2016

A Mobile phone solution for systematically identifying and reporting non-standardised medicinal drugs in Nairobi, Kenya.

Barasa, Mark Misiko
@iLabAfrica
Strathmore University

A Mobile Phone Solution for Systematically Identifying and Reporting non-standardised Medicinal drugs in Nairobi, Kenya.

Barasa, Mark Misiko

A research dissertation submitted in partial fulfillment for the requirements for the Degree of Master of Sciences in Mobile Telecommunication and Innovation.

Faculty of Information Technology
Strathmore University
Nairobi, Kenya.

June, 2016

DECLARATION AND APPROVAL

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

Mark Misiko Barasa

……..

Date: 22 June 2016

Approval

The dissertation of Mark Misiko Barasa was received and approved by the following;

Dr. Joseph Sevilla,
Senior Lecture, Faculty of Information Technology,
Strathmore University.

Dr. Joseph Orero,
Dean, Faculty of Information Technology,
Strathmore University.

Prof. Ruth Kiraka
Dean, School of Graduate Studies,
Strathmore University.

ACKNOWLEDGEMENTS

First, I give thanks to the almighty God for patience, knowledge, strength and wisdom bestowed to me that immeasurably contributed to completion of this dissertation.

I'd like to express gratitude to my supervisor Dr. Joseph Sevilla for the useful comments, remarks and engagement through the learning process of writing this dissertation. Not to forget participants of my survey, who willingly shared their views and sacrificed precious time during the interview process.

I thank Safaricom Academy and @ILab Africa for granting me this Scholarship. The opportunity to acquire the knowledge, skills and expertise necessary to complete this work is priceless.

Finally, to my family, friends and colleagues who assisted when I was in need, I give heartfelt regard and gratitude.

Thank you all!

ABSTRACT

Effective observation and reporting of uncertified/counterfeit drug items demands timely identification and dissemination of information to parties' responsible for consumption, prevention, distribution and control of drugs to warrant necessary action in case of a flaw. Tools used to identify and report existence of such drug items determine the level of efficiency and effectiveness of the exercise. Traditional paper based and rigid computer based reporting procedures compromise on completeness, timeliness and correctness of data. This scenario creates unprecedented opportunities that researchers can use to improve the current way of identifying and reporting counterfeit drugs. This dissertation gives an analysis of the distribution and effects of counterfeit drugs to the human population in Kenya and internationally with focus on emerging markets. A comprehensive investigation of mobile scanning techniques and existing technologies used to track drug items is also covered. Data collection instruments used were through holding interviews and observations. Both qualitative and quantitative methods of data analysis were employed. Results of the data analysis aided to inform system requirements and design of the application. SCRUM, an agile methodology was adopted as the software methodology for development of the application. PEPELEZI DAWA, a mobile application was developed as a tool to offer an interactive menu where users can scan medication and report counterfeit drug items using their mobile devices. A web application was also developed to provide a portal for authorized personnel, registered under local drug quality control organisations to; manage users, view and edit stored records of drug items and view reports posted by users. System testing was done to ensure usability, reliability, completeness and correctness of both developed applications.

Keywords: Counterfeit, Drugs, Reporting, Control

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS/ACRONYMS

AIDS – Acquired immune Deficiency Syndrome

CA – Communication Authority of Kenya

FDA – Food and Drug Administration

FSHSS – Federal Service for Health Sphere

GPS – Geographic Positioning System

GIS – Geographic Information System

HTTP – Hypertext Transfer Protocol

ICT – Information Communication and Technology

KEBS – Kenya Bureau of Standards

ANMAT – Medical Authority of Argentina

NQCL – National Quality Control Laboratories

NFC – Near Far Communication

PPB – Pharmacy and Poisons Board

QR – Quick Response Code

RFID – Radio Frequency Identification

SPSS – Statistical Package for Social Sciences

SMS – Short Message Service

TDMA – Time Division Multiple Access

USA – United States of America

URL – Uniform Resource Locator

UML – Unified Modeling Language

WHO – World Health Organisation

WORM – Write Once Read Many

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

According to WHO (2015), a drug is any chemical agent that alters the biochemical physiological processes of tissues or organisms. A counterfeit drug as defined by the World Health Organisation (WHO) is medicine that is fraudulently mislabeled with respect to identity and source (Essential Medicines & Health Products, 2015).

The problem of counterfeit medication/drug is that the pharmaceutical product is produced and sold with the intent to deceptively represent its origin, authenticity or effectiveness. Counterfeit drugs may contain inappropriate qualities of active ingredients or none at all. These may be improperly processed within the body.

In Kenya the practice of Pharmacy has been present for the past 50 years. Regulations on the quality of medicine was done in the year 1977. The Drug Analysis and Research Unit (DARU), a research unit that deals with routine analysis on Pharmaceutical products and market surveillance was developed in the same year. In addition the laboratory also carried out consultancy and research into various aspects of quality control and good manufacturing practices (Kibwage, 2008).

Figure 1.1: Report on Poor Quality of Drugs (Kibwage, 2008)

Figure 1.1 shows extracts from selected media newspapers reporting on the poor quality of drug items identified in Kenya. Extracts are from the Standard, Kenya Times and Daily Nation Newspapers.

Currently Kenya has no systematic way of identifying counterfeit drugs. The drugs can be traced in the market after reports of having substandard value or observation, while others are encountered in the course of quality control. There is therefore need to have a systematic way to identify and monitor counterfeit drugs within the Kenyan market.

1.2 Problem Statement

Quality of medicine is the dimension of output that has the highest impact on consumers including pharmaceuticals. For a long time the media has reported on poor quality, non-efficacious and counterfeit pharmaceutical products that lack adequate policing. Currently there is no systematic surveillance of drugs to establish levels of counterfeit drugs in the Kenyan market.

1.3 Research Objectives

i) To do a market research on the effects of counterfeit products in Kenya and internationally.

ii) To determine a contemporary technology used to track and report existence of genuine and counterfeit products in the market.

iii) To develop a mobile device application that can give information on genuine products and flag counterfeit products in the market through an appropriate technology.

iv) To test the effectiveness and efficiency of the developed mobile device application.

1.4 Research Questions

i) To what extent is the penetration of counterfeit drugs within the Kenyan market and what are its effects on the population?

ii) What are the current technologies used to identify and report existence of genuine and counterfeit products in the Kenyan market?

iii) How can a mobile device application be used to identify and flag genuine and counterfeit goods in the Kenyan market?

iv) What are the findings of testing and evaluation of the developed application?

1.5 Scope of the Study

For purposes of creating a model mobile application, the case study will be conducted in Nairobi, Kenya. The proposed study will be customized for the Kenyan market. The developed application will implement the Android Operating System as the underlying software platform targeting users with access to data enabled mobile devices embedded with a camera. In the proposed study the researcher will only deal with factors affecting software development of the prototype and not mass printing of QR-Codes that need to be attached to specific drug items.

1.6 Significance of the Study

The significance of this dissertation is to help solve a real life problem. The Kenyan market is currently flooded with a wide range of counterfeit drugs. Drug users are therefore at risk in using such drugs as they are harmful to their health or ineffective for treatment. It is therefore mandatory that a solution be found that will make it easy for users to identify and report counterfeit drugs upon purchase.

Development of a mobile based application solution is one such way that is deemed to easily identify and report counterfeit drugs. The mobile application will be used by retailers, consumers and KEBS officials within different counties in Kenya. The solution is scalable and can be customized and replicated to other countries.

A secondary benefit to the solution is that data can be collected and analysed further. The data can be used to generate different reports such as:

i) To know more about the distribution and usage of drugs in the Kenyan market.
ii) To keep an account of key areas where certain drugs are acquired and sold.
iii) To study the usage patterns of specific drugs by the population. Such as the availability or preference to use certain drugs by the populace of an area.
iv) To study symptoms accompanied through the use of certain drugs by the populace of an area.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The U.S. Food and Drug Administration (FDA) terms Counterfeit medicine as fake medicine which may be contaminated or contain the wrong or no active ingredient. The drugs may also have the right active ingredient but at the wrong dose. The FDA classifies counterfeit medicine as illegal and harmful to human health (Counterfeit Medicine, 2015).

In Kenya Counterfeit drugs are identified as those that are deliberately and fraudulently mislabeled with respect to their identity or source. Generic drugs are those that are produced and distributed without patent protection. They are a chemically equivalent, lower-cost version of a brand-name drug. Both drug classifications have the same active ingredient, dosage, safety, strength, usage directions, quality, performance and intended use (Generic versus Brand Medication, 2014).

Countries with weak drug regulations and enforcements, unregulated markets, scarcity or erratic supply of basic medicines and unaffordable drug prices are prone to counterfeiting becoming more sophisticated including Kenya. The Kenyan market has been flooded with counterfeit drugs making it possible for any individual to come across medicine that is packaged correctly in the form of capsules, syrups or tablets but containing wrong ingredients that maybe toxic.

2.2 Effects of Counterfeit Drugs on Humans

Chemical substances taken as drugs have diverse pharmacological effects on the human biological system. Some of the effects are contraction of muscles, secretions from glands, alterations of hormonal levels, modulation of nervous activities and many other physiological body changes (Erwin , 2014).

Third world countries due to meagre foreign exchange earnings are short of financial muscle to buy drugs leading to restrictions in importing large quantities of quality drugs. Issues related with modern drugs in third world countries include quality assurance, drug availability and the stability of drugs in the tropics (Ahmed, 1985).

Governments are faced with the challenge to guarantee quality of drugs being imported due to lack of skills and expertise to ensure that drugs are genuine and can be well preserved it the tropical climate without deteriorating (Ahmed, 1985).

Counterfeit drugs have adverse effects on the health of humans (Akunyili, 2005). Regular use of such drugs can lead to therapeutic failure or drug resistance and in some cases leading to death (Counterfeit Medicine, 2015). Some of the characteristics of fake drugs include:

i) *Unintended Effects;* counterfeits may substitute a drug for another. An example is whereby insulin can be found to have been substituted for a more expensive injectable drug. It is evident that counterfeiters emptied bottles of Zyprexa, a drug used to cure schizophrenia and acute bipolar mania, and replaced them with white tablets printed with the word "Aspirin".

ii) *Toxic Effects;* some counterfeit drugs may contain lethal ingredients that when ingested or injected can cause health problems. An example is a recent counterfeited drug called Procrit, important drug for Cancer and Acquired Immune Deficiency Syndrome (AIDS) patients contained nonsterile tap water which causes an infection in the bloodstream when used.

iii) *Ineffective Treatments;* other fake drugs contain active ingredients but are sub potent. Others will try and copy the real drug but still pose safety risks because they are not formulated in a way that achieves the right therapeutic levels in the patient's blood.

iv) *No active ingredients;* some drugs have no active ingredients. A counterfeit version of Serostim, a growth hormone used by patients with AIDS was found to contain no active ingredients hence leading to therapeutic failure and deterioration of health.

v) *Fake Labels;* counterfeiters have made perfect the art of duplicating packaging and labeling of legitimate prescription drugs. It requires thorough inspection to be able to identify differences between counterfeit and legit drugs.

All in all patients at the minimal face the risk of therapeutic failures or deteriorating health issues that a drug was intended to treat. Criminals engaging in counterfeiting practices have disregard for the wellbeing of ill patients and the safe practices of legitimate companies and individuals involved in the distribution of prescription drugs.

A number of cases of fatalities have been reported in many countries. According to Diaz (2006) a healthy 22 year old woman living in Viedma Argentina had been diagnosed with mild anaemia caused by insufficient iron in her blood. She needed iron injections. In December 2004, she fell sick and died of liver failure after receiving a 7^{th} out of 10^{th} injection treatment. The medicine authority of Argentina (ANMAT), after a postmortem concluded that her cause of death was from a highly toxic counterfeit drug. Authorities were however unable to determine the source of the counterfeit product due to fabricated paper work. A

thorough investigation was done. Majority of the counterfeit drugs in the market were recovered with the persecution of four individuals involved in the production of the lethal drug. Due to the highly fragmented distribution system the recall exercise was not 100% successful. In May 2005 one woman died and another survived on the same drug. The survivor was a 22 year old pregnant woman who gave birth to a 26 week premature baby. To date, Argentinean law doesn't consider counterfeiting of medicine a crime (WHO, 2006).

2.2.1 Documented Cases of Fatalities Caused by the Use of Counterfeit Drugs

Niger Republic – in 1995 during a Meningitis epidemic more than 50,000 individuals were inoculated with fake Meningitis vaccines resulting to the death of nearly 2,500 individuals (WHO, 2006).

Haiti – in 1995, 89 infants died due to the consumption of Paracetamol Syrup prepared with a toxic chemical called, Diethylene Glycol. Diethylene glycol is a clear, odourless, viscous liquid with a sweetish taste. It is used as an industrial products but has also been prominent in mass poisonings dating back to the 1930's (Beasley, Temple, Slaughter, & Schep, 2015).

Enugu State, Nigeria – in 1989 several children were killed in the University of Nigeria Teaching Hospital due to poorly compounded Chloroquine Syrup. It is believed that many more died in the early 1980's. No statistics were recorded partly due to unreported death cases (Diaz, 2015).

Ibadan and Jos, Nigeria – in 1990, 109 children died in Ibadan and Jos after consuming Paracetamol cough syrup laced with the toxic Ethylene Glycol solvent instead of Propylene Glycol. The incident had previously occurred more than 50 years ago in the United States of America (USA) (Diaz, 2015).

India – in 1998, 30 infants died due to the consumption of Paracetamol Syrup prepared with a toxic chemical called, Diethylene Glycol (Diaz, 2015).

Cambodia – in 1999, about 30 individuals died after taking counterfeit anti-malarial drugs prepared with Sulphadoxine - Pyrimethamine, an older less effective anti-malarial. The drugs were sold as artesunate. Approved by the FDA, artesunate is a non-oral drug used to treat severe Malaria in the USA (Diaz, 2015).

2.3 Reported Cases of Counterfeit Drugs in Third World Countries

Below is a list of reported cases of counterfeit drugs in third world countries (Essential Medicines & Health Products – Counterfeit Medicines, 2015).

Angola – in 2004 a report by the National Department of Intellectual Copyright Crime of the Economic Police stated that approximately 70% of drugs used by the Angolan population were counterfeit.

Kenya – in 2005, a random survey was conducted by the National Quality Control Laboratories (NQCL) and the Pharmacy and Poisons Board. Results showed that almost 30% of drugs in Kenya were counterfeit. Counterfeiters were so crafty that some of the drugs used were no more than chalk and untreated water sold as legitimate pharmaceutical products. The Kenya Association of Pharmaceutical Industry also reported that counterfeit products account for approximately $130 million annually in sales. Figure 2 below shows netted counterfeit drugs valued at approximately KES 5 million being burnt in Nairobi, Kenya.

