile devices	Better user experience, specifically designed

	Navigation enabled from top to bottom by default. Left to right navigation requires additional customization and modification in layout and code	for mobile phone and improving further with HTML5 technology Left to right navigation enabled to support carousel navigation
On-going Maintenance	Lower maintenance cost and effort Single version to maintain for the website and across a wide range of mobile devices Provides control and flexibility to make changes in website, which are reflected across all mobile devices	Medium Separate for website version and mobile web app version Requires changes to be made separately in website and mobile web app versions

3.3.6. Database Implementation

The propped approach to implementing the persistence layer of the application is the use of a NOSQL database which allows the storage od data in a simple format as the data schema of the MedTrak application is quite simplistic and the main concern is predominantly around ensuing that the database used can handle large data sets and store this in a simple format. The technology to be used is the MongoDB database, which is a NOSQL database and is free to use and stores data in JSON style documents, which means it, becomes easy to manipulate the data retrieved from a database.

3.3.7. User Testing

To test the how well the features of the proposed application solve the problem identified, the application will be tested by pharmacists who will provide useful feedback in the usability of the application and whether it achieves its intended utility which is to track essential medicines usage as well as share dispensation pattern and loss data to KEMSA. A user test basically involves providing a user with a use case

to achieve some task on the application and verifying whether the user is able to accomplish the task.

3.4. Ethical Considerations

It was well understood that there are certain privacy requirements when it comes to health-related data and precaution was taken to ensure that measures to ensure anonymity and confidentiality were put in place. The researcher also made a point of disclosing the purpose of the study to get full consent from respondents in participating in the study.

3.5. Conclusion

Research methodology involved a deeper look at the activities to be undertaken to realize the proposed solution. The activities included initiatives to clearly understand the specific requirements by the users and stakeholders, design and analysis, implementing and testing the prototype. The next chapter details the design and architecture path taken to model the proposed solution.

Chapter 4: System Design and Analysis

This research aimed at considering whether a mobile application is a viable solution to ensuring the availability of essential medicines by facilitating information gathering and sharing for effective decision-making. System analysis was a key process in designing the system and various diagrams such as use cases, data flow diagrams among others were drawn and comprehensive information for each design was illustrated. This chapter presents the various components of the system design associated with the MedTrak application and the intricate details of the implementation technologies will be discussed further in the System Implementation section of this report, which can be found in Chapter 5.

4.1. System Design

System Architecture

The system architecture comprises of a responsive application for KEMSA agents and pharmacy vendors to register, login and view information as well as access other features of the system. The application was developed using AngularJs version 1.6.2 and MongoDB NoSQL database was used to persist data. The Continuous Integration Technology considered was Travis CI and the visualization library used was a version of D3.js built for AngularJS dubbed "***Angular-NVD3***". A previous iteration of the application made use of a DHIS2 instance to allow collection of information by various health facilities but the cost of deployment of an instance did not make it a viable option for the purposes of this study hence this has been omitted.

Figure 4.1 illustrates a simplified architecture of the MedTrak system.

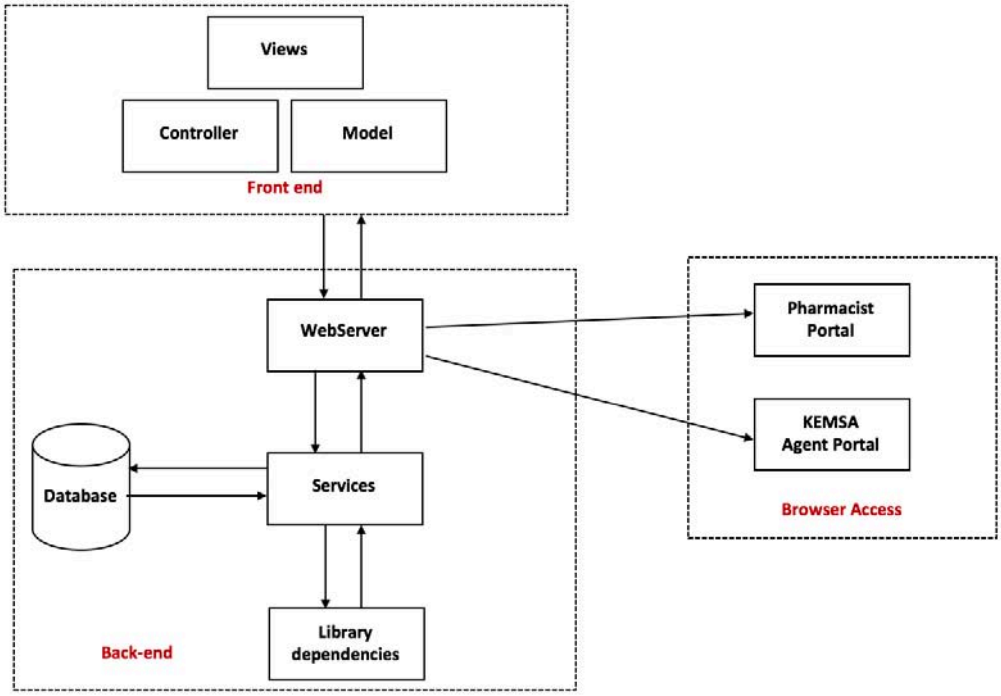

Figure 4-1 MedTrak's System Architecture

The MVC (Model View Controller) approach to designing the architecture was considered. This pattern is an architectural pattern for implementing applications and it mainly divides an application into three distinct components that are interconnected and these include the following:

i) **Mode**l: The model stores data retrieved through use of commands from the controller and this component is displayed on the view.

ii) **View**: This generates the output to the user based on changes on the model.

iii) **Controller**: This sends commands to the model to update the model's state.

The main advantages of this approach to development is the ability to separate different concerns, ensure reusability of code as well as ease of debugging and testing among other myriad benefits. With regards to using AngularJs as the framework of choice, this means that it is possible to build a responsive application with the advantage of ease of testability with a full feature rich framework. Unlike most jQuery heavy applications, which often turn into functional spaghetti code, the breaking down of code into different components makes the code more maintainable. Figure 4-2 illustrates the MVC architecture using the AngularJs framework.

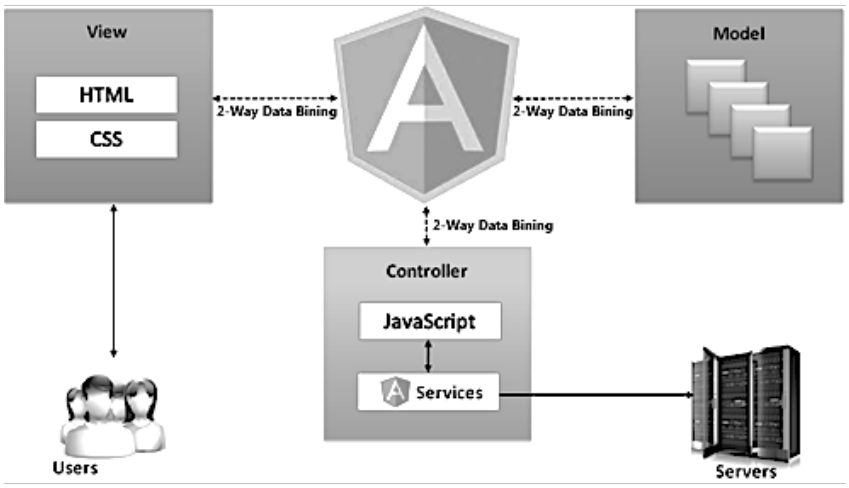

Figure 4-2 MVC Architecture Using AngularJS Framework

(Source: AngularJs Tutorials)

The application consists of a responsive mobile web application that is optimized for mobile phones. The Pharmacists portal essentially allows pharmacists with an essential medicines UI tracker dashboard to carry out various functions. The application also presents a portal for KEMSA agents to register and use the County KEML Monitoring UI dashboard. This can be thought of as the admin portal as in the case of many client-server applications and here KEMSA agents can get an aggregation od data per county and be able to carry out various functions on the dashboard that will be further explored in Chapter 5 of this report under the System Implementation and Testing sections.

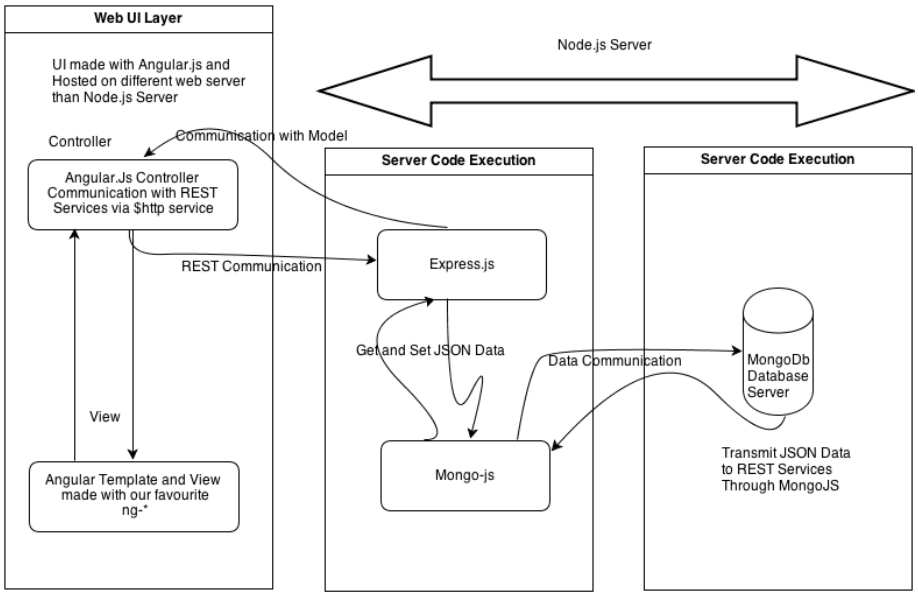

Figure 4-3 Detailed Diagram of the MedTrak Architecture

4.2. Data and Process Modelling

4.2.1. Data Flow Diagram

Figure 4-4 below shows the Data Flow diagram for the MedTrak system.