Russia – in 2006 the Federal Service for Health Sphere (FSHSS) reported that 10% of all drugs in the Russian market were counterfeit. Other sources indicated that the results were higher.

Dominican Republic – in 2005 the Republic's public health Department reported that 50% of the pharmacies in the country operated illegally and 10% of medicines arriving in the country were fake. Medicines found in some of the pharmacies were found to be over 10 years old.

Indonesia – in 2005, the International Pharmaceutical Manufacturers Group (IPMG) estimated that pirated drugs constituted 25% of Indonesia's $ 2billion pharmaceutical market.

Figure 2.1: Destruction of Counterfeit Drugs in Kenya (Business Daily Africa, 2013)

Figure 2.1 shows burning of counterfeit drugs estimated to be valued over KES 5 million in Nairobi Kenya. A report by the Kenyan Association of Pharmaceutical Industry (KAPI) estimates that counterfeit pharmaceutical products account for approximately KES 12.7 billion annually in sales as at the year 2010 (Ciuri, 2015).

2.4 Major Challenges in Combating the Use and Distribution of Counterfeit Drugs

Some of the challenges faced in combating the use and distribution of counterfeit drugs as reported by Markey & Liang (2011) are:

i) Lack of proper regulations and law enforcements in many developing countries encroaches in the quality, safety and efficacy of locally manufactured and imported medicines making them substandard.

ii) Smuggling of counterfeit drugs is also prevalent in developing countries with some acting as zones for exporting or re-exporting counterfeit drugs.

iii) In an attempt to avoid detection counterfeiters engage in collaborative schemes to disguise their activities. Such activities include; establishing fake businesses and companies, exploitation of weaknesses in border controls especially when governments reduce border inspections in an attempt to promote international trade, falsifying documents to obtain essential active pharmaceutical ingredients as well as manufacturing products that emulate genuine products.

iv) Policy makers in governments perceive drug regulations as unnecessary barriers to trade and should be reduced to the minimum (Mackey & Liang, 2011).

However, it should be noted that counterfeiting of medicine is a lucrative business due to the continued high demand for medicines and low production costs. The seemingly high price of legit medicine and the steep price difference between identical fake products creates and incentive for consumers to seek medicine outside legal supply chain systems. Sometimes official supply chains fail to reach many poverty stricken communities and rural areas. It is these major factors that contribute to creating markets for counterfeit products.

2.5 Control of Drug Manufacturing and Distribution in Kenya

The practice of pharmacy has been in existence in Kenya for over fifty years. The need to have a body to regulate quality of medicine for use by the public began in the year 1977 (Kibwage, 2008). The Pharmacy and Poisons Board (PPB) within the Ministry of Health was established in 1982 with the following mandates (Maitai, et al., 1982):

i) Drug Market Authorisation.
ii) Market surveillance of medicines circulating locally.
iii) Quality control facilities to support market surveillance and authorization.

2.5.1 Drug Market Authorisation

This is the process of auditing application dossiers for drug registration by an expert committee. Quality of the drug may also be determined through laboratory testing. The process aims at creating Efficacy, Safety and Quality through appreciation of good manufacturing practices. Once achieved, Market Authorisation allows a product to be released to the market (Maitai, et al., 1982).

Release of drugs in the market creates competition of generic and innovator products which in turn attracts counterfeiting of drugs. Manufacturers have therefore been tasked by regulators to provide information on product's new uses, adverse effects, relocation of factory sites, processes or production and ingredients. Drug registration must be renewed every five years in Kenya (Kibwage, 2008).

In the years 1982 to 2008, the average number of drugs registered in Kenya was about 700 annually with about 20,000 drugs being registered in the whole range of years (Kibwage, 2008). Table 2.1 shows the total number of registered drugs and those registered in 2007.

Table 2.1: Total Number of Registered Drugs in Kenya in 2007

Registration status	**Number of products**
Drugs registered between 1982 to 2007	19,570
Newly registered drugs in 2007	643
Drugs re-registered in 2007	1,126

Source: Pharmacy and Poisons Board, Ministry of Health (200 (KEBS, 2014)*7).*

2.5.2 Drug Quality Control

Laboratory testing creates a strong statement when confirming the quality of drugs through a regulatory body of certain medicines within a market under its area of jurisdiction. Two laboratories, the Drug Analysis and Research Unit (DARU) and the National Quality Control Laboratory (NQCL) are mandated to carry out quality control functions in Kenya. The Drug Analysis and Research Unit (DARU) is a premier laboratory in Kenya established in the Department of Pharmaceutical Chemistry at the College of Health Sciences (College of Health Sciences, 2016). Samples are received from local industries, private practitioners, non-governmental organisations, regulatory authorities and hospitals. Drugs are then analysed under specification of the European Pharmacopeia, British Pharmacopeia and the United States Pharmacopeia. Drugs not subject to official compendia are analysed with accordance to the manufacturer's specifications and methods (Kibwage, 2008).

2.6 Theoretical Review

Numerous Information Communication and Technology (ICT) systems have been designed with a bias towards social aspects and are impervious to learn (Lyytinen and Damsgaard, 2001). Often they require advanced skills and proficiency during implementation, operation and adorption (Attewell, 1992; Andriessen, 2003; Lyytinen and Damsgaard, 2001; West et al., 2007).

According to Bagozzi et al. (1992), ICT systems need to be better understood in the whole adoption process as is the role of learning their use. Inadequate ability to learn and use systems can hamper adoption and implementation of a potentially productive system. It was therefore mandatory to learn the implication of research theories and how they can be applied in implementing and adopting ICT in the area of management and business.

This dissertation was supported by two theories namely: Technology Acceptance Model (TAM) theory and Theory of Reasoned Action (TRA).

2.6.1 Technology Acceptance Model

This model is concerned with ICT usage behaviour and what causes potential adopters to accept or reject use of information technology. Based on the TRA two theoretical constructs were used: Perceived

Usefulness; referring to the degree to which users believe that using a system will enhance job performance. Perceived Ease; referring to the degree which users perceives a system to be free of effort (Davis, 1989).

2.6.2 Theory of Reasoned Action

This theory makes the assumption that a user's behaviour is determined by the intention to perform an action. The intention is further determined by the user's attitude and perception from individuals, other than him, towards the user's behaviour (Fishbein & Ajzen, 1975).

2.7 Empirical Review

This section will give an overview of challenges faced by regulatory bodies, in this case, The Kenya Bureau of Standards (KEBS) and how they cope with the problem of counterfeited items.

2.7.1 The Kenya Bureau of Standards

Kenya has a legal framework and mechanism to determine that all commodities imported or manufactured comply with certain standards. The Standards Act. Section 4 (1) (c & d) of the Act establishes KEBS as the main regulatory body whose functions are, inter alia *"to make arrangements or provide facilities for the examination and testing of commodities and any material or substance from or with which and the manner in which they may be manufactured, produced, processed or treated"* and *"to control, in accordance with the provisions of this Act, the use of standardization marks and distinctive marks"*, respectively (Laws of Kenya, 2012).

2.7.2 Challenges Facing KEBS in Combating Counterfeit Trade

Key areas that pose as a challenge to KEBS in conducting its business normally fall under the following: Administration, Counterfeit Intelligence, Legal and Supply Chain. Specific challenges encountered under key areas mentioned above were (Kenya Bureau of Standards, 2009):

i) Lack of complaints by customers regarding ineffectiveness of items.
ii) Lack of proper international support in combating counterfeiting of items.
iii) High levels of poverty and ignorance.

iv) Weak laws governing counterfeit items.

v) Lack of resources (human and financial).

v) Lack of state of the art equipment and procedures in testing products.

vi) Porous borders acting as transit corridors for entry of counterfeit items into the country.

vii) Lengthy legal process before disposing of cases relating to counterfeit items.

ix) Lack of well trained staff as is required by international standards.

This dissertation undertook to solve the problem that specifically deals with supply chain, management and distribution of drug items. The specific problem addressed was the inability of consumers to detect and report uncertified drug items. A big challenge that KEBS faces is the use of fake Standardisation marks (KEBS, 2014).

KEBS administers a conformity assessment program on behalf of the government based on Article 5 of WTO-TBT (World Trade Organization/ Agreement on Technical Barriers to Trade) agreement on regulated goods in Kenya. This is to minimize risk of substandard and unsafe goods entering the Market. KEBS provides a list of classifications of products with unique codes that should undergo the verification process. Figure 2.2 shows the KEBS code chart of PVoC regulated items in the Kenyan market (KEBS, 2014).

KENYA BUREAU OF STANDARDS PVOC COVERED PRODUCTS

EAC HS Code	Product Description	Category Code	Category Description
0201.10.00	Meat of bovine animals, fresh or chilled. - Carcasses and half-carcasses	01	Food and Related Products
0201.20.00	Meat of bovine animals, fresh or chilled. - Other cuts with bone in	01	Food and Related Products
0201.30.00	Meat of bovine animals, fresh or chilled. - Boneless	01	Food and Related Products
0202.10.00	Meat of bovine animals, frozen. - Carcasses and half-carcasses	01	Food and Related Products
0202.20.00	Meat of bovine animals, frozen. - Other cuts with bone in	01	Food and Related Products
0202.30.00	Meat of bovine animals, frozen. - Boneless	01	Food and Related Products
0203.11.00	Meat of swine, fresh, chilled or frozen. – Carcasses and half-carcasses	01	Food and Related Products
0203.12.00	Meat of swine, fresh, chilled or frozen. – Hams, shoulders and cuts thereof, with bone in	01	Food and Related Products
0203.19.00	Meat of swine, fresh, chilled or frozen. –Fresh or Chilled; Other	01	Food and Related Products
0203.21.00	Meat of swine, fresh, chilled or frozen. –Frozen; Carcasses and half-carcasses	01	Food and Related Products
0203.22.00	Meat of swine, fresh, chilled or frozen. – Frozen; Hams, shoulders and cuts thereof, with bone in	01	Food and Related Products
0203.29.00	Meat of swine, fresh, chilled or frozen. – Frozen; Other	01	Food and Related Products
	Meat of sheep or goats, fresh, chilled or frozen. - Carcasses and half-carcasses of lamb, fresh or		

Figure 2.2: KEBS Code Chart (KEBS, 2014)

KEBS utilizes marks that are attached to certified products to visually show that products have been certified. Some examples are as follows:

The Mark of Excellence (Diamond mark)

A voluntary mark based on excellent performance of products. This is superior to all other quality marks.

Figure 2.3: The Mark of Excellence (KEBS, 2014)

The Standardisation Mark (SM)

This mark is mandatory for all locally manufactured products.

Figure 2.4: The Mark of Standardisation (KEBS, 2014)

2.7.3 Technological Solutions KEBS is undertaking to curb the Problem

Currently KEBS officers are equipped with technology that aids them in identifying whether items have been certified or not. The technology consists of palm tops used to detect counterfeits. Officials input the product's name and information about the item's certification then the status pops up on the mobile device. If no information pops up the item is considered counterfeit (Kenya Bureau of Standards, 2009).

2.8 Current Technologies to Check the Use and Distribution of Counterfeit Drugs

The researcher reviewed current technologies used to verify and report the existence of counterfeit drug items in Kenya and internationally.

2.8.1 MPedigree

MPedigree is an African based startup founded in the year 2007 by a young Ghanaian by the name Bright Simons. The company sells software that manufacturers use to label individual packs of medication with a random 12-digit code. The code is hidden under an easily scratch panel, similar to an airtime scratch card that is attached on the medication packaging. When purchasing medicine the buyer can text the code to MPedigree for free getting an instant response confirming that the product is authentic. A report by the Bloomberg Business magazines states that currently MPedigree has produced labels on more than 500 million drug packets (Yepoka, 2015).

Figure 2.5 shows a verification process via SMS of a drug item with a label from MPedigree.

Figure 2.5: MPedigree Drug Verification Process (Yepoka, 2015)

A Architectural Structure of MPedigree

Figure 2.6 represents an illustration of the architectural structure of MPedigree. Through an active and existing GSM network in Ghana, end users can query for information of specific products through product codes, MPedigree Network (2013). Branded medicine from manufacturers are approved and registered at a central repository managed by MPedigree.

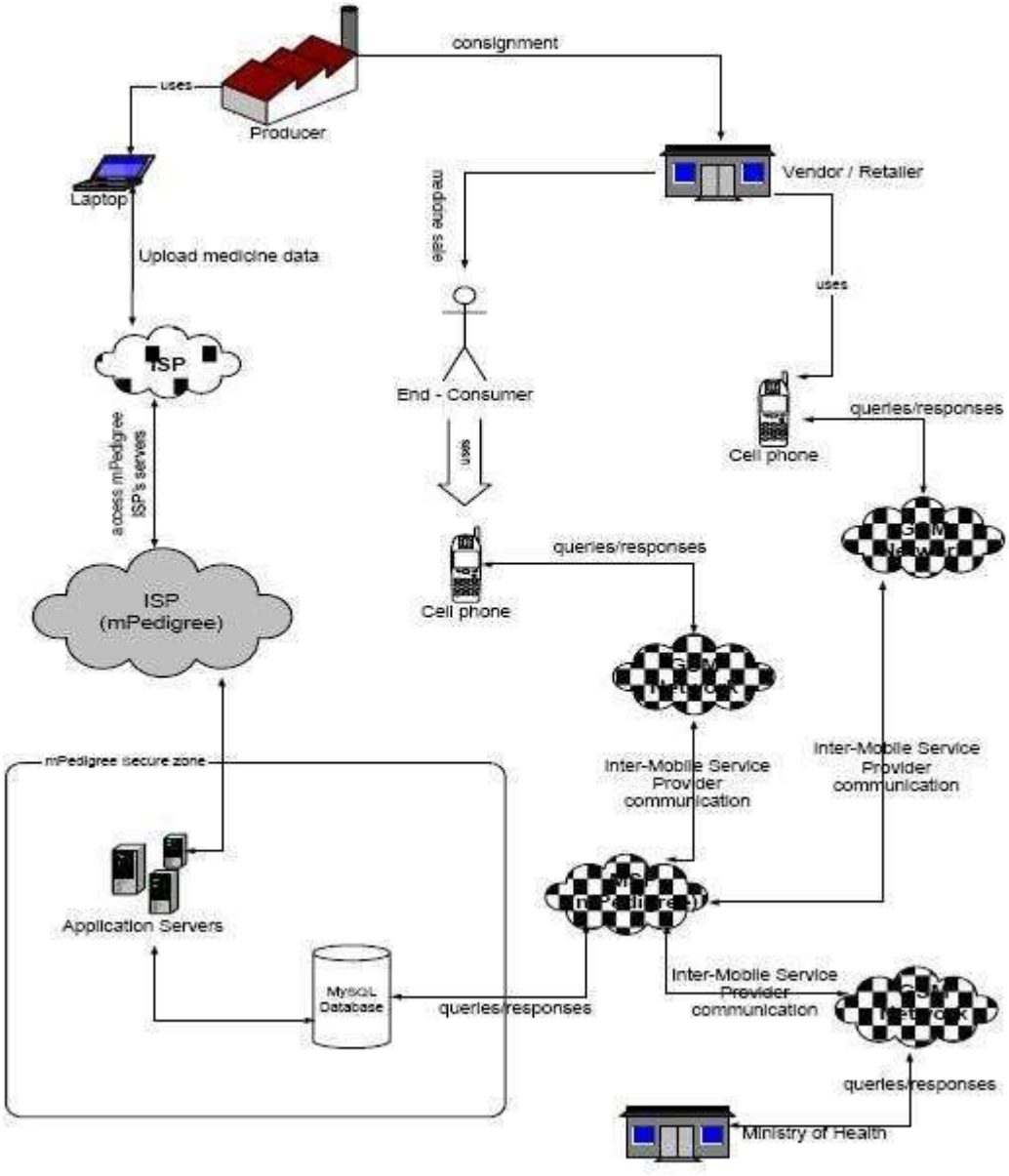


Figure 2.6: Illustration of MPedigree Systems Architecture (MPedigree, 2015)

B Challenges experienced by MPedigree

A major challenge reported by MPedigree is when users try to manipulate working of the system. In one complaint a single authentication code had been checked 1500 times more than two days. It was later realized that someone had taken a genuine code and made thousands of its copies and attached them to counterfeit morning after pills somewhere in the neighboring country Nigeria. A similar incident had occurred previously. MPedigree was able to locate a warehouse full of counterfeit malaria medication in the previous incident. To counter the problem MPedigree started calling users who tested the fake code to find out where they got the drug. This was in an attempt to locate the source so as to alert regulators and law enforcers.

Customers may sometimes experience delays in responses to queries through SMS's taking too long to be delivered. This may be attributed to clogging on the network within a particular area or unforeseen technical hitches with network devices such as transponders.

MPedigree's mobile application is restricted to SMS and GSM platforms. This means it doesn't support data enabled devices. This is a major setback to the future of the application as mobile devices are now developed to be fully dependent on data based applications and systems. 5G technology which is a data based communication technology is expected to be standardized by the year 2020 (Sutton & Tafazolli, 2015).

C MPedigree's Competitive Advantage

MPedigree's competitive advantage is in its geographic location. It is based in a region worst hit by counterfeit drugs. This ensures that its mandate, which is to fight counterfeit drugs, always receives welcome from governments and other institutions concerned with the well-being of its populace. MPedigree's long-term vision is to be the most trusted repository of information about consumer goods (Yepoka, 2015).

2.8.2 PharmaSecure

PharmaSecure is a startup mobile based solution founded in the year 2007 by Nathan Sigworth. The company is based in Lebanon – New Hampshire and Gurgaon – India. The company helps drug companies' combat counterfeit medication in the developing world. The startup company partners with pharmaceutical companies throughout India to print serial numbers on drug bottles. Consumers of the

drug items are then given the option of texting the serial numbers to a provide mobile phone number to verify that the medication is authentic. Other than that valuable information it given out to pharmaceutical companies about their customers. Pharmaceutical companies pay a premium to get the service (Lapowsky, 2012).

2.8.3 Sproxil

Sproxil operates by placing a label with a scratch-off panel on all its protected products. Just as the above mentioned mobile based applications, consumers scratch off at the point of purchasing a drug to reveal a unique code that can only be used once. The code is sent via Short Message Service (SMS) or a mobile application to a specific short code. The consumer will receive a reply instantaneously indicating that the product purchased is genuine or uncertified. Figure 2.7 shows an image of the response from a drug item verified by Sproxil Mobile phone application.

Figure 2.7: Sproxil Drug Process (Sproxil, 2015)

In July 2011 it was reported that the Kenya's Pharmacy and Poisons Board (PPB) adopted Sproxil's SMS based anti-counterfeiting system however, there is no evidence showing existence of the application in the market. Sproxil claims that to date it has processed over 14million verifications from consumers making it the highest recorded number of verifications of its kind (Ukoh, 2015).

A Sproxil's Business Operations Model

Figure 2.8 shows an illustration of Sproxil's Business Operations Model. Pharmaceutical companies, drug manufacturers and distributors are the main customers of Sproxil.

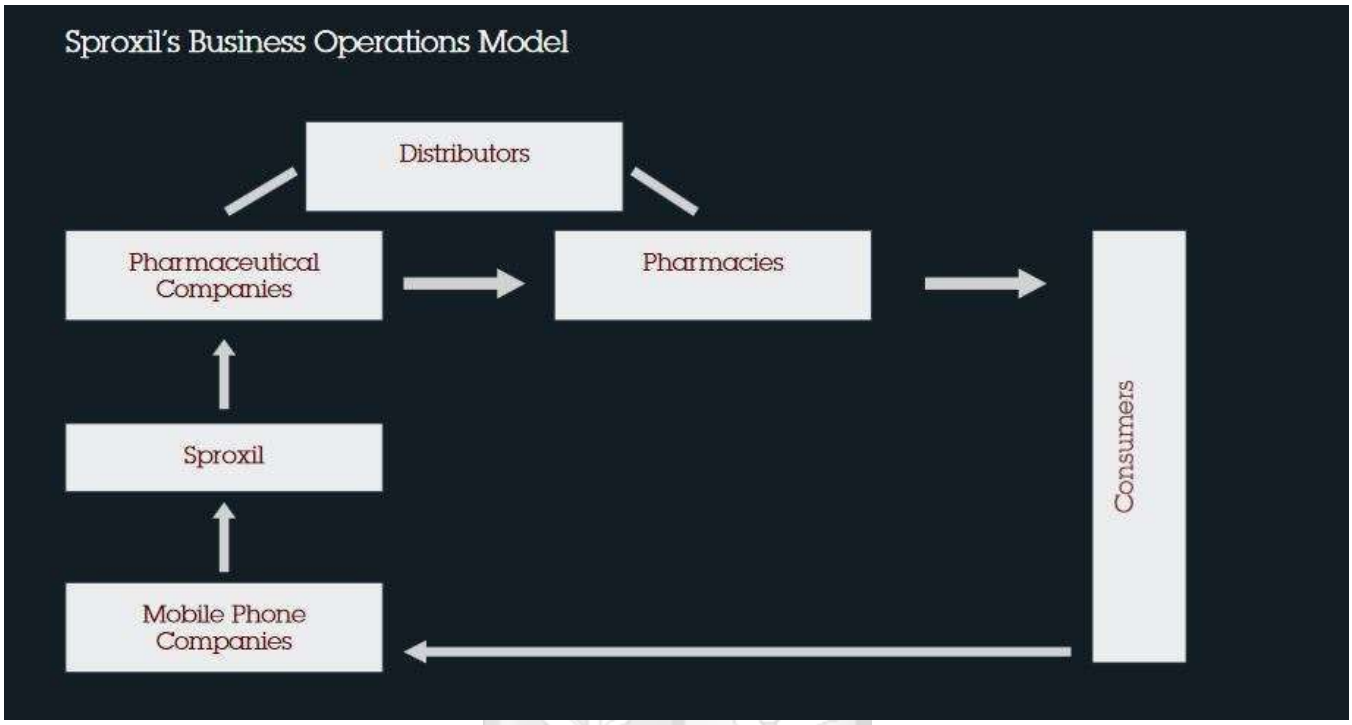


Figure 2.8: Sproxils Business Operations Model (Sproxil, 2012)

2.9 Scanning Technologies

There are a number of scanning technologies that are in use today, some dedicated device scanning or mobile based scanning. Listed below are mobile device scanning technologies used synonymously with mobile devices. A mobile device could be used in place of a dedicated scanning device having an inbuilt reader that transmits radio frequencies over a tag or a mobile device camera to scan over barcode/QRCode.

2.9.1 Mobile Based Scanning Technologies

These scanning technologies include scanning processes that rely on a user physically scanning items using a smartphone held by hand. Some of these technologies include: QR-Code Scanning, RFID Scanning and Scanning through SMS.

A QR-Code Scanning

QR-Code is an abbreviation for Quick Response Code. It is a type of Matrix Barcode or two dimensional Barcode designed initially for the Automotive Industry in Japan. A barcode is defined as a machinereadable optical label containing information about an item that it is attached to (Ullrich, 2011).

Figure 2.9 shows an example of a QR-Code.

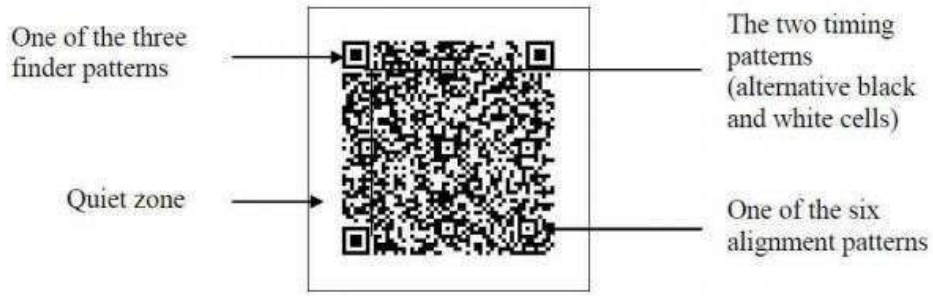


Figure 2.9: QR-Code (Denso Wave, 2014)

QR-Codes can be used on a variety of mobile device operating systems. The mobile devices support URL Redirection that allows the codes to send metadata to existing applications on the device. Many purchased of free mobile based applications come with the ability to scan the codes and hard-link to external URLs (Law & So, 2010).

A QR-Code is a kind of two dimensional symbol developed by Denso Wave (a division of Denso Corporation). Figure 2.10 shows the comparison between a QR-Code and a traditional Bar Code. This technology was launched in 1994 with the aim of being a symbol to be easily interpreted by a scanner (Denso Wave, 2014).

Figure 2.10: Comparison between QR-Code and a Traditional Barcode (Denso Wave, 2014)

QR-Codes use four Standardised encoding modes namely; numeric, alphanumeric, byte/binary and kanji to store data efficiently. They consist of black square dots arranged in a grid the shape of a square on a white background. These dots can be read by imaging devices such as cameras and dedicated scanners. The image captured is then processed using Reed-Solomon error correction until it can be interpreted appropriately. Data is extracted from the images patterns present on both its vertical and horizontal components.

The amount of data stored in a QR-Code symbol depends on the datatype, version and error correction level. Maximum storage capacities for the codes occur for 40-L symbols (Version 40, error correction level L), (Stechz, 2012).

Error Correction

This process uses code-words that are 8 bits long. Reed-Solomon error correction algorithm is used with four error correction levels. A higher error correction level translates to a low storage capacity. Table 2.2 lists approximate error correction capabilities at each of the error correction levels (Plank, 1997).

Table 2.3: Approximate Error Correction Capabilities at each level

Error Correction Level	**Code-words that can be restored**
L (Low)	7%
SM (Medium)	15%
Q (Quartile)	25%
H (High)	30%

Uses of QR-Codes

QR-Codes are more commonly used in consumer advertising. Ideally, a smartphone is used as the code scanner which converts the code into useful data such as a standard URL for a website. This removes the need for a user to type the URL into a web browser.

QR-Codes are also used other applications such as Commercial tracking of commodities; Entertainment and transport ticketing, product/loyalty marketing and In-store product labeling.

Many of the mentioned applications target mobile phone users (via mobile tagging). After scanning QRCodes users may receive a message, compose an e-mail or test message, add a virtual card contact to their device or open a URL. QR-Codes may also be linked to a location to track where a code was originally scanned. An applications scanning the code receives the geo information by using GPS and cell tower triangulation. The URL encoded in the QR-Code may itself be associated with a location (Geo Tagged QR Codes, 2011).

Some advantages of using QR-Codes are (Johnson, 2011):

i) ***Ease of use;*** the code can be added to any kind of product making it versatile for marketers.
ii) Can be used for a variety of uses.
iii) ***Traceable;*** through web analytics and unique codes placed on different products valuable information can be acquired from the behaviour of the market to the products.
iv) ***Easy way to direct mobile users to online/web content;*** as the name suggests, a quick response mechanism saves the time and effort of a use typing in a URL or an SMS short-code.
v) ***The technology is appealing to mobile users;*** due to it being rather new mobile users have the urge to scan and find out where it leads. Of course through time its novelty will wear off (Charlton, 2011).
vi) ***Cost effective;*** QR-Codes can be created at no cost.
vii) Some disadvantages of using QR-Codes are:
viii) ***Users need to download a QR-Code scanner/reader;*** mobile users usually have to download a (free) QR-Code reader which limits many.
ix) ***Scanning can be a long process;*** Low INTERNET speeds can render the scanning process very slow. A user may not be patient enough to wait for the outcome (Charlton, 2011).
x) ***Lack of awareness;*** a small percentage of mobile users are aware that QR-Codes can be useful than to be redirected to a website.

B Radio Frequency Identification (RFID) Scanning

RFID is the use of electromagnetic fields to transfer data. This usually is for the sole purpose of automatically identifying and tracking tags attached to objects. The tags contain electrically stored information (Violino, Farm Harvests RFID's Benefits, 2004).

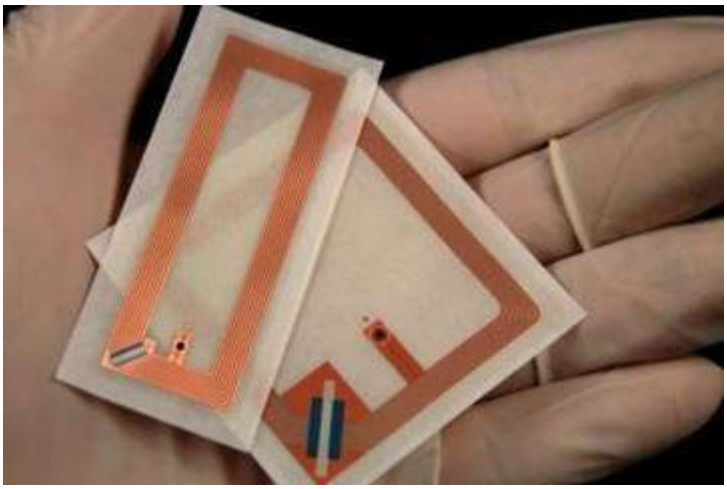


Figure 2.11: An RFID Tag (Kevin & Felon, 2007)

Figure 2.11 shows an RFID tag specifically designed for fitting in a luggage and large parcel for tracking.

Basic working of an RFID tag

Below are the basic workings of an RFID tag as reported by RFID Journal (2005).

i) Data stored within an RFID tag's microchip waits to be read.
ii) The tag's antenna receives electromagnetic energy from an RFID reader's antenna.
iii) Using power from its internal battery or power harvested from the reader's electromagnetic field, the tag sends radio waves back to the reader.
iv) The reader picks up the tag's radio waves and interprets the frequencies as meaningful data (RFID Journal, 2005).