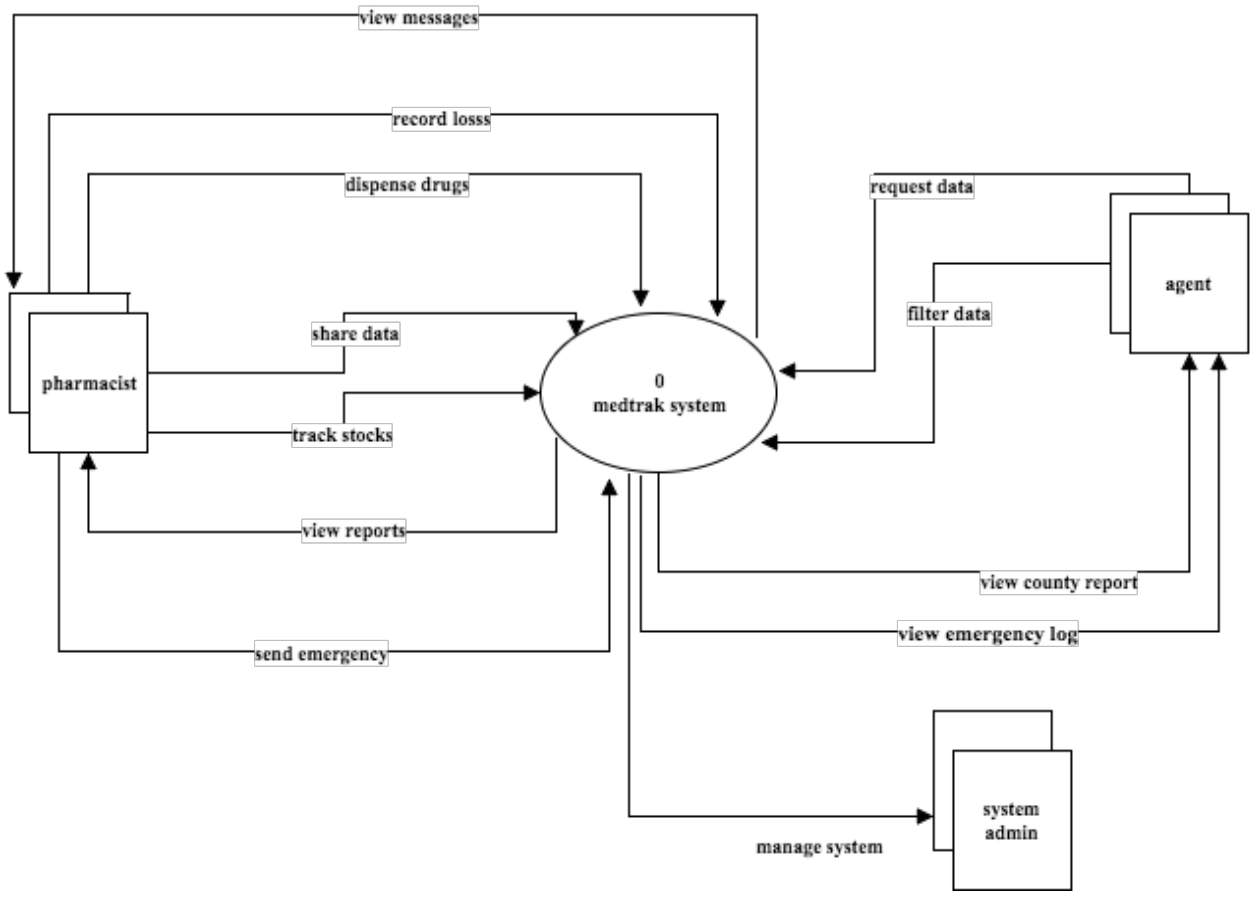

Figure 4-4 Dataflow Diagram for MedTrak Application

Figure 4.5 shows a Level 1 DFD for the MedTrak system. The diagram shows the various sub processes that make up the system. The flow of information among the various entities is also shown in this diagram.

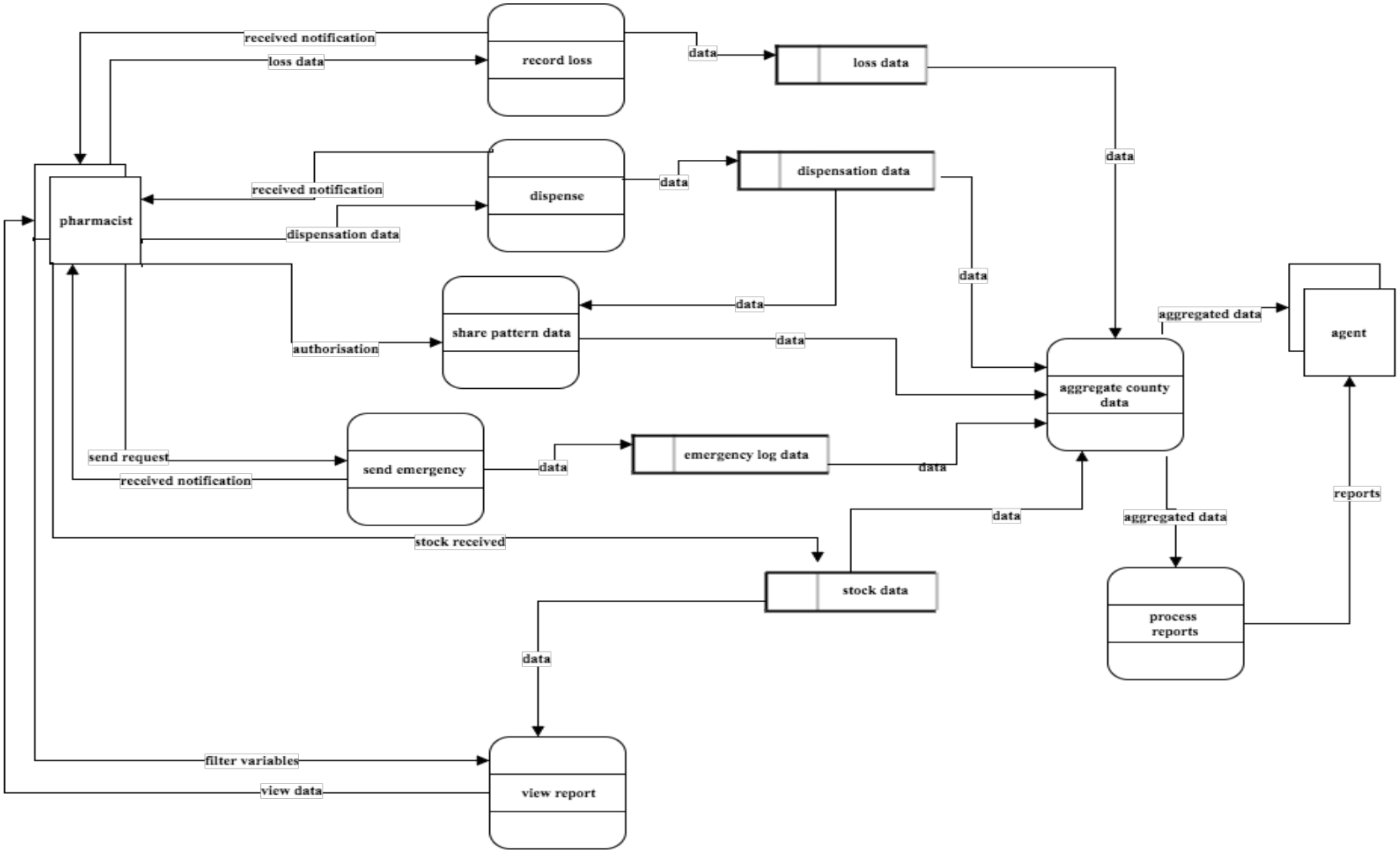

Figure 4-5 Level 1 Data Flow Diagram for MedTrak Application

4.2.2. Use Case Diagram

The use case diagram indicates how various users of the system interact with it and this is shown in Figure 4-6. The two main actors are the pharmacist and KEMSA agent.