Types of RFID tags

These are less expensive tags to produce and can be made small enough to fit on almost any product. Frequencies transmitted by RFID tags can be adjusted to avoid interference with other electronics or RFID tags and readers in the form of tag interference or reader interference.

RFID tags can make use of RFID systems called Time Division Multiple Access (TDMA) to make sure that the wireless communication is handled correctly (Violino, Farm Harvests RFID's Benefits, 2004).

Active

Uses internal battery to power its circuit also uses its battery to broadcast radio waves to a reader. Contains more hardware than passive RFID making it more expensive than passive. Reserved for costly items that are read over great distances. 850 to 950 MHz can be read about 100 feet away (Violino, Farm Harvests RFID's Benefits, 2004).

Semi-passive

Uses internal battery to power its circuit. Relies on the reader to supply its power for broadcasting. Contains more hardware than passive RFID making it more expensive than passive. Reserved for costly items that are read over great distances. 850 to 950 MHz can be read about 100 feet away (Violino, Farm Harvests RFID's Benefits, 2004).

Passive

Relies entirely on the reader as their power source. These tags are read up to 20 feet away and they have lower production costs, meaning they can be applied to less expensive merchandise. Generally these tags are manufactured to be disposable, along with the disposable consumer goods on which they are placed e.g. RFID tag on a bottle of shampoo (Kevin & Fenlon, 2007).

Another factor that influences the cost of an RFID tag is data storage. There are 3 storage types: readwrite, read-only and WORM (write once, read many).

Some of the common uses of RFID are:

Asset tracking

This is the most common way of implementing the technology. Companies have been known to put RFID tags on assets that are often stolen, underutilized or are hard to locate when needed. A company such as Air Canada saves millions each year by tracking food carts used at airports around the world. RFID has benefited the company by ensuring there are fewer loses of carts and less time and money spent taking inventory (Violino, Farm Harvests RFID's Benefits, 2004).

Manufacturing

In manufacturing RFID is used to track parts and work in process to reduce defects, increase throughput and to manage the production of a variety of versions of the same product. A company by the name Johnson Controls based in Milwaukee, USA is a supplier of car and truck interiors. The company supplies dashboards, seats and other components three big automakers. Johnson controls later installed a system to track different versions of truck and car seats it supplied. The system was a success as it proved to be very extremely accurate in tracking their commodities (Collins, 2013).

Supply Chain Management

RFID is increasing being used to companies to track shipments among supply chain partners. In other instances RFID has been used to automate parts of the supply chain within a company's control. Some benefits associated with such systems are increased throughput, reduced shipping error and reduction in labour costs (Violino, Farm Harvests RFID's Benefits, 2004).

Some advantages of RFID are:

i) Tags can be read at a faster rate as compared to other technologies such as barcodes (Wireless Technology Advisor, 2014).
ii) Processes can be run with minimal human intervention. iii) Frequencies can be read from greater distances (RFID vs Barcodes, 2012). iv) No need to position the scanner and tag in a straight line of sight (Piasecki, 2012). v) Tags have read/write capabilities, meaning they can be customized.
vi) Have high capacities of storing data.
vii) Are highly secure; data can be encrypted, password protected or permanently deleted.

Some disadvantages of using RFID are:

i) Systems are often more expensive than systems such as QR-Code and Barcodes (Wireless Technology Advisor, 2014).
ii) In cases where two signals from different readers overlap there can be a dead zone. This is where there a reader collision occurs causing no response from readers.

iii) A Tag collision may occur when numerous tags in the same area respond to a reader at the same time (RFID vs Barcodes, 2012).
iv) Tags are may appear larger than labels such as Barcodes or QR-Codes.
v) Tags are programmed to operate on specific applications (Wireless Technology Advisor, 2014).
vi) Readers use up lots of energy when picking up information through metal or liquid.
vii) Reader collision can occur where two signals from different readers overlap and the tag is unable to respond to both (RFID vs Barcodes, 2012).

2.10 Gaps and Limitations on Existing Technologies

Existing techniques used to scan and verify products to find out whether they are genuine or uncertified revealed that the only automated techniques available to the public in Kenya is through the use of SMS, QR-Code and RFID.

SMS requires that a user scratch off a hidden code/serial number after purchasing a product. The code/serial number is then sent via SMS to a specific short code that extends its service to a database for verification. The user will then receive an instant response confirming that the product is authentic or fake. This approach is limiting since a user will have to purchase a product before scratching off to reveal the hidden code. Once a user purchases an item and identifies that it is counterfeit he/she has no option of returning the fake item but to purchase another. The process of acquiring a short code to send SMS's is also quite expensive. Another setback is seeding for funds to make such a service free to the public which can be time consuming. So far the SMS verification approach has been made available only to large multinational companies that have the financial muscle to implement the system for tracing their own products.

According to Xhiang, et al. (2004) the limitation of using RFID tags is that the approach would be beneficial when focusing on an already secure supply chain. The research location of study is in a third world country struggling to have an efficient legal framework to control and manage entry of counterfeit drugs into its borders. A better solution is the development of a system that will aid in detecting illegal drugs that have reached their destination. RFID tags are also quite expensive to implement in this region due to the complex manufacturing process and maintenance.

The use of QR-Codes in identifying and reporting the existence of counterfeit or uncertified products in Nairobi - Kenya bridges the gap and limitations reflected in SMS and RFID use. Technology is moving towards digitization of mobile communication. Implementation of QR-Codes in future will be cheaper for the government and local manufacturers to implement compared to RFID tags and the use of SMS as a media of communication. QR-Codes also eliminate the need of having a mobile phone carrier route communication through its servers. This information can be sent directly to servers located in offices of regulatory bodies such as the Kenya Bureau of Statistics and the Pharmacy and Poisons Board enabling devolution and easy management of services. Furthermore we now have INTERNET enabled phones offered at the same price as features phones making them available to a large population. With the initiative of the government in ensuring public users in major counties including Nairobi and its environment acquire free INTERNET services by December 2015 only puts the research at an advantage.

2.11 Proposed Solution from the Literature Review

Currently there is no systematic way of identifying counterfeit/registered drugs in Nairobi, Kenya. Methods used to identify counterfeit drugs are by tracing them in the market after reports of having substandard value, by observing the drug's physical appearance, while others are encountered in the course of quality control.

The mentioned approaches of identifying counterfeit drugs have been used extensively for tracking commodities in first world countries especially in supply chain management through the use of RFID. This however doesn't add value when trying to identify and report counterfeit products that are already in the market as the case is in third world countries.

The use of SMS is the only practically available technology for addressing the problem of identifying and reporting counterfeit/uncertified drug items in emerging markets more so in Kenya. Unfortunately, the cost of accessing such a service is still too high for many startup companies.

The use of QR-Code predominantly stands out as an approach that could help alleviate the problem by the public both presently and in future. With the availability of cheap INTERNET enabled mobile devices to the public the approach greatly favours this research in making its goals achievable.

This research is therefore justified in helping to alleviate the problem of systematically identifying and reporting the existence of counterfeit drugs in Nairobi, Kenya given the costly and highly restrictive alternative technologies mentioned. A mobile device, QR-Code reader, dedicated mobile based

application and QR-Codes all combined bring about benefits such as accountability, compliance, productivity, accuracy and accountability. Services can further be extended to include additional functionalities such as instant reporting, location based services, accountability, tracking and others.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This section is concerned with the methodology of the software in development process of the prototype. The section is made up of key areas namely; Business Study, Feasibility Study, System Analysis and Design Methods, Implementation Methods, Testing and Evaluation Methods.

3.2 Software Methodology

The System Design method implemented was SCRUM which is an AGILE methodology. The nature of this study is highly emergent with a large populace. The methodology allows for flexibility in incorporating changing user requirements due to its incremental and iterative nature. Additionally Design, Implementation and Testing was done throughout the project lifecycle (Scrum, 2015).

Figure 3.1 shows the steps involved in the SCRUM methodology process.

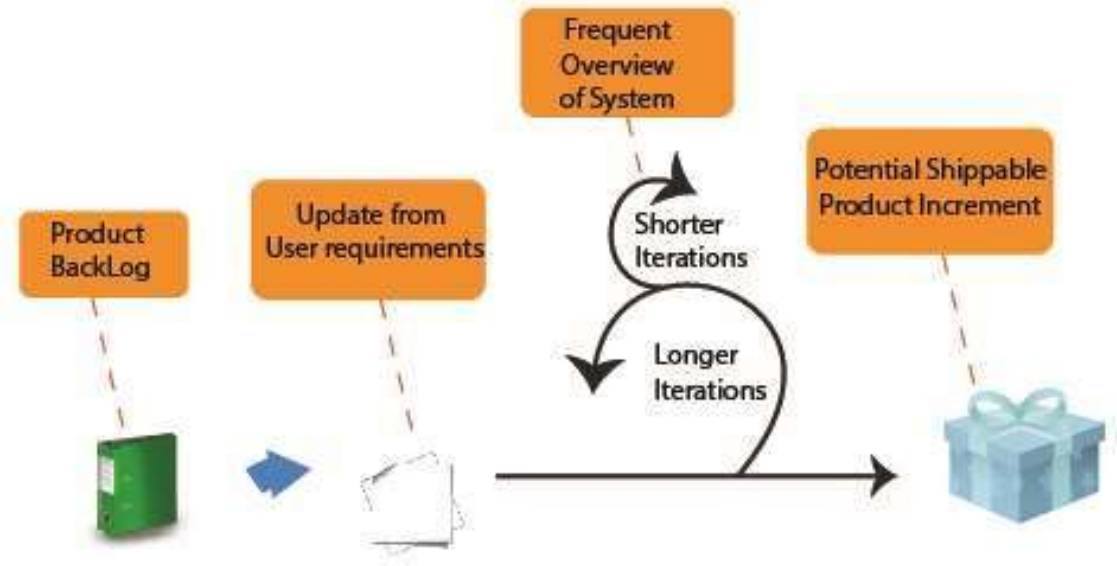


Figure 3.1: SCRUM Methodology process

SCRUM was chosen because of its useful agile practices such as Test-Driven Development (James, 2013). The entire application development process was involved in delivering business value. No discrepancies were there for made between the “business side” and “technical side”. Emphasis on decision making was done from real world results rather than speculation.

The researcher incorporated three main roles namely the Product Owner, Scrum Master and the Team.

i) Product Owner: The researcher acted as the project/product owner with the vision, authority and was entirely available throughout the projects lifetime.

ii) Scrum Master: The researcher acted partly as the Scrum Master through facilitation from the Supervisor. Impediments obstructing progress of the project were removed through frequent audits of the system flow by the researcher.

iii) Team: According to the founder of SCRUM, the team is self-managing (Scrum, 2015). Here team members were responsible for self-organizing to complete work. The team comprised of the researcher as the main UI designer and programmer of the application, testers and other programmers who provided assistance when needed. The team had responsibility and autonomy to meet the goals of each sprint.

3.2.1 Feasibility Study

This is a trivial study done to aid in designing a further confirmatory study (Arnold , et al., 2009). A feasibility study was done through reviews of relevant literature on existing systems related to identification and verification of counterfeit drug items. The study was performed to analyse and evaluate the impending solution of the proposed system.

3.2.2 Business Study

Research Design

To capture the full perspective of the research study a Descriptive research and Qualitative Research was done.

i) *Descriptive Research;* this research type helped the researcher define the characteristics of the population in study. This provided a deeper understanding of interactions between the populace, drug items and the ability of the populace in identification of counterfeit drug items. The information acquired greatly influenced the decision on the technology to be adopted.

ii) *Qualitative Research;* this research type was used to gain an understanding on views of the populace of the study in context to the area of study. The results from this research aided in guaranteeing user satisfaction of functional and non-functional requirements of the application.

Location of Study

The study was done at a local supermarket for data collection within the County of Nairobi. The name of the Supermarket was Quickmatt located in Rwaka Township. Only one branch of the supermarket was visited. The area was selected for study due to easy access by the researcher and also due to its strong presence within the area of research.

Target Population

The target population was drawn from consumers or shoppers exiting from the retail store and willing to answer the researcher's interview questions. Respondents were picked randomly as they exited the retail store.

Sampling Strategy

The researcher used Stratified Sampling technique. The stratum consisted of individuals leaving the retail store. These individuals were chosen as subjects to be interviewed for the study. This technique aided in focusing on the population that was most expected to interact with the proposed application.

Sample Size

25 respondents were interviewed daily for a span of 8 days. The total number of respondents interviewed was 200. This sample size also comprised of mixed gender, age, educational level and either employed or not. The sample size was deemed appropriate as it consisted of individuals that were highly likely to interact with drug items by purchasing directly from any retail store or chemist.

Data Collection Procedure

Different analytical tools were used to collect and analyse interviews and questionnaires namely: SurveyMonkey Analytical Tool for analyzing online questionnaires. Charts and bar graphs were used to provide clear visual presentations of responses. Below is a list of data collection methods that the researcher used to get feedback from the population of study.

i) *Questionnaires;* an online survey consisting of open and close ended questionnaires was administered to a targeted number of respondents. This was done as a Pre-Test analysis of the study to gain an understanding of how knowledgeable the study population was with regards to awareness of availability of counterfeit drug items in the market. The exercise was done through posting a set of questionnaire online. This enabled the researcher to know whether the population was in contact with other technologies used to identify and report existence of counterfeit items in the market. Data gathered was used to formulate requirements specifications.

ii) *Oral Interviews;* Oral interview consisted of a set of questions that were performed individually to respondents to acquire user feedback on the developed prototype. Results were used to further refine the prototype.

iii) *Review of existing documentation;* this involved the process of reviewing data by evaluating and analyzing existing documents. Documents reviewed by the researcher consisted of hard copy and electronic; reports, journals, newsletters, magazines, books, academic articles, texts and marketing materials.

3.3 System Analysis and Design

System analysis and design methods guided the researcher to understand what was needed to analyse data flow systematically, process data, store data and output information in context of the study (Kendall & Kendall, 2013).

In selecting an appropriate methodology the researcher performed one on one interview using pre-defined questions that sought to understand the workings of current systems. Consideration was made on limitations of the system at the time of study to identify key user requirements. Outcomes from the interview greatly influenced results of the system analysis and design process. Through the concept of Object Orientation Analysis was done to ensure user requirements were modelled and analysed profoundly. Relationships of real world Objects were also identified.

Unified Modelling Language (UML) was used as the modelling language. This aided in modelling analysis and design diagrams. Other than that the UML notation offered clarification to user requirements. Use - Case descriptions and diagrams were used to model system functionality. The System Sequence Diagram modelled the System Flow showing data passing between main entities of the system. Various entities with corresponding attributes and methods of implementation were modelled using Class

diagrams. The Entity Relationship Diagram was used to model the database. This showed the tables, attributes and relationships. The Database Schema modelled the table structure showing fields, data types and descriptions.

Wireframes were later used to illustrate process flows of both the web and mobile applications. In both systems flow Adobe Illustrator CS6 was used as the designing tool.

3.4 Prototype Implementation

The prototype comprised of development of a mobile and web application connected to a central database. Below are approaches employed in the development of the applications:

i) *Mobile Application;* the Operating System for the mobile application implementation was Android. The source code was written in Java, utilizing android classes. The application was compiled and tested using the android Software Development Kit (SDK) emulator and an android device. The application is optimized for android version 4.4.2 compatible with android devices on minimum version 2.0 and maximum version 4.4.4. JSON was used as the web service that provides the interface between the android application and the database. Reasons for choosing android as the client application include: flexible SDK, availability of Android Development Tools (ADT) and availability of abundant support from online developer communities.

ii) *Web Application;* the web based application was developed using Hypertext Preprocessor (PHP). The website was hosted on an online Apache HTTP server. Reasons for using PHP were; it is an Open Source platform, it is platform independent; it supports all major webservers and databases; it has multiple layers of security to prevent threats and malicious attacks.

iii) *Database;* the database was developed using the MySQL database. The reasons for using MySQL were; it is an open source platform; it is fully compatible with PHP and other platforms; it is secure in that all passwords are encrypted before storage restricting unauthorized access to the database.

3.5 Evaluation of the Prototype

The prototype underwent the following tests to find out whether it was in tandem with the specified goals of this dissertation:

i) *Functional Tests*; functional and non-functional tests were performed on the prototype.

ii) *Compatibility Tests;* compatibility test were performed on different mobile and web-based applications on different Android based platforms and browsers respectively.

iii) *User Tests;* this test was done on the developed application to measure user satisfaction and collect feedback for refining the prototype.

CHAPTER 4: SYSTEMS DESIGN AND ARCHITECTURE

4.1 Introduction

This section will provide a detailed explanation of the Design and Architecture of the proposed solution. Design diagrams were drawn under the unified Modelling Language (UML).

4.2 Systems Analysis

Systems Analysis is concerned with research findings of the study. Results were used to answer research questions evident in section 1.3 of this dissertation. The overall results contributed to design of the application through integration of various functionalities.

4.2.1 Pre - Survey Analysis

Prior to performing Systems analysis on the characteristics of the population a Pre-Survey analysis was performed. This analysis was done to maximise and justify the effectiveness and efficiency of the proposed application. This was done through holding brief interview sessions with the respondents. A copy of the questions can be found in the Appendices section under Appendix B. SurveyMonkey, an online Survey tool was used to set and analyse online questions that were emailed to a group of 28 respondents. A copy of the questions can be found in the Appendices section under Appendix A.

Figures 4.1 – 4.10 show the analysis of responses acquired from the online Pre-Survey Analysis questions. A summary of the responses from the questions is as follows:

Figure 4.1: Feedback on Existence of Counterfeit Items

Figure 4.1 indicates that all ten respondents encountered counterfeit drug items in the Kenyan market. This proves that existence of counterfeit drugs in the Kenyan market as a problem is real and in need of a solution. This dissertation is therefore justified in posing as a solution to the problem.

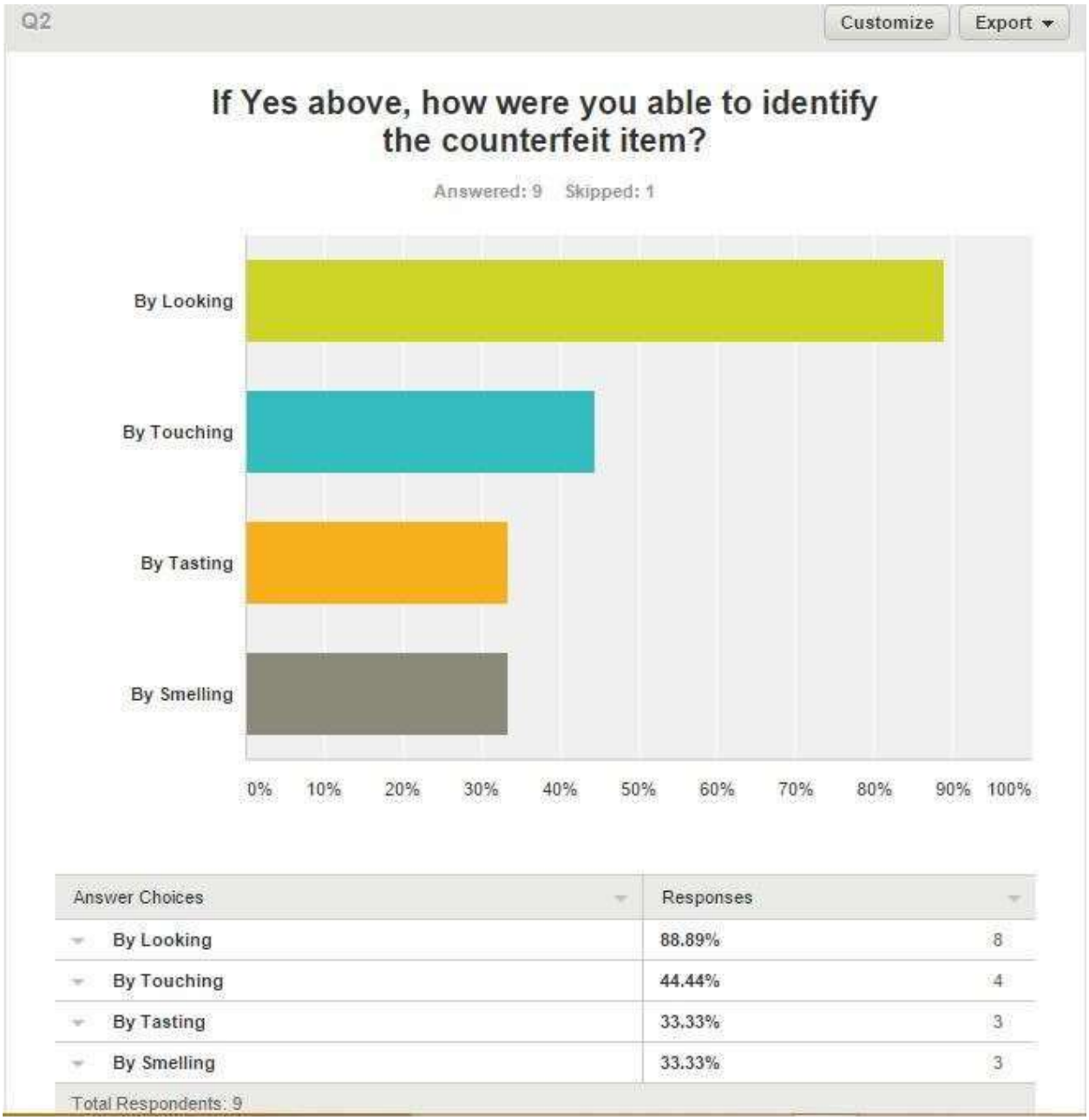


Figure 4.2: Feedback on Identifying Counterfeit Items

Figure 4.2 indicates that all respondents relied on human senses to detect legitimacy of drug items. Although many would agree that the above criteria for identifying counterfeit items can be perceived unreliable, it can only mean the lack of proper tools to perform such a task. Nine respondents answered this question with a majority opting to identify counterfeit drug items visually.

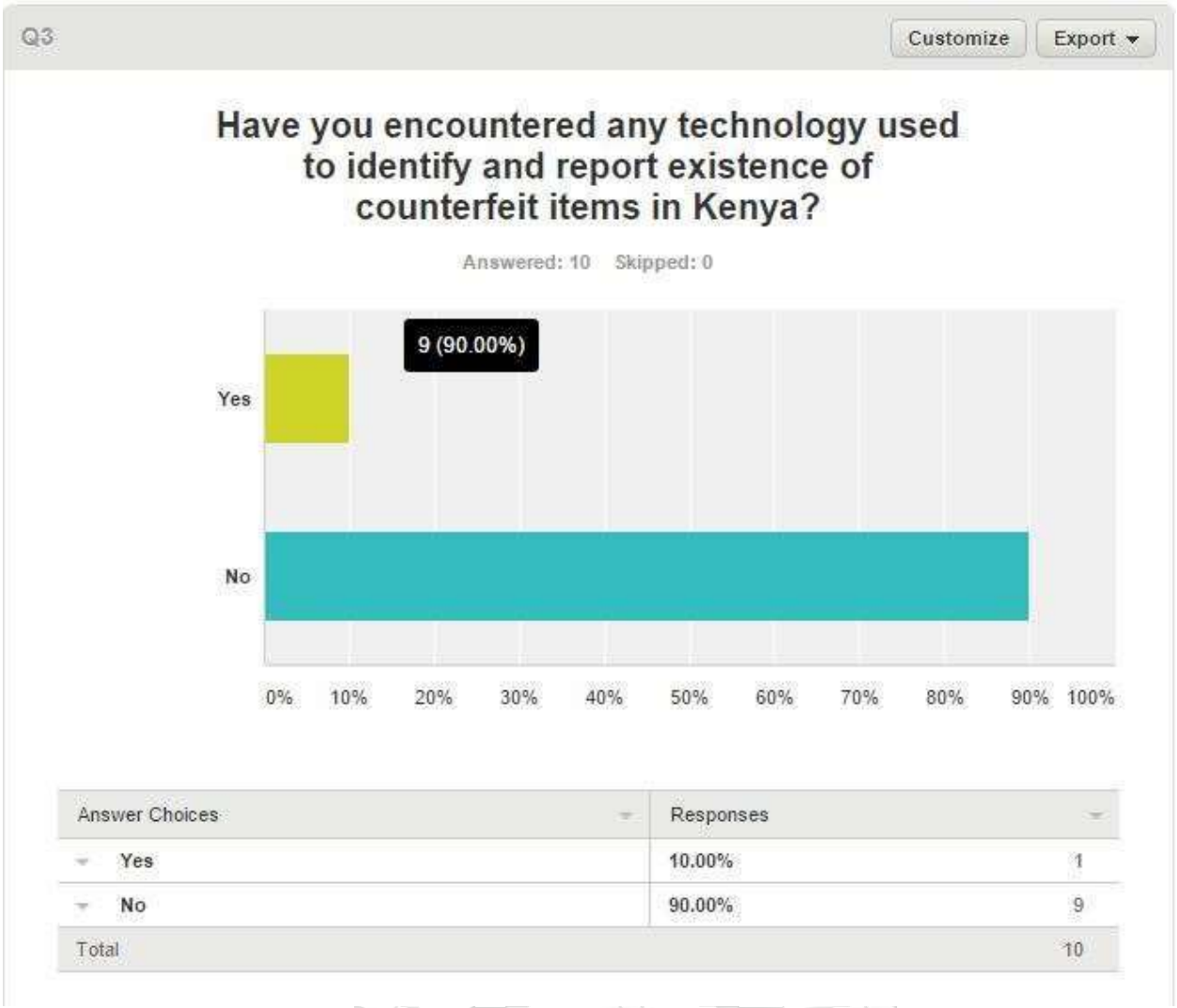


Figure 4.3: Feedback on Existing Technology for Identifying Counterfeit Items

Figure 4.3 indicates that all ten respondents answered this question. Nine respondents claimed to have never encountered any automated technology in the market used to identify existence of counterfeit drug items. It only proves that there is need to have a reliable automated system to help alleviate the problem further justifying the proposed solution as a potential problem solver.

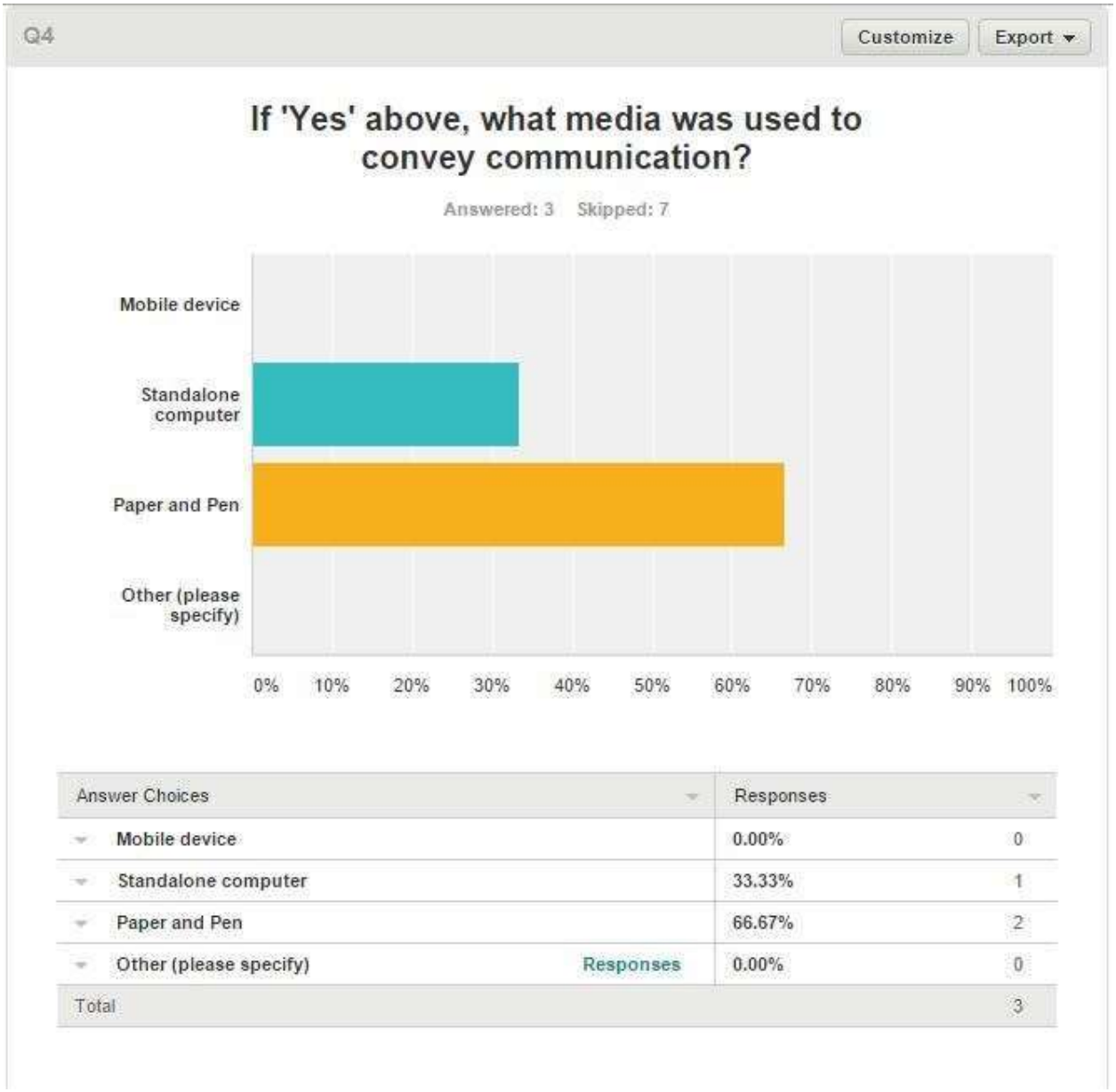


Figure 4.4: Feedback on Media of Communication Used on any Existing Technology

Figure 4.4 indicates that three respondents answered this question. The only electronically automated technology existing in the market is a software application accessible via a standalone desktop computer. The other controlled form of reporting encountered by respondents is the traditional paper and pen based process. In the current scenario development of a mobile based application would be the ideal solution to the research problem.