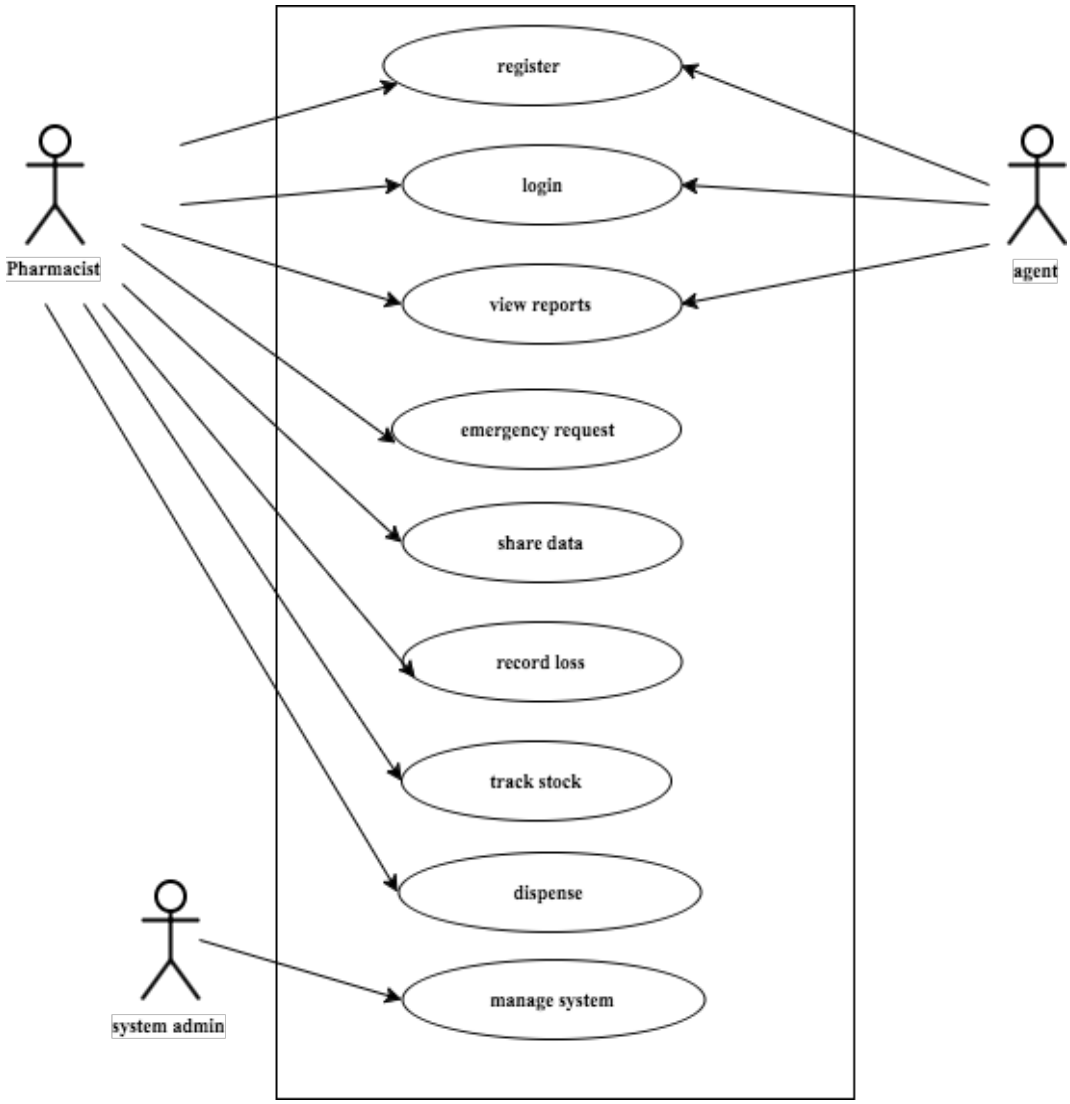

Figure 4-6 Use Case Diagram for MedTrak Application

4.3. Database Design

The database design of the system consists of a NoSQL schema specifically MongoDB. Data is stored as a document and can be easily parsed and manipulated as JSON objects and this was a convenient approach given the fact that this format is easy to work with when it comes to creating data visualizations with Angular NVD3 library.

4.4. Development

The system comprises of two major components, the KEMSA agent web portal and the pharmacist's portal. The mobile application is the main component of the system with majority of the functionality and a pharmacist must register into the application before accessing its core functionalities. The pharmacist can dispense medication, log losses as well as view stock levels and make emergency refill requests. The KEMSA agent Portal provides a monitoring interface to be able to check various data related to submitted data by pharmacists as well as respond to emergency logs.

Chapter 5: System Implementation and Testing

5.1 Introduction

5.2 System Implementation

The system is an application, which is a responsive application accessible on any mobile device with an Internet connection. The application is dubbed ***"MedTrak".*** Sample screenshots of the application (KEMSA agent portal and the pharmacy portal) are attached in Appendix B of this report.

5.2.1 Mobile Device Support

The application is supported on most mobile smartphone devices. The testing of the application's responsiveness was done using the chrome browser developer tools during the development period. As the application does not make use of native device specific libraries, majority of the android mobile device versions are supported but these devices need to have JavaScript enabled or supported.

5.2.2 Application Components

Several features are provided by the MedTrak application and the two-shared features by the agent and pharmacist portals include the following:

i) Registration

The registration module provides a mechanism for a user to register on the application and specify their user type to be able to route them appropriately to the correct portal. The two main types of users are the pharmacist and the KEMSA agent. On registration, the users specify their county to be able to group geographically related data together which is later aggregated so that KEMSA agents can pull up reports for decision making. Pharmacist registrations are required to be associated with a practice registration number so that it is possible to identify inauthentic registrations so that clean data is collected. The screenshots are provided in Appendix B.

ii) Login

The login module is the entry point into the MedTrak application for a registered user and after supplying the relevant information, the users

are presented with a suitable dashboard to be able to carry out the necessary tasks depending on what type of user they have logged in as. The screenshots of the login feature are provided in Appendix B.

The pharmacists' portal contains the following features and functionalities:

i) **Dashboard**

This mobile application has a dashboard, which serves as the home page, and this provides the user with several main options. This is illustrated in the attached screenshots in appendix B.

ii) **Dispensation**

The dispense module is used to dispense commodities to patients who have come to the facility. A pharmacist can browse to the commodity name through the search feature on the dispense module. Drug commodities are categorized based on the classification provided by the Essential Medicines List classification published by the Kenya Ministry of Medical Services. This is illustrated in the attached screenshots in appendix B.

iii) **Share data**

The share data module is a component that allows a user to be able to push data to KEMSA to be able to share information concerning their dispensation pattern, loss rates, expiry rates and stock levels. The screenshots are provided in Appendix B.

iv) **Reports**

This module is used to view reports on the movement of commodities in the facility.

v) **Record Losses**

This module allows a pharmacist to record losses of drugs experienced in the pharmacy and these could be due to various reasons such as expiry, damage, theft or other reasons. The screenshots are provided in Appendix B.

vi) **Track Stocks**

This module allows a pharmacist to keep track of the stock levels in their facility by being able to quickly view the current inventory levels

without having to access the facility database or physical files. The screenshots are provided in Appendix B.

vii) Messages

This module is used to view and act on all notifications within the application. It is divided into two:

- Alerts which pop up when the amount of stock of a commodity are going below a certain threshold. The main alert provided is the low stock alerts.
- Notifications, which are messages that require the user's intervention.

5.3 KEMSA Portal

5.3.1 Browser Compatibility

The KEMSA login portal was developed on Mac OS X operating system but the main requirement to use the application is a working Google Chrome, Apple's Safari or Firefox browser. The application was developed with consideration for ES5 support (ECMAScript 5).

5.3.2 Main Features Provided

The main features for the KEMSA web portal are as follows:

i) View Data

This module allows a KEMSA agent to be able to view aggregated data related to a county in the form of data visualizations to be able to be well informed when making decisions. The screenshots are provided in Appendix B.

ii) Reports

This module allows a KEMSA agent to be able to generate reports related to pharmacies in the county and pull out information such as average loss rates in a county as well as drilling down on what class of drugs in associated with certain loss rates. The screenshots are provided in Appendix B.

iii) Emergency Log

This module allows a KEMSA agent to be able respond to emergency orders by pharmacies.

5.4 Technologies Used

5.4.1 Workflow Management

For the purposes of workflow management, Trello was used as the tool of choice. Trello is an application used to manage tasks and it gives a visual summary of what is being worked on and what are the next tasks to be carried out and it utilises the Kanban system to manage workflows. It is best represented as a whiteboard filled with post-it notes. Each post-it represents different tasks involved in the project. Figure 5-1 shows a Trello board used to manage the MedTrak development activities.

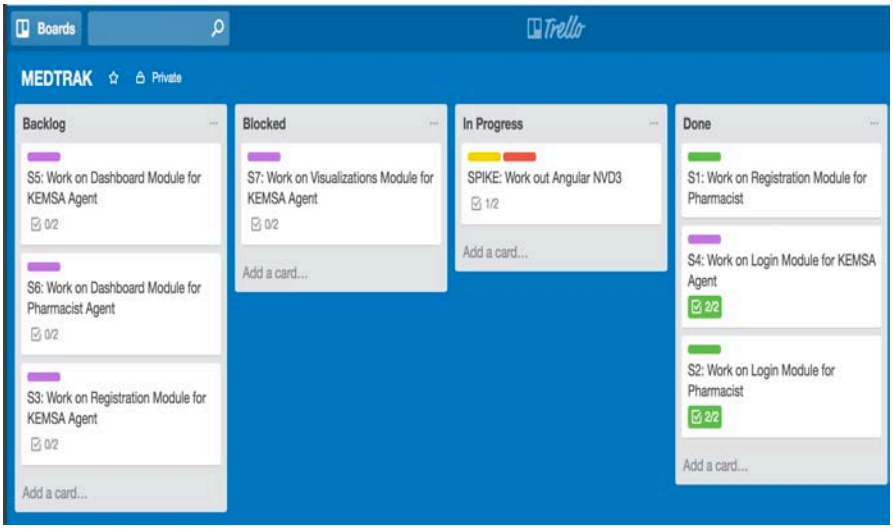

Figure 5-1 Trello Board for Project Management

5.4.2 Virtualization

Virtualization is a technology in where an application, guest operating system or data storage is abstracted away from the true underlying hardware or software. A key use of virtualization technology is server virtualization, which uses a software layer called a hypervisor to emulate the underlying hardware. Virtualization was required to be able to develop the application in a suitable development environment with all required dependencies without having to install all these on the host environment. Vagrant is an example of

commonly used open source software for configuring and deploying multiple development environments. This technology was used and the provider used was VirtualBox for virtualization needs. During development, the server was running inside an Ubuntu 14.04 vagrant box retrieved from the vagrant community. Figure 5-2, Figure 5-3 and Figure 5-4 show how use of this in the development phase.