A total of 25 respondents were interviewed daily for a span of 8 days dispersed randomly in a month. The total number of respondents interviewed or Sample Size was 200 individuals. This group consisted of mixed gender groups, different ages and different socioeconomic status. The number of respondents who participated in the survey was 200 while the number of respondents who completed the survey was 187. The response rate therefore was 93.5%. This was calculated as:

Response Rate = Number of respondents who completed the Survey/Total Sample Size

(187/200) * 100 = 93.5%

Questionnaires can be found under the Appendices section.

4.2.2 Demographics

A. Age Distribution of Shoppers

Respondent's ages were recorded to help the researcher find out age groups that were likely to frequent a retail store to purchase items. This aided in development of proper aesthetics customised for the larger population of the age group.

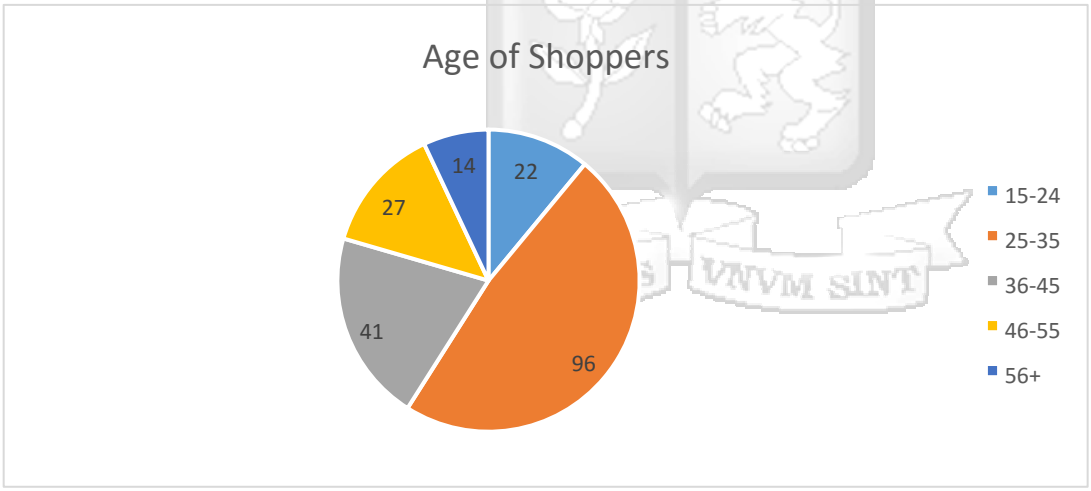


Figure 4.5: Variations of the Different Age Groups

Figure 4.5 shows the variation of the different age groups of the study group. This enabled the researcher to find out the age group of respondents that were actively shopping. This was to customize the developed application to the right age group. The findings indicated that majority of shoppers were aged 25- 35 years with a number of 96 respondents. 36-45 years were 41. The group of 15-24 years were 22, and the group of 46-55 years were 27 and finally 56+ were 14.

B. Gender Distribution of Shoppers

Respondent's genders were recorded to help the researcher find out the gender population that was likely to visit a retail store to purchase items.

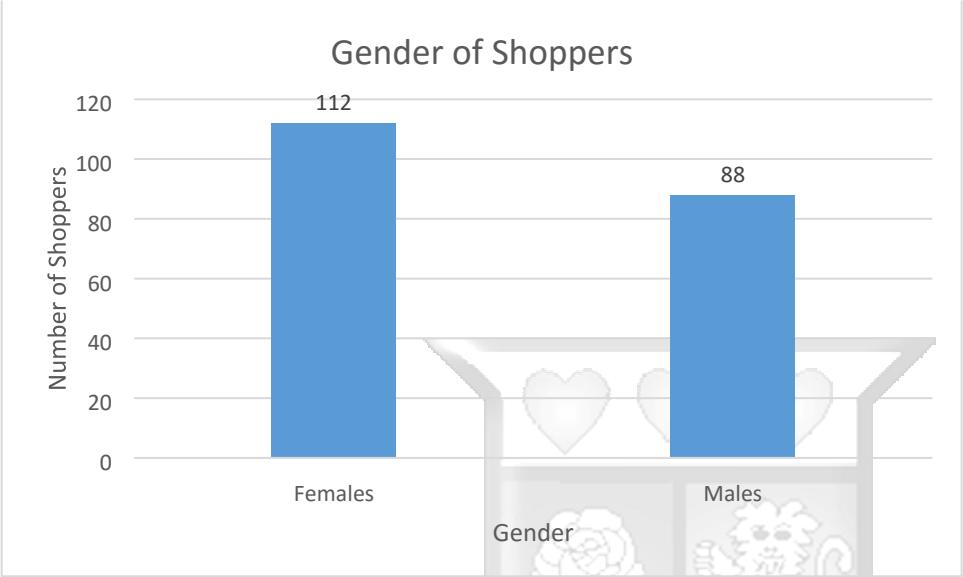


Figure 4.6: Discrepancies between Genders

Figure 4.6 shows discrepancies between genders of the study group. This study aided the research in identifying the actively shopping gender group to customize the developed application to suit majority of this population. It was evident that females formed majority of shoppers with a total of 112 compared to 88 for men.

C. Marital Status of Shoppers

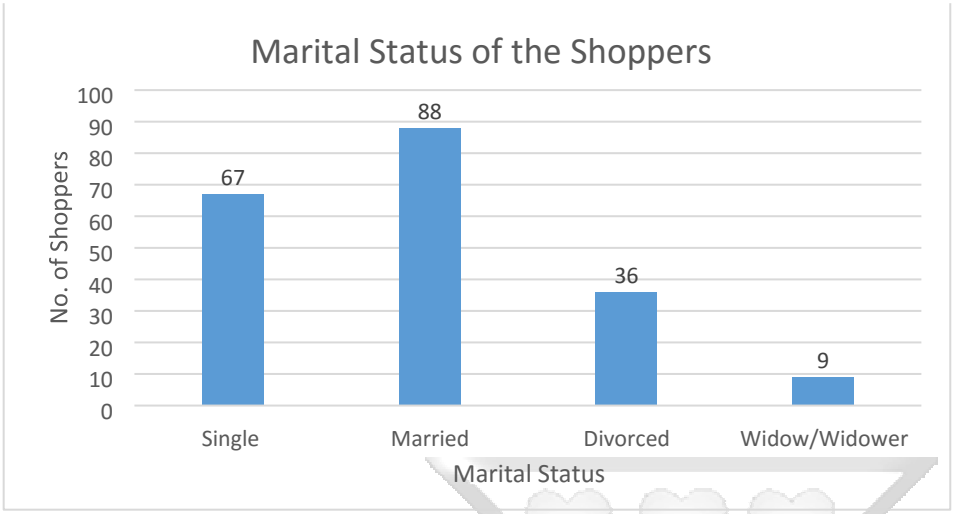


Figure 4.7: Marital Status

Figure 4.7 shows marital status of the study group. This aided the researcher in knowing whether the study population of shoppers was an audience geared towards a family unit. The developed application would then be customized to appeal to a broad range of users and not focused to individuals. Most of the shoppers were married persons.

D. Educational Disparities of the Shoppers

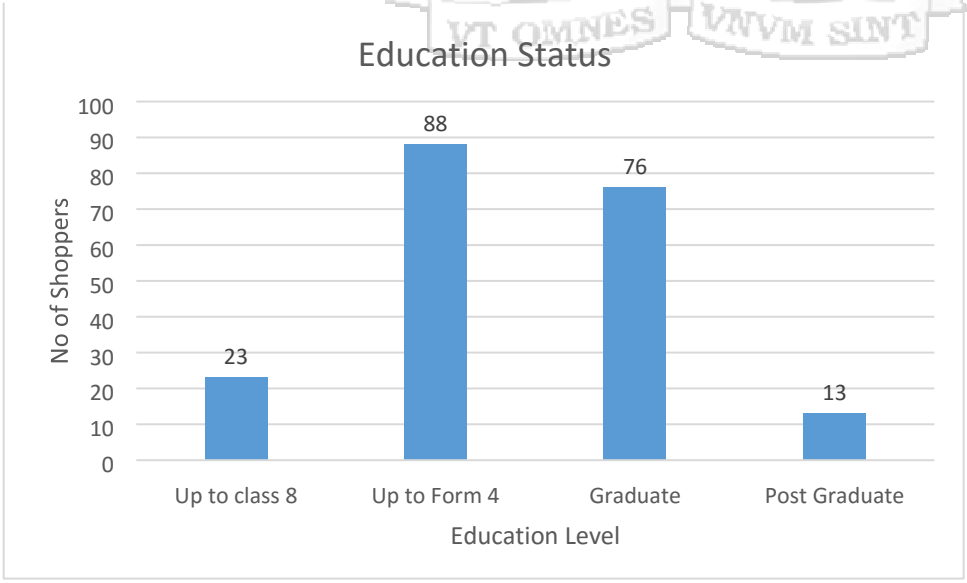


Figure 4.8: Education Levels

Figure 4.8 shows the education levels of the study population. This aided the researcher in determining whether users were individuals who could read instructions and follow simple gestures while using the developed application. The ability to read and write was deemed very important especially in cases where there was no human assistant to users of the application. Majority of the shoppers were people with educational level above form four level.

E. Employment Disparities of the Shoppers

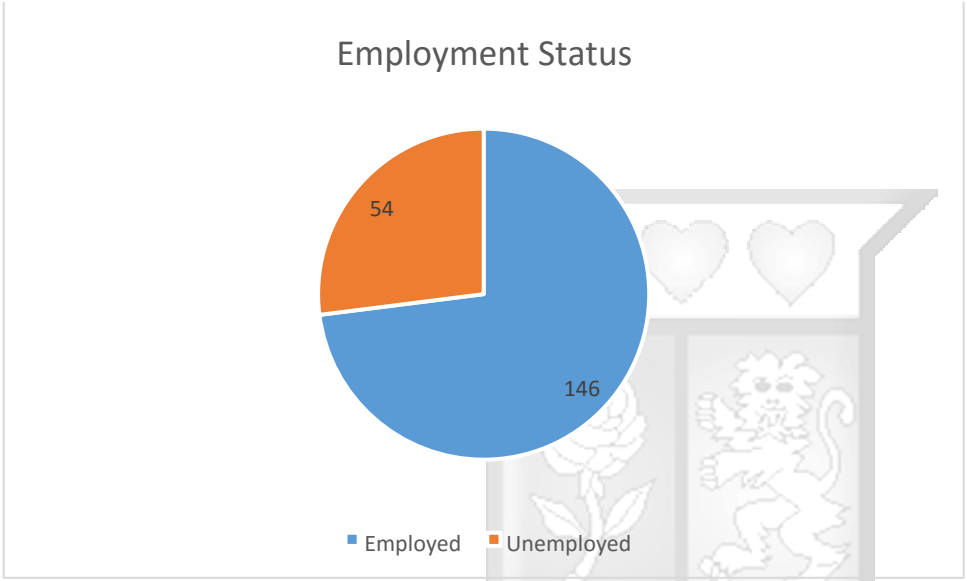


Figure 4.9: Employment Status

Figure 4.9 shows the levels of employment for the study group. Majority of the shoppers were employed 146 personnel out of the total 200. This showed the researcher that the population of study could get access to a data enabled phone proving the available large population of users for the potential mobile application.

F. Mobile Phone Usage and Service Experience

Figure 4.10 shows the mobile phone use and service experience of the study group.The findings indicated that majority of shoppers have had mobile phones between 1-5 years and sent an average SMS of between 25-50 per day as shown in figure 6. Moreover, majority of the respondents used data/INTERNET services for accessing social media activities and checking their personal or official mail. 3G/GPRS/WAP was used very often. An indication of growing culture of INTERNET usage and people possessing INTERNET enabled phones.

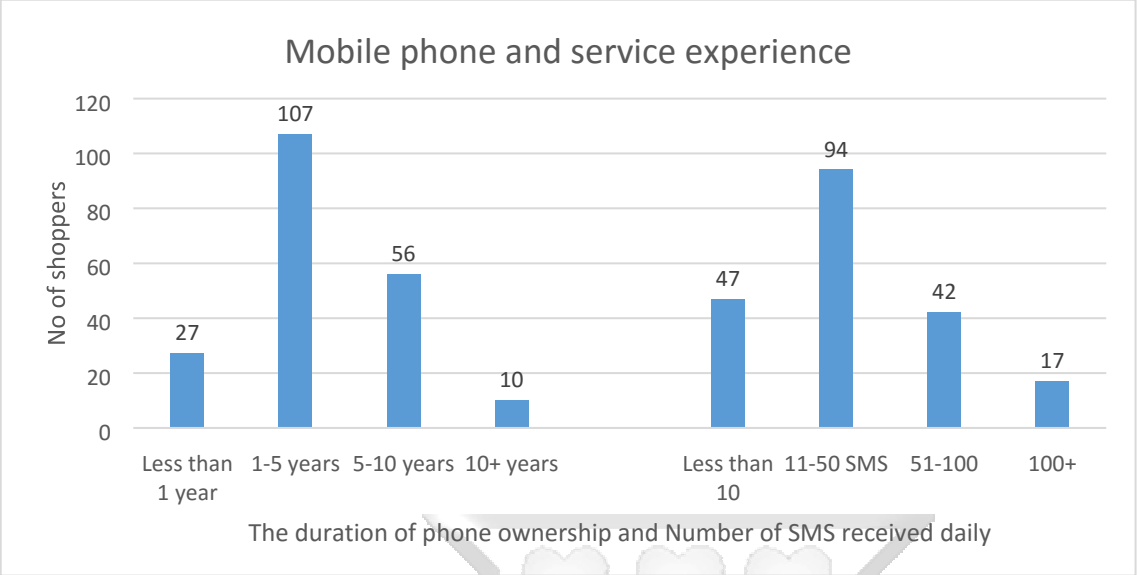


Figure 4.10: Mobile Phone Use and Service Experience

4.2.3 Adaptation of Complex Features

Majority disagreed strongly on using advanced features such as NFC (Near Far Communication), RFID (Radio-Frequency Identification) and some location based of their mobile phones. This guided the researcher to put into consideration the need to reduce complexity for the application use. They however agreed on using simple features such as taking photos and sharing them on social media. Moreover, they agreed strongly that simplicity of scanning products to verify their legitimacy would positively affect their decision of adopting it. Majority of the respondents were of the opinion that they would be willing to follow 2-5 steps in order to complete a mobile device scanning process. Lastly, all respondents strongly disagreed that they would be reluctant to adopt the developed application if they had to pay a small fee for every scan.