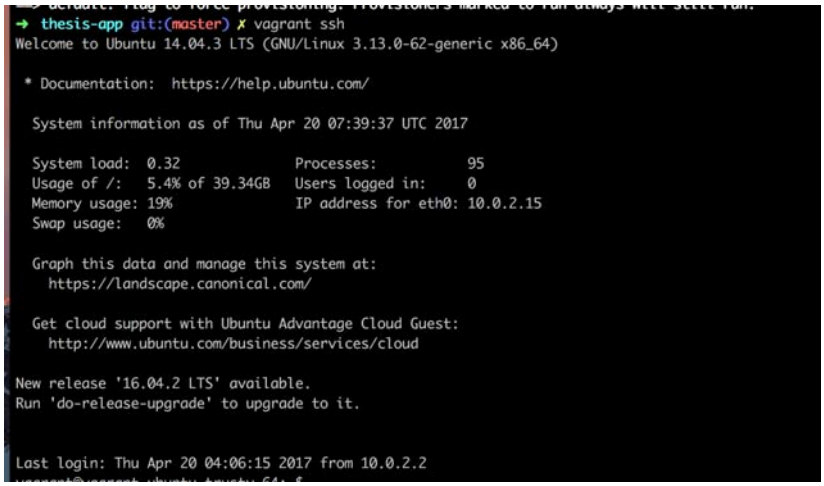

Figure 5-2 User Logged in to a Vagrant Ubuntu 14.0.4 Box

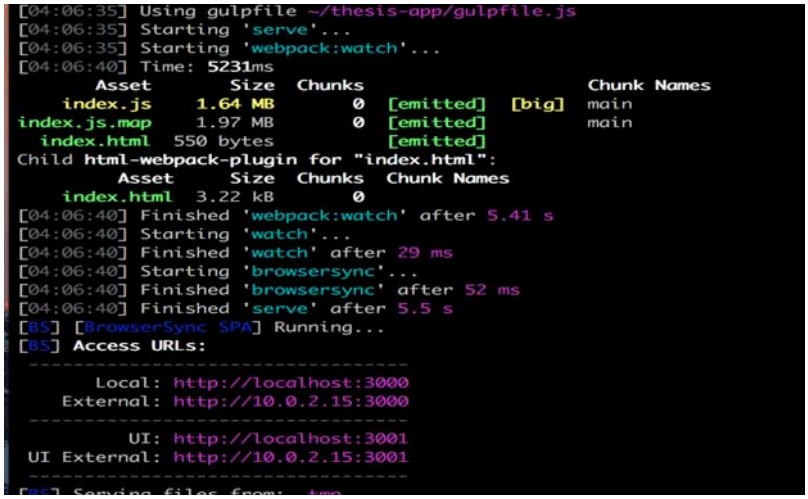

Figure 5-3 Running the Web Server on the Vagrant Box

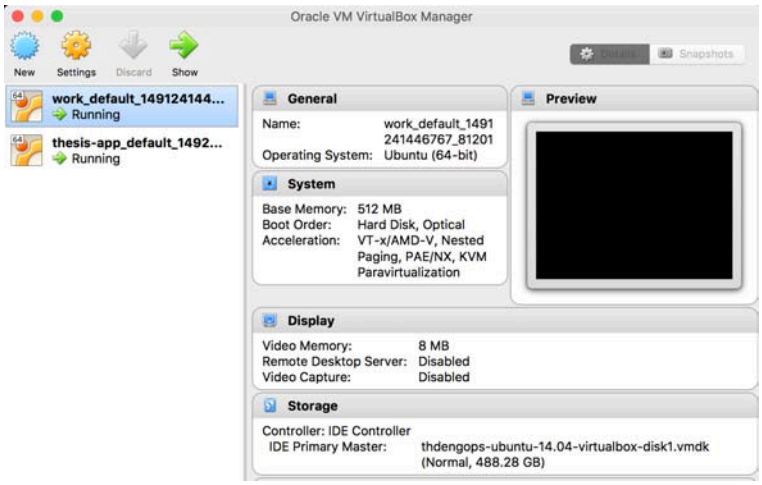

Figure 5-4 VirtualBox Showing a Running VM Instance

5.4.3 External Libraries

The application made use of various node modules and node package manager (npm) was used to manage the external dependencies. Other tools used for development were gulp, which is a toolkit for automating repetitive time-consuming tasks in the development workflow such as minification, building executables as well as running automated tests and running the local server. Yeoman generator was also used for scaffolding and setting up the application. Other libraries such as web pack as the module bundler, which comes with yeoman scaffold generator, were also used.

5.5 Testing

5.5.1 Unit Testing

This class of tests examines testable code at the smallest component level in an application, separates it from the rest of the code, and examines whether it works exactly as the developer expects it to. Each small piece is tested separately before integrating them into modules and at this level the interfaces between modules are tested. Unit testing allows ease of identification of defects as well as ease of extending code without breaking existing functionality.

5.5.2 Functional Testing

Functional Testing is a type of software testing whereby the system is tested against the functional requirements/specifications. To test a function or feature, test input data is used and the output is examined to identify whether the feature or function works as expected. Functional testing ensures that the requirements are properly satisfied by the application. The level of testing that this class of tests is concerned with is more on results of processing rather than the how.

The following steps are usually involved in functional testing:

- Confirming that the software carries out the functions that it expected to perform.
- Creating test input data for each test scenario based on the function's specifications.
- Determine the output based on the function's specifications.
- Execute the test case.
- Comparing the actual and expected outputs.

5.5.3 Acceptance Testing

An acceptance test usually describes the behaviour of a software application using usage scenarios. Acceptance test can either be automated or manual and for this application automated tests have been used using protractor as the tool of choice which works well with AngualrJS.

5.5.4 System Testing

The following sections show sample test use cases used for system testing.

Table 5-1 Registration Use Case

Case Name	Registration	**Case Number**	**001**
Summary	Assess the action of registering a new user into the system.		
Pre-conditions	User does not exist in the system.		
Step	Action	Expected Response	Verdict
1	User lands on the login page and clicks on the create account link	User is taken to the registration form	Pass

2	The user fills in all the required fields	The submit button becomes active and can be clicked	Pass
3	The use clicks on the submit button	The application sends a successfully registered notification and takes user to the dashboard page	Pass
Post Conditions:	A new user has been created.		

Table 5-2 Login-in User Case

Case Name	Log in	**Case Number**	**002**
Summary	Asses the action of logging in as a registered user		
Pre-conditions	User is a registered		
Step	Action	Expected Response	Verdict
1	User lands on the login page and fills in login information	The submit button becomes enabled	Pass
2	The user clicks the submit button	The user gets a successfully logged in message and the application takes user to the dashboard page	Pass
Post Conditions:	The user is on the dashboard page of the appropriate user type		

Table 5-3 Track Inventory Information

Case Name	Track inventory	**Case Number**	**003**
Summary	Asses the action of filling in the form for viewing inventory information		
Pre-conditions	User is a registered user of type pharmacist and has already logged some stock information		
Step	Action	Expected Response	Verdict
1	User taps the track stock button	User is taken to track stock input form	Pass

2	The user fills in all the required fields	The user is requested to confirm the submission	Pass
3	User gets a success message after submitting the form.	The application presents a summary view of current inventory	Pass
Post Conditions:	A summary of available stock information is presented to user.		

Table 5-4 Dispense Medication

Case Name	Dispense essential drugs	**Case Number**	**004**
Summary	Assess the action of dispensing an essential drug.		
Pre-conditions	User is a registered user of type pharmacist and is logged in.		
Step	Action	Expected Response	Verdict
1	The user taps on the dispense option on the dashboard	The user is taken to the dispense drug form	Pass
2	The user fills in all the required fields	The user is requested to confirm the submission	Pass
3	User gets a success message after submitting the form.	The application returns the user to the dashboard page	Pass
Post Conditions:	The dispensation data is logged into the system		

Table 5-5 Share Pattern Information

Case Name	Share dispensation data	**Case Number**	**005**
Summary	Asses the action of sharing the dispensation information		
Pre-conditions	User is registered as user of type pharmacist and is logged in.		
Step	Action	Expected Response	Verdict
1	The use taps on the share data option on the dashboard	The user is taken to the share data form	Pass
2	The user selects the collection of drug information categories that are going to be	The submits button is enabled	Pass

	shared.		
3	User gets a success message after submitting the form.	The application returns user to the dashboard page	Pass
Post Conditions:	The information is pushed to the KEMSA endpoint where it is aggregated with other county data		

5.5.5 Usability Testing

Usability testing was conducted to test the ease of use of the application. Certain key aspects were analysed and these are discussed below with the overall results of the application's usability shown in Table 5-6 and Figure 5-5.

Table 5-6: Overall Usability results

Responses	Very good	Good	Fair	Bad
Number of respondents	6	6	0	0

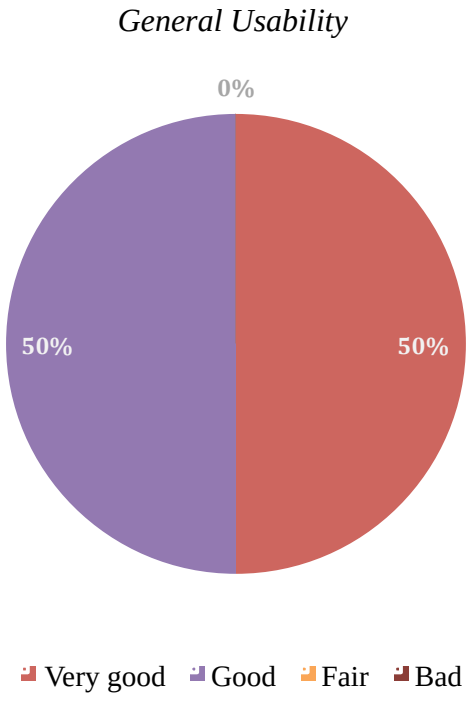

Figure 5-5 Overall Usability results

5.5.5.1 Navigation

Users found the application to be reasonable when it comes to navigating menus, which had appropriate icons and has an intuitive flow. The results of the application navigation are shown in Table 5-7 and Figure 5-6 below.

Table 5-7: Application Navigation Results

Responses	Very good	Good	Fair	Bad
Number of respondents	0	8	4	0

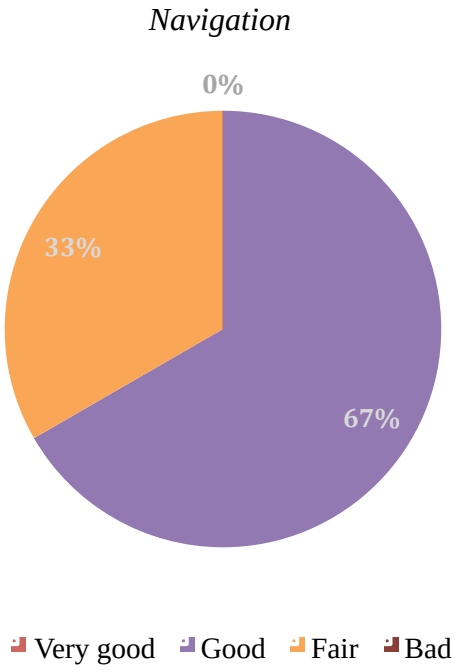

Figure 5-6 Ease of Navigation Results

5.5.5.2 Data Input

Forms were found to be reasonable to fill and not crowded though only a few users insisted that they generally hesitate to fill out lengthy forms on smaller devices. The results are shown in Table 5-8 and Figure 5-7.

Table 5-8: Data Input Results

Responses	Very good	Good	Fair	Bad
Number of respondents	5	7	0	0

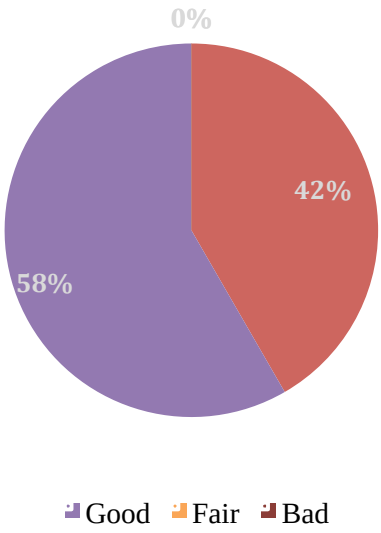

Figure 5-7 Ease of Data Input Results

5.5.5.3 Look and Feel

Overall the users found the application to be simple and neat and the colour scheme not to be distracting. The icons were clear and they accurately expressed the intention of the item on the screen. The results are shown in Table 5-9 and Figure 5-8.

Table 5-9: Look and Feel Results

Responses	Very good	Good	Fair	Bad
Number of respondents	1	2	9	0

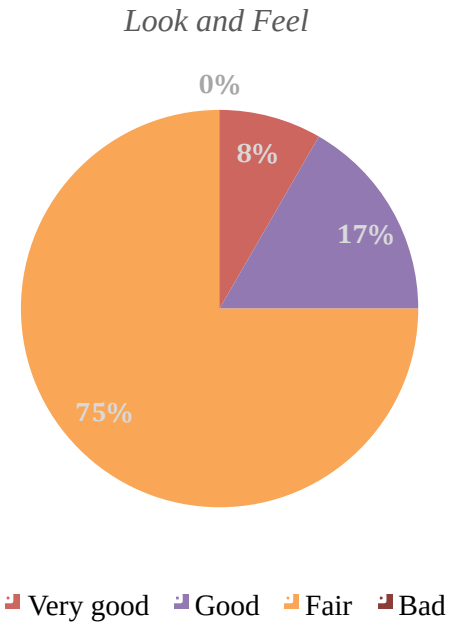

Figure 5-8 Overall Look and Feel Results

5.5.5.4 Feedback from the System

The system was found to give appropriate feedback to users such as error messages when details are left unfilled on forms or success messages when a user has successfully complete an action. The results are shown in Table 5.10 and Figure 5-9.

Table 5-10 System Feedback Results

Responses	Very good	Good	Fair	Bad
Number of respondents	7	3	2	0

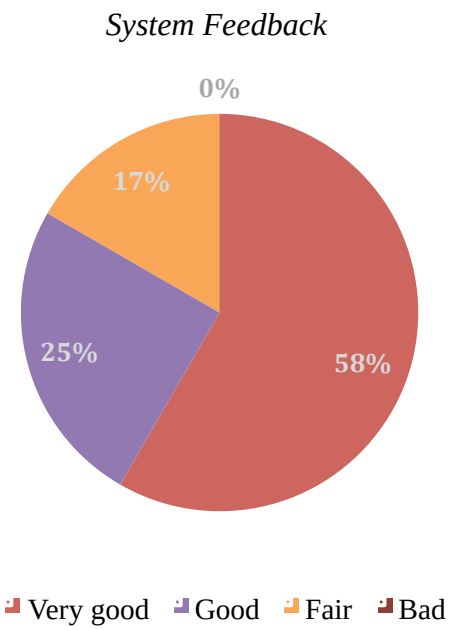

Figure 5-9 Overall System Feedback Results

5.5.6 Compatibility Testing

The essence of compatibility testing is to verify what range of devices work well with the developed application and if the application works well as intended in the target devices. The results for this study are shown in Table 5-11.

Table 5-11: Compatibility Results

Test Point	**Compatible**	**Not Compatible**
Samsung Galaxy S4	Yes	
Samsung Galaxy S3	Yes	
Samsung Galaxy S5	Yes	
Nexus 5X	Yes	
Chrome Browser	Yes	

Chapter 6: Discussions of Results from Testing

The purpose of this research was to determine the challenges in collection and analysis of information related to dispensation pattern data as well as loss rates of essential medicines in pharmacies and proposes an application to assist in mitigation of these issues. The technology used to develop this application has been identified along with a detailed explanation on the steps followed with regards to the methodology. The researcher looks at the existing systems and applications currently utilized by KEMSA as the chosen supply body to identify improvements and key functionality that could be included in the developed mobile application.

6.1 A Review of Research Objectives in Relation to the Solution

The research objectives identified in Chapter 1 of this report guided the development of the mobile application. One objective was to investigate whether web and mobile technologies can be employed to track availability of essential medicines. In order to achieve this objective, the researcher looked at different scholarly journals, application stores, private software vendor offerings, literature review articles, technical and market reports to identify if indeed there have been solutions built around this area. The second objective was to review existing architectures or mobile applications that have been implemented to help with tracking essential medicines availability. This was achieved using document review that is on Chapter 2 which is the Literature Review section of this report.

The third objective was to design and develop a mobile application that helps in tracking essential medicine drug supplies. This was achieved by building the MedTrak application and the design of the system is discussed in Chapter 4 of this document, which is the System and Analysis section. The last objective was to test and validate a mobile application that helps in tracking essential medicine drug supplies and the results are documented in Chapter 5, which is the Implementation and Testing section that sought to validate the developed system.

6.2 Functional Testing

Most of the main functions of the MedTrak application seemed to work as expected across the various basic add, edit, view and delete functions of the various modules which include the dispense function, log losses, track stock and reports modules. The order execution process was not a key feature as the application and

stock data was tracked from imported data from orders made.

6.3 Usability Testing

The results from the usability tests indicate that 50% of the potential users that were involved in the User Acceptance tests found the application reasonably usable and specific aspects of usability such as ease of use, intuitiveness among other aspects are discussed below.

6.3.1 Data Input Ease

Over 100% of the users agreed on the ease of data input on the MedTrak application with responses for ease of use ranging between very good and good. During the analysis stage, it was identified that there would be a need to minimize the input fields on forms since the application targets pharmaceutical retailers in public facilities and quick and efficient data input is key. Certain data inputs such as medication categories and drug names were developed as simple dropdowns to make it easier for the user to find a drug item on the list. Further improvements could be made to include autocomplete features to further ease the process of data input on forms.

6.3.2 Navigation Ease

The test for ease of navigation found that 67% of the test users found the application's navigation to be good and 37% reported that it was fair and the feedback on the users' concerns were noted as future improvements to the application.

6.3.3 Application's Appearance

About 75% of the test users reported that the look and feel was fair and there were a few suggestions from users on the colour scheme, which was the only main concern when it came to the appearance of the application. In general, the application's minimalistic design was found to be simple and did not have an overwhelming set of features for users.

6.3.4 System Feedback

It was important to ensure that relevant feedback on user actions was given by the application and from the User Testing activities, 58% of the users indicated

that the system feedback was very good and the overall response on this aspect of usability was 100% with responses ranging from fair to very good.

6.4 A Review of the Proposed System

6.4.1 Advantages of Proposed System

The MedTrak system presents a great opportunity for facilities to become more empowered in ensuring that they respond accordingly to changes in demand for essential medicines in their locales by allowing them to keep close track of loss rates and dispensation patterns as well as stock rates. The application also allows the pharmaceutical retail outlets in public health facilities to be able to share relevant information with KEMSA to further enhance their service delivery to facilities. Owing to the changes in procurement processes related to essential medicines in Kenya, it is quite important for facilities to be more proactive in their planning and ensure that they make well informed decisions to avoid issues such as stock-outs or losses. The use of an application that utilizes inexpensive devices is also an added advantage as this allows them to leverage on available technology to improve processes. The functionalities provided such as allowing users to create visualizations and view reports on the go also facilitates a better experience analysing data collected over time.