From the general questions asked to the respondents, majority strongly agreed that ease of use, convenience and efficiency would influence their decision of adopting the solution. Most respondents were also in agreement that remote mobile payments such as MPESA, MOBI-CASH and AIRTEL MONEY have been successful in Kenya, which can be attributed to the strong mobile industry and mobile device use in Kenya.

4.2.4 Results from data Collection and Analysis

Following collection of data and analysis of results the researcher came up with the information below:

- The proposed solution would be feasible for identifying and reporting the existence of illegitimate drug items in the Kenyan market especially in Nairobi.
- It was evident that Android was the most popular and accessible operating system to majority of the populace. It was therefore the preferred platform for development of the application.
- No technology was readily available and in use for identifying and reporting counterfeit drug items in the market. Existing technologies weren't utilised by a majority of the populace.
- From the results system requirements were formulated that aided in designing the system and in the implementation process.

4.2.5 System Requirements

A Requirements Analysis

This section outlines the Functional and Non- Functional requirements based on the user requirements collected alongside the initial study objectives.

B Functional Requirements

These requirements define capabilities and functions that the implemented application or its components must perform successfully. They include a set of input, behaviour and outputs concurrent with objectives of the study, such as:

i) Login/Logout; to gain access to the extra services such as viewing a history of all scanned items users are required to Login using a Username and Password. Users need to Logout to exit from the records.

ii) View Scanned Items; users of the application should view the history or a list of products that they had previously scanned. iii) Report Scanned items; users of the application should be able to report on items that have been flagged as "not registered".

iv) Modify Drug Details; administrative users should be able to modify details of drug items.

C Non – Functional Requirements

These are requirements that specify the criteria used to judge the operation of the system. They were contrasted in agreement with functional requirements that define specific behaviour or functions. They included:

i) Performance; the system should have an acceptable response time while performing its functions.

ii) Usability; the system should have an interface that is easy to use.

iii) Integrity; the system being data oriented should ensure that data analyzed and stored is not altered or corrupted.

iv) Security; the system should only allow authorized users to use its core functionalities.

v) Reliability and availability - The system should be reliable and always available to perform tasks requested by the user.

vi) Scalability; the system should be able to adopt additional functionalities. Additional data should be easy to incorporate.

4.2.6 Level 0 Data Flow Diagram

This data flow diagram shows the interaction between external entities and processes of the system. It also shows what kind of information will be input to and output from the system, data stores and where data will come from and go to (Burge, 2011).

External entities of the system include:

i) **The Customer:** the customer acquires information from the drug item by scanning it and posting it to a server. The customer can also view, review and rate chemists that he/she has interacted with. The customer can finally view details of drugs that have been previously scanned.

ii) **The System Administrator:** the primary function of the System administrator is to manage data applications through adding, deleting and modifying information. In addition the admin can view details of the drugs purchased by the customers and their details.

iii) Processes through which external entities interact include:

iv) **View drug information:** provide detailed information of the drug purchased such as product name and generic name.

v) **Post location:** provides the location of scanned drug items.

vi) **View user/customer information:** provides detailed information of users. Users must have registered to use the application at one point.

vii) **Report drug:** counterfeit drugs can be flagged on the database. Action can be taken by agencies that have access to the database.

Figure 4.11 shows the level 0 data flow diagram.

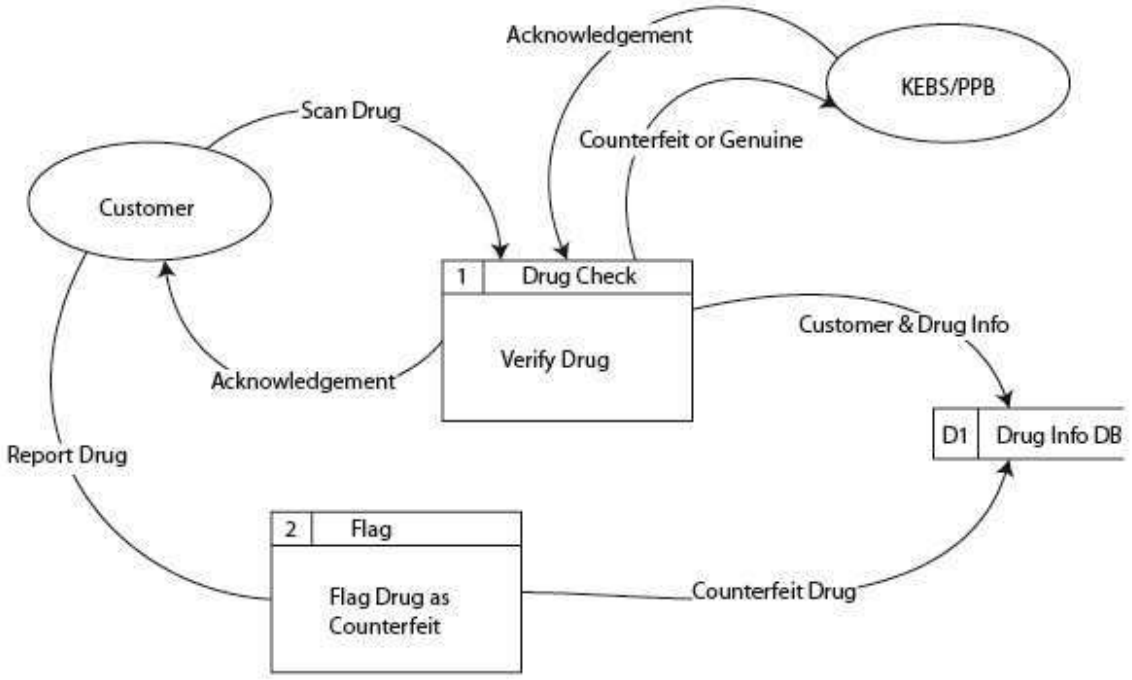


Figure 4.11: Level Zero Data Flow Diagram

4.2.7 Level 1 Data Flow Diagram

Figure 4.12 represents a level 1 data flow diagram of the system. This highlights the systems main functions. The diagram expounds on processes experienced by key users of the system consisting of the System Administrator, End Customer an existing organization such as KEBS or PPB and system data stores.

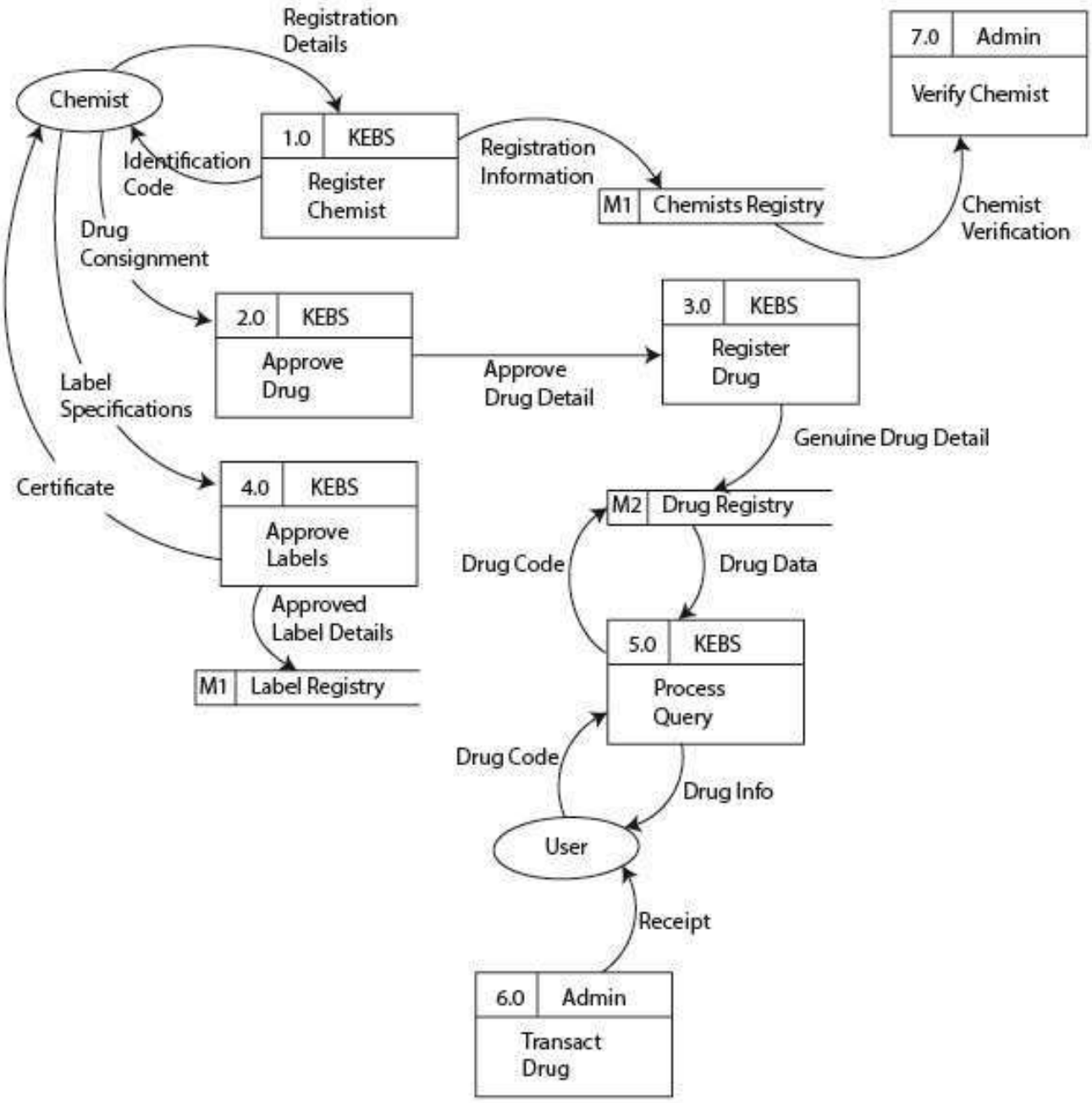


Figure 4.12: Level One Data Flow Diagram

4.3 Systems Design

The System Design will present the proposed solution in a logical manner using different Design diagrams.

It will consist of six components:

i) User Interface Flow Diagram

ii) Use Case Diagrams/Descriptions

iii) Sequence Diagrams

iv) Partial Domain Diagrams

v) Context Diagram

vi) Level 0 Data Flow Diagram

4.3.1 User Interface Flow Diagram

This section deals with the flow of screen presentations when the user interacts with the application. On the applications first run a splash screen appears followed by the main menu screen. The main menu screen or home screen displays shortcuts to all functionalities of the application including a help menu button, login button and social media buttons. In this application a user has the option of accessing the settings menu; Login to view items scanned by the user and a social media portion.

4.3.2 Use Case Diagram and Descriptions

This is a behavioral diagram that shows the functionality provided by a system in terms of actors, their goals as represented by use cases and any dependencies on those use cases. The main actors of the system are the customers who purchase drugs and the system administrator. The main processes in this application are:

i) Scan Drug Item; Primary actor is the customer who initiates the process of scanning drugs that he/she may want to purchase.

ii) Report Drug Item; Primary actor is the customer/user who reports on an identified counterfeit drug item.

iii) View Drug Item; Primary actor here is a user who can login and view the number of drugs used and details of the drugs he/she has used so far.

iv) Modify drug details; A systems administrator is the primary actor who adds, edits or deletes drugs from the database.

Table 4.1: Use Case Description of the Application

Use - Case	**Description**
UC 1 - Scan Drug Item	i) Primary Actor; Customer ii) Stakeholders: - Owner of the Chemist - Chemist attendant/Pharmacist iii) Preconditions: - User must have selected a drug - User must have purchased a drug iv) Success Scenarios: - User can verify that a drug is genuine v) Frequency of occurrence - Process occurs often
UC 2 - Report Drug Item	i) Primary Actor; Customer ii) Stakeholders: - Owner of the Chemist - Chemist attendant/Pharmacist iii) Preconditions: - User must have selected a drug - User must have purchased a drug iv) Success Scenarios: - User can report that a drug is counterfeit v) Frequency of occurrence - Process occurs often
UC 3 - View Drug Item	i) Primary Actor; Customer ii) Stakeholders: - Owner of the Chemist - Chemist attendant/Pharmacist

	iii) Preconditions: - User must have selected a drug - User must have purchased a drug - User must have logged into the system
	iv) Success Scenarios: - User can view a list of all drugs purchased and scanned by the app v) Frequency of occurrence - Process occurs often
UC 4 - Modify Drug Details	i) Primary Actor; System Administrator ii) Stakeholders: - Owner of the Chemist - Chemist attendant/Pharmacist iii) Preconditions: - No Preconditions iv) Success Scenarios: - Details of the Drug can be edited - Users can view drug details v) Frequency of occurrence - Process rarely occurs

Table 4.1 shows the Use Case Description of the proposed mobile and web application. It comprises of the following major Use Cases; Scan Drug Item, Report Drug Item, View Drug Item and Modify Drug Item.