6.4.2 Limitations of Proposed System

The limitations of the proposed system include the following:

i. The mobile application requires mobile devices that can access Internet connectivity hence offline capabilities have not been implemented in this iteration of the application.

ii. The application is quite JavaScript heavy so it would not work so well on some simple smartphone devices with poor JavaScript support.

6.5 Discussions Summary

The benefits of the application indicate that a mobile application can used to keep track of essential medicines availability as well as provide a mechanism to share dispensation pattern information and loss rates with key bodies to enhance the availability of essential medicines in public pharmacies.

Chapter 7: Conclusions and Recommendations

7.1 Conclusion

The research identified the problems faced by pharmacies in keeping accurate information related to ensuring availability of essential medicines in their locale. Challenges identified were the lack of an effective information sharing mechanism beyond the order process as well as poor tracking of dispensation patterns to inform procurement decisions effectively or to provide sufficient heuristics to suppliers to better serve their needs. Based on an examination of these challenges, a mobile and web application was created.

The application sought to facilitate a way to keep track of stock information, track loss of drugs, dispense medication as well as share information with KEMSA with the aim of further enhancing the process of availing these drugs to a facility. Prior research has shown that there are still quite several challenges in ensuring essential medicines availability to Kenyans in health facilities and centres and some of these challenges can be addressed by utilizing systems and applications that encourage proactivity in planning such as MedTrak. The application was tested and it was found that it worked as expected and several recommendations from users were identified which would aid in advancing future research and implementations.

The application also made use of an upcoming and popular industry approach to application development that focuses on code reuse and leveraging one codebase to create an application that can be used in multiple devices and platforms.

7.2 Recommendations

The research was conducted with a focus on KEMSA due to the corporation's longstanding partnership with public health facilities in Kenya as well as its attempts to use mobile technology in its current order process. KEMSA has also shown plans to further extend its eMobile application to further suit its new business model hence the additional features proposed in this research would be useful additions to the existing application. There are various recommendations that came out from this research and these include the following:

i. Testing the application outside Nairobi to identify key limitations other than connectivity.
ii. Technology improvements and enhancements on the development stack to

provide more sophisticated features.

iii. Integrate this on existing KEMSA application to leverage on the existing order functionality.

7.3 Future Work

There is a need to further consider how to leverage the existing KEMSA eMobile application and add some of the features proposed in this research as together they would provide a meaningful experience for KEMSA customers and the various county hospitals that they serve. It would also be worthy to investigate how the various emergent technologies in the SCM and Logistics realm can be incorporated to enhance the application further.

References

AngularJS Tutorials. (n.d). AngularJs MVC Architecture. Retrieved February 14, 2017 from AngularJs Tutorials: http://angularjstutorials.net/angularjs_mvc.html

Aronovich, D. G. (2001). Assessment of the Health Commodity Supply Chains and the Role of KEMSA. *Arlington, Va.: DELIVER/John Snow, Inc*.

Aungst, T. D. (2013). Medical applications for pharmacists using mobile devices. *Annals of Pharmacotherapy*, *47*(7-8), 1088-1095.

Chaharsooghi, S. K., & Heydari, J. (2010). Supply chain coordination for the joint determination of order quantity and reorder point using credit option. *European Journal of Operational Research*, *204*(1), 86-95.

Chuchu, S. A., Adoyo, M., & Osuga, B. O. (2015). Information management for essential medicines supplies in public primary care facilities in Nairobi County, Kenya. *African Journal of Pharmacy and Pharmacology*, *9*(19), 532-539.

Christopher, M. (2011). *Logistics & supply chain management (4th ed.).* Financial Times/ Prentice Hall, 2011

Elnaem, M. H., & Jamshed, S. Q. (2017). Mobile applications in clinical practice: What is needed in the pharmacy scenario? *Archives of Pharmacy Practice*, *8*(1).

Gatero, G. M. (2011). Utilization of ICTs for accessing health information by medical professionals in Kenya: A case study of Kenyatta National Hospital.

Gathura, G. (2013, March 26). Devolving healthcare system. The Standard Extra, p. 2.

Harrison, A., & Van Hoek, R. I. (2008). *Logistics management and strategy: competing through the supply chain*. Pearson Education.

Hayford, K., Levine, O., & Privor-Dumm, L. (2008). Improving access to essential medicines through public-private partnerships.

KEMSA. (2013). Frequently Asked Questions. Retrieved January 3, 2017 from KEMSA: http://www.kemsa.co.ke/index.php?option=com_content&view=article&id=11&Item id=112

KEMSA. (2014). A case study of the ongoing transition from an ungainly bureaucracy to a competitive and customer focused medical logistics organization. Retrieved March 22, 2017 from World Bank: http://documents.worldbank.org/curated/en/876311468277741016/pdf/918640WP0P14870e0ongoing0Transition.pdf

Mecca, L. W. (2014). *Financing and availability of essential medicines before and after introduction of the national hospital insurance fund civil servants and disciplined services medical scheme: a case study of Webuye district hospital, western Kenya* (Doctoral dissertation, University of Nairobi).

Mezzanine Ware. (2016). Key features of SVS. Retrieved December 15, 2016 from Mezzanine Ware: www.mezzanineware.com/health-solutions/

Ministry of Health. (2009). Access to Essential medicines in Kenya: A Health Facility Survey. Retrieved February 26, 2017 from WHO: http://apps.who.int/medicinedocs/documents/s18695en/s18695en.pdf

Ministry of Health. (2010). Access to Essential medicines in Kenya: A Health Facility Survey. Retrieved February 27, 2017, from WHO: http://apps.who.int/medicinedocs/documents/s18695en/s18695en.pdf

Ministry of Health. (2010). National Pharmaceutical Policy. Retrieved February 27, 2017, from WHO: http://apps.who.int/medicinedocs/documents/s18697en/s18697en.pdf

Ministry of Health. (2013). Press Statement. Retrieved February 27, 2017, from KEMSA: http://www.kemsa.co.ke/index.php?option=com_content&view=article&id=68:press -statements&catid=13:news&Itemid=150

Ministry of Health. (2016). Kenya Essential Medicines List. Retrieved from apps.who.int/medicinedocs/documents/s23035en/s23035en.pdf

Ngumi, W. G. (2013). Use of mobile applications to gain sustainable competitive advantage at the Kenya Medical Supplies Authority (kemsa).

Oballah, Dorothy, Esther Waiganjo, and W. E. Wachiuri. "Effect of inventory management practices on Organizational performance in Public health institutions in Kenya: A case study of Kenyatta national hospital." *International journal of education and research* 3.3 (2015): 703-714.

Pratyaya, .M. (2014). Challenges and Opportunities for mHealth in Kenya. *TechChange*. Retrieved on November 15/11/2014 from https://www.techchange.org/2014/11/03/mhealth-challenges-opportunities-kenya-india/

Ranganathan, C., Teo, T. S., & Dhaliwal, J. (2011). Web-enabled supply chain management: Key antecedents and performance impacts. *International Journal of Information Management*, *31*(6), 533-545.

Sestini, J. K., Mansfield, P. K., Wurman, P. R., Graybill, J. C., Lecky, N., & Curlander, J. C. (2015). *U.S. Patent No. 9,129,250*. Washington, DC: U.S. Patent and Trademark Office.

Shretta, R., Johnson, B., Smith, L., Doumbia, S., de Savigny, D., Anupindi, R., & Yadav, P. (2015). Costing the supply chain for delivery of ACT and RDTs in the public sector in Benin and Kenya. *Malaria journal*, *14*(1), 57.

Subramanian, H. (2015). Mobile and the health care supply chain. Retrieved on 10/02/2015 from https://www.novationco.com/media/industryinfo/UsingMobileTechnology.pdf

United Nations Population Agency (UNFPA) (2014): *Inventory of Information and Communication Technology for Supply Chains*. Retrieved on 30/06/2014 from http://www.everywomaneverychild.org/images/ICT_Solutions_Inventory_FINAL_1.pdf

USAID. (2011). Annual Report: Program Year 1. Retrieved January 2017 from http://apps.who.int/medicinedocs/documents/s21709en/s21709en.pdf

Velarde, P., Maestre, J. M., Jurado, I., Fernandez, I., Tejera, B. I., & del Prado, J. R. (2014, September). Application of robust model predictive control to inventory management in hospitalary pharmacy. In *Emerging Technology and Factory Automation (ETFA), 2014 IEEE*.

Vodacom Business. (2016). Vodacom partners with SA department of health. Retrieved January 22, 2017 from Vodacom: http://now.vodacom.co.za/article/2016/07/14/vodacom-partners-with-sa-department-of-health-business

Wamai, R. G. (2009). The Kenya Health System—Analysis of the situation and enduring challenges. *Jmaj*, *52*(2).

Wangu, M. M., & Osuga, B. O. (2014). Availability of essential medicines in public hospitals: A study of selected public hospitals in Nakuru County, Kenya. *African Journal of Pharmacy and Pharmacology*, *8*(17), 438-442.

WHO. (2004). Equitable access to essential medicines: a framework for collective action. Retrieved April 1, 2017 from WHO: http://apps.who.int/medicinedocs/pdf/s4962e/s4962e.pdf

WHO (2009). Access to essential medicines in Kenya: A household survey. Nairobi Ministry of Medical Services and Ministry of Public Health & Sanitation in collaboration with WHO and Health Action International-Africa (HAI-A), Nairobi, Kenya

WHO. (2010). Access to essential medicines. Retrieved March 22, 2017 from WHO: http://www.who.int/healthinfo/systems/WHO_MBHSS_2010_section4_web.pdf?ua=1

Yadav, P., Stapleton, O., & Van Wassenhove, L. N. (2010). Always cola, rarely essential medicines: comparing medicine and consumer product supply chains in the developing world.

APPENDIX A: Existing Applications

Figure A-1 Accessing KEMSA USSD Application
(Source: KEMSA, 2013)

Figure A-2 KEMSA USSD Application Menu
(KEMSA, 2013)

Figure A-3 Logistimo Application (Source: BetterPlace Lab, 2014)

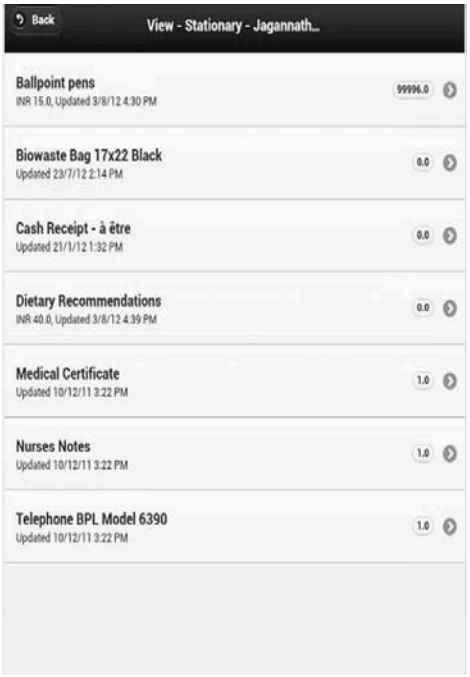

Figure A-4 View Stock Menu (Source: BetterPlace Lab, 2014)

APPENDIX B: Sample MedTrak Screenshot

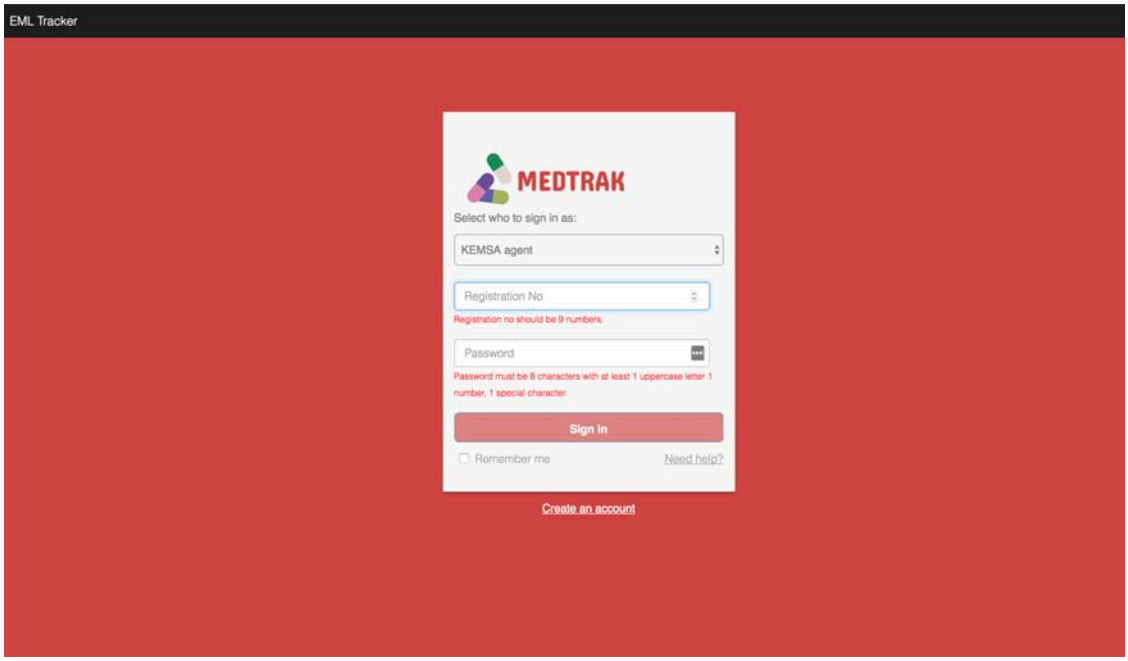

Figure B-1 Web view of the login module

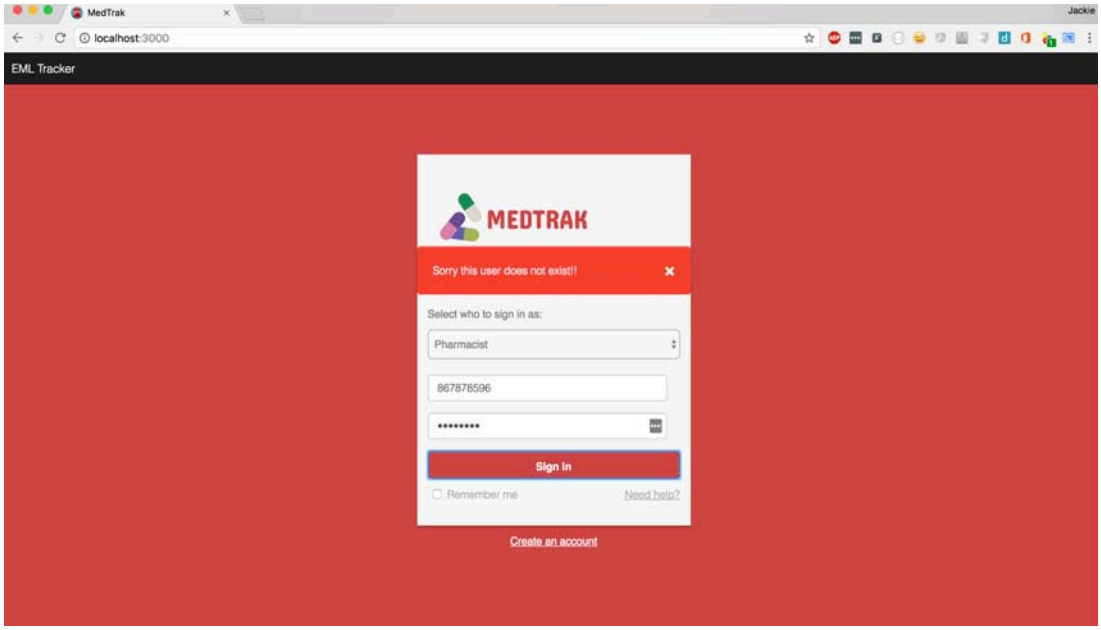

Figure B-2 Web view of the login module with validation checks

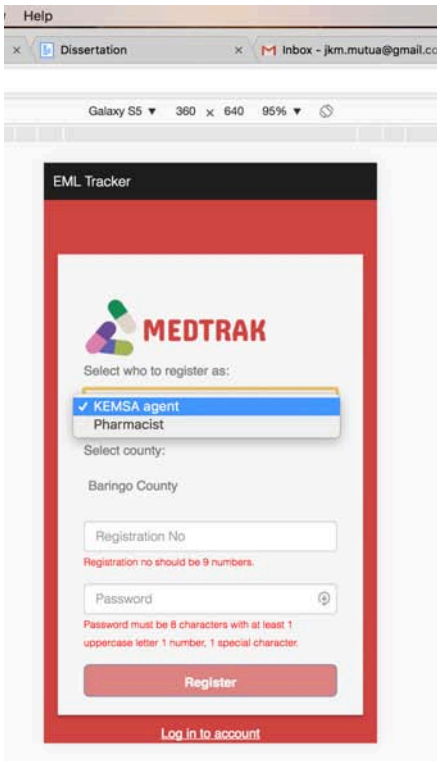

Figure B-3 Mobile view of login module on Nexus 5X Android device

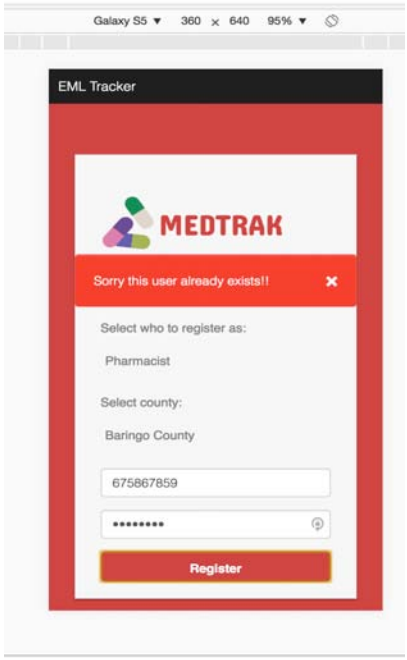

Figure B-4 Mobile view registration module with validation checks

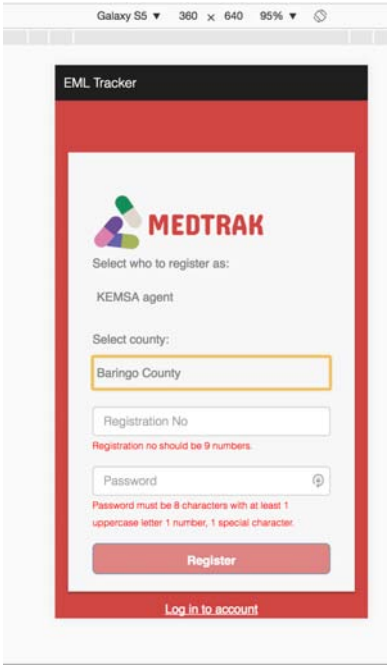

Figure B-5 Mobile view of registration module on a Samsung Galaxy device

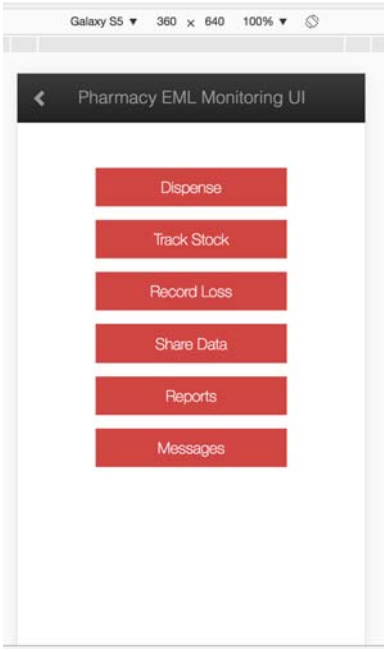

Figure B-6 Pharmacist's Dashboard

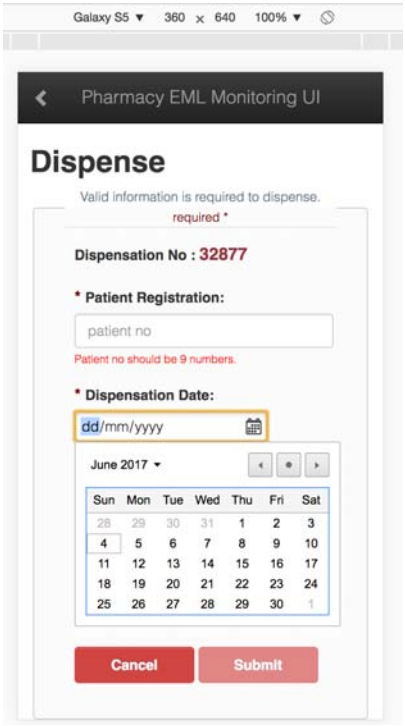

Figure B-7 Dispensation module

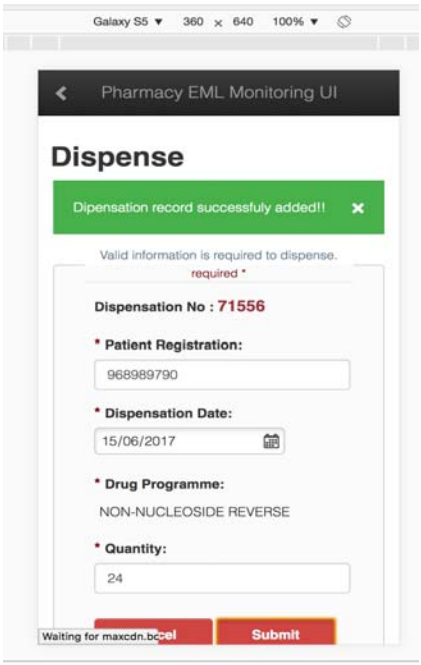

Figure B-8 Successful drug dispensation using the dispensation module

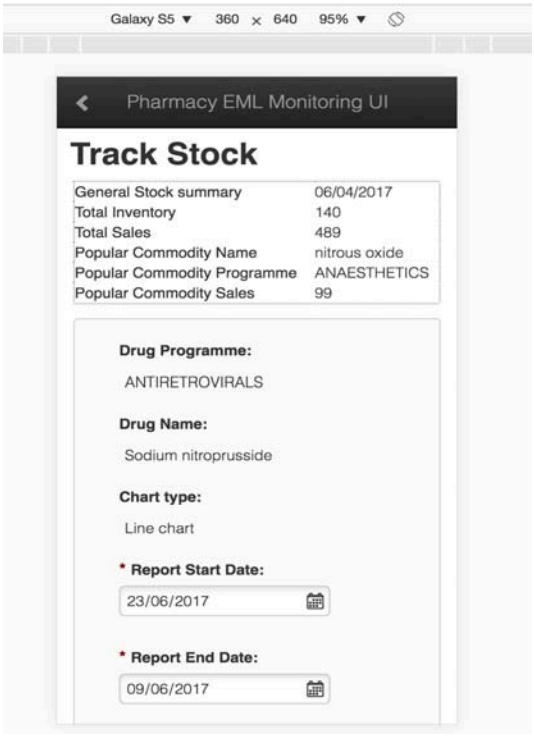

Figure B-9 Tracking Stock Data

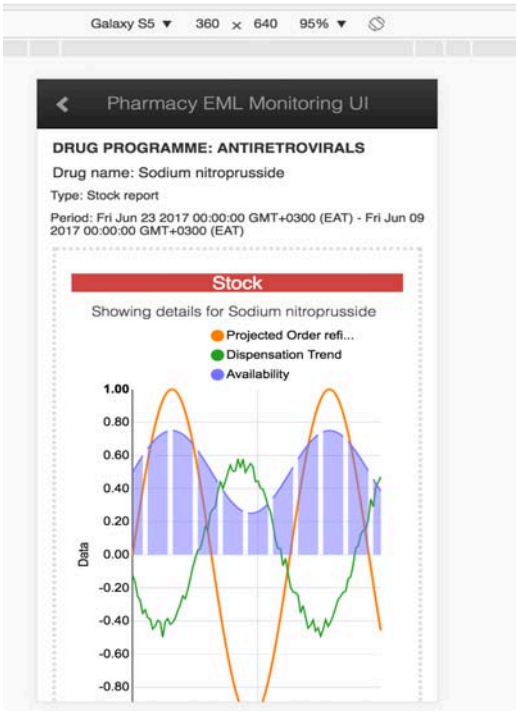

Figure B-10 Viewing a Stock Report Visualization

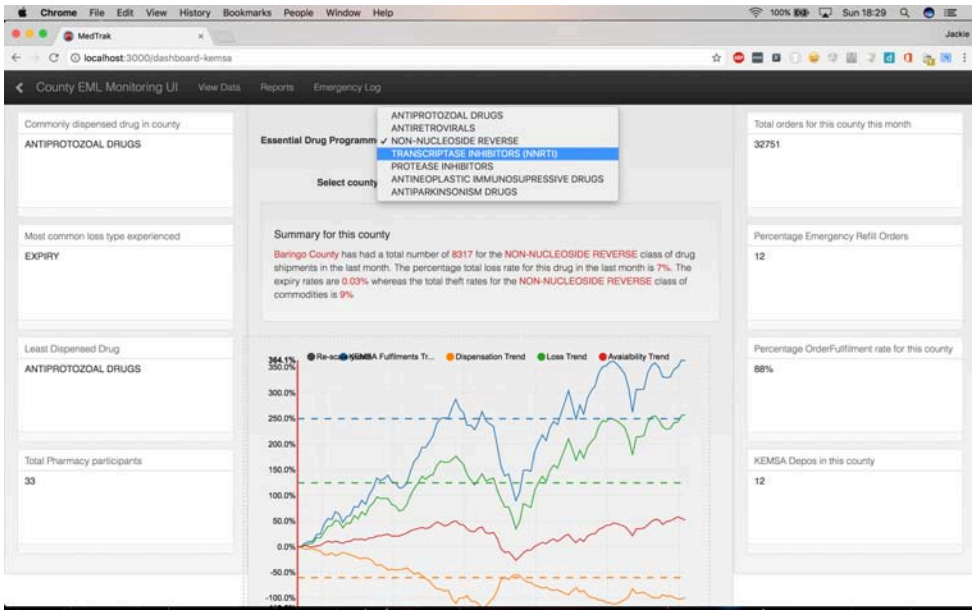

Figure B-11 KEMSA Dashboard

APPENDIX C: TurnitIn Report

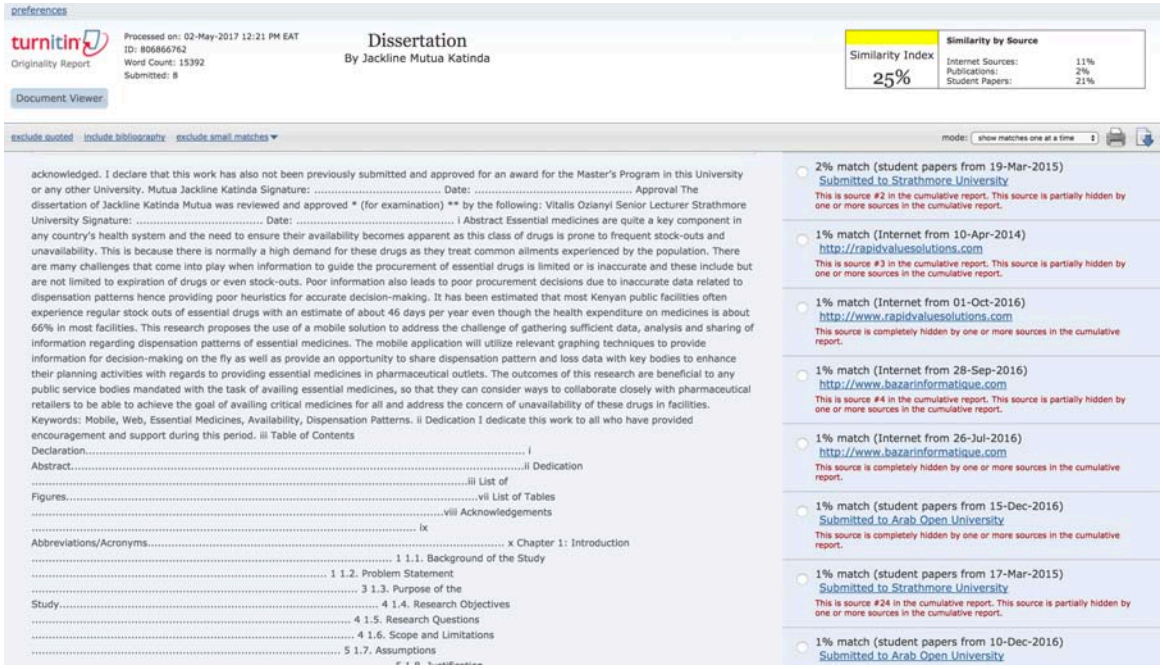

Figure C-1 TurnitIn Report