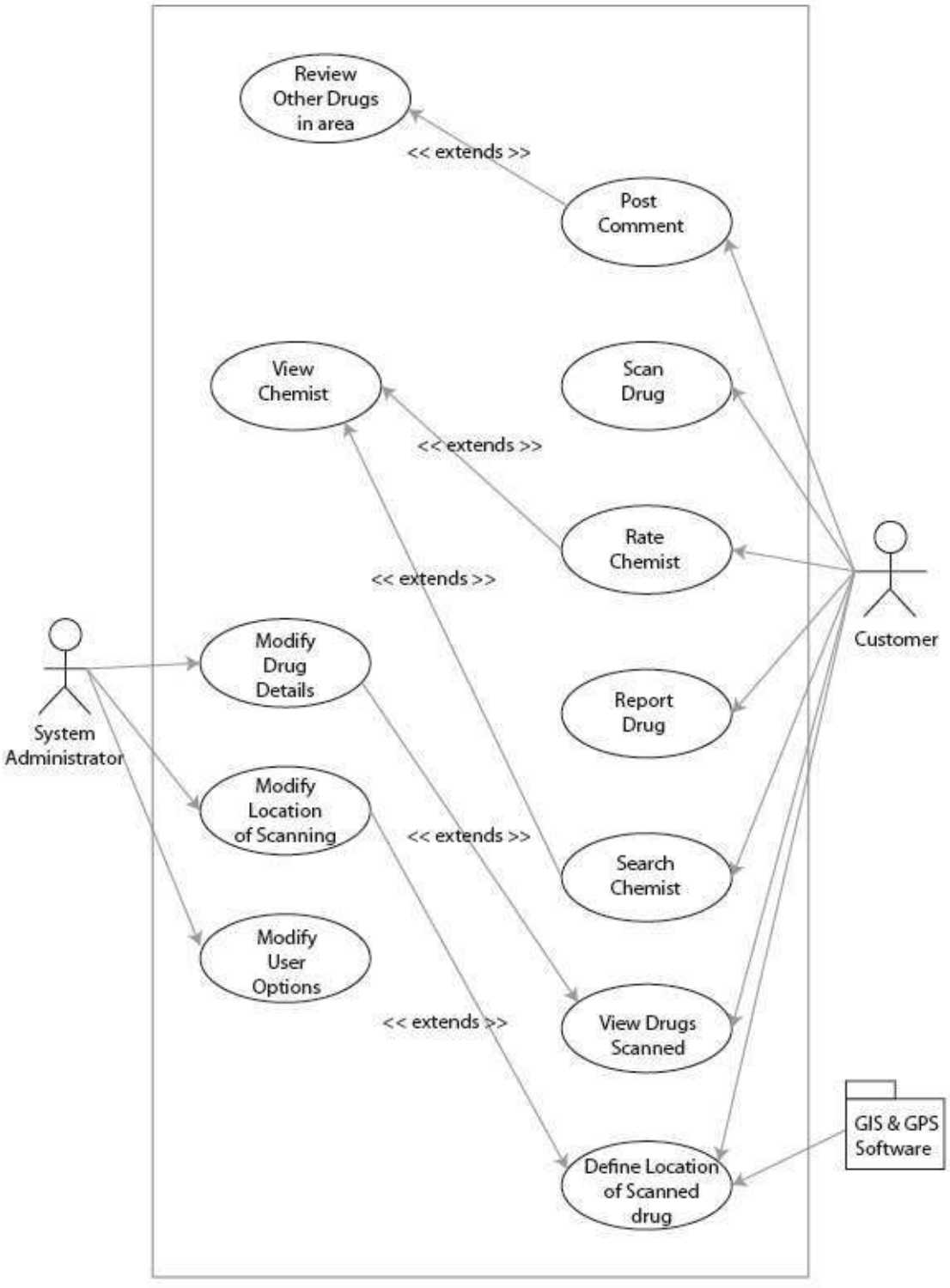


Figure 4.13: An Illustration of the USECASE Diagram

Figure 4.13 shows an illustration of the Use Case Diagram with all Use Cases. The Use Cases describe sequences of actions providing some value to the actor and is represented as a horizontal ellipse. An actor is a person or an external entity, in this case, a person and a GPS server. Associations between Actors and Use Cases are indicated by use of solid lines with arrow heads pointing towards the direction of initial invocation of the relationship (UML 2 Case Diagrams: An Agile Introduction, 2014).

4.3.3 System Sequence Diagram

The system sequence diagram shows how users interact and receive feedback and messages to and from the system. It also shows how other activities in the system communicate i.e. from the applications interface and the database where information is added and retrieved. The diagram also shows how users receive feedback messages from the system. Major entities of the system sequence diagram were:

i) The Customer: The customer scans drugs and verifies whether the drugs are genuine or counterfeit. The response from the server will be a confirmation message acquired by parsing through an identity list of drugs approved by a Quality Assurance body such as the Kenya Bureau of Standardisation (KEBS) or the Pharmacy and Poisons Board. Interactions between the customer and application also included viewer ratings and other reviews on posts from users.

ii) The System Administrator: the primary function of the System administrator is to manage data applications through adding, deleting and modifying information.

iii) The Software Application: both the system administrator and customer interact with the application.

Figure 4.14 shows major entities communicating with each other in the systems sequence diagram. The system sequence diagram is used to show interactions between objects in the sequential order that interactions occur (Bell, 2004).

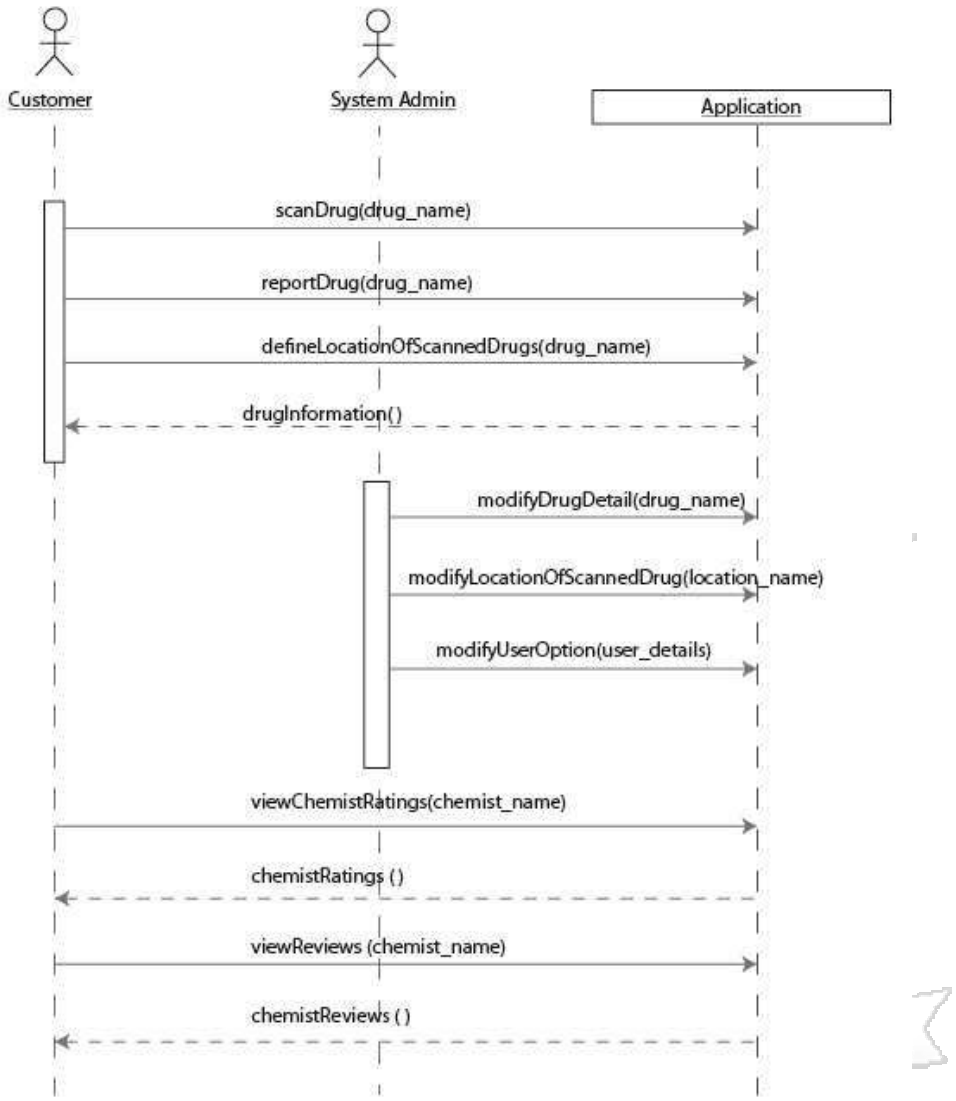


Figure 4.14: System Sequence Diagram

4.3.4 Partial Domain Diagram

Figure 4.15 shows the partial domain diagram identifying relationships between entities of the application. A domain model is a visual representation of conceptual classes or real-situation objects in a domain (Larman, 2002).

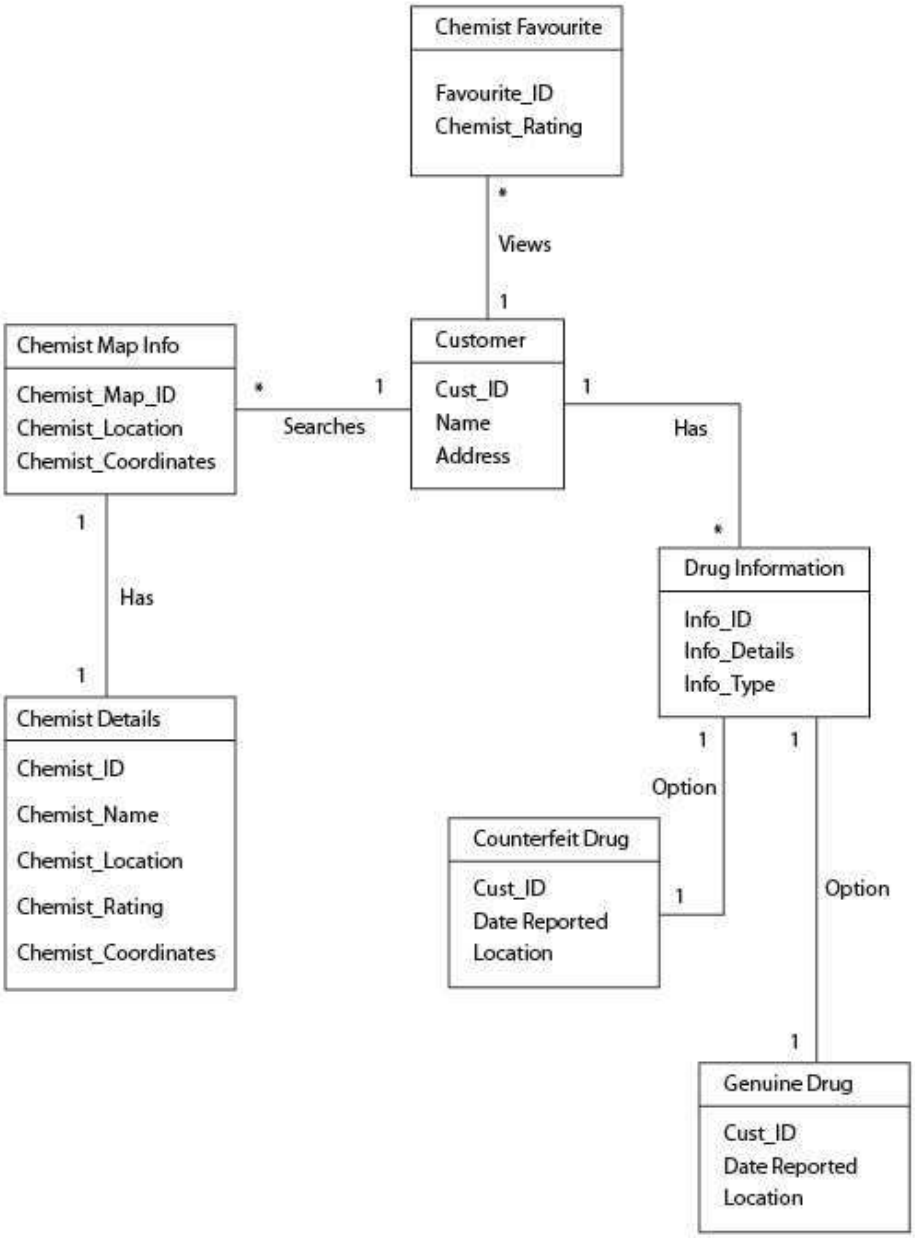


Figure 4.15: Partial Domain Diagram

4.3.5 Context Diagram

A Context Diagram is a component of Functional Modelling that stands out on its own as a valuable tool. This allows for the production of a high level model of an existing/planned system defining the boundary of the system of interest and interactions with critical elements in its surroundings (Burge, 2011). A context diagram was used to represent actors outside of the system that directly interacted with the mobile

application. They consisted of entities and relationships. Entities represented the main system while multiple external entities represented external actors.

Entities of the application included:

i) **Customers:** these represented primary entities of the application ii)

System Administrators: Manages application data

Figure 4.16 shows relationships between entities representing flow of information through a context diagram.

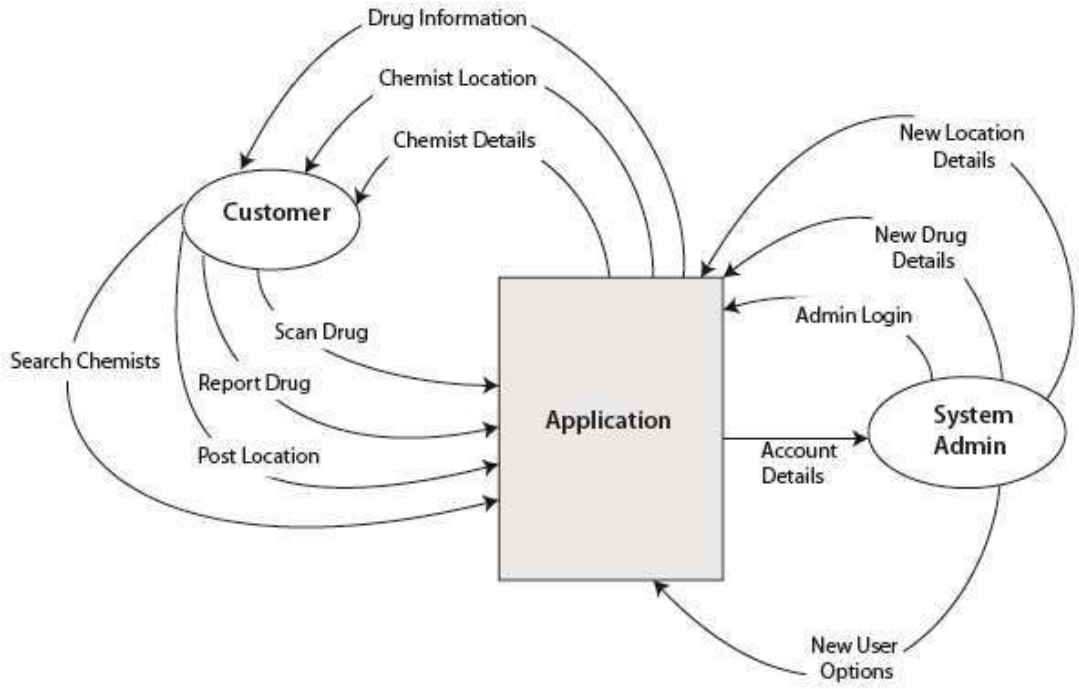


Figure 4.16: Context Diagram

4.3.6 Database Schema

A Database Schema is the skeleton structure that represents the logical view of the entire database. It gives a definition of how data can be organized and how the relations among them are associated (Database Schema, 2015). Figure 4.17 represent the Database Schema presented the logical view of the entire database.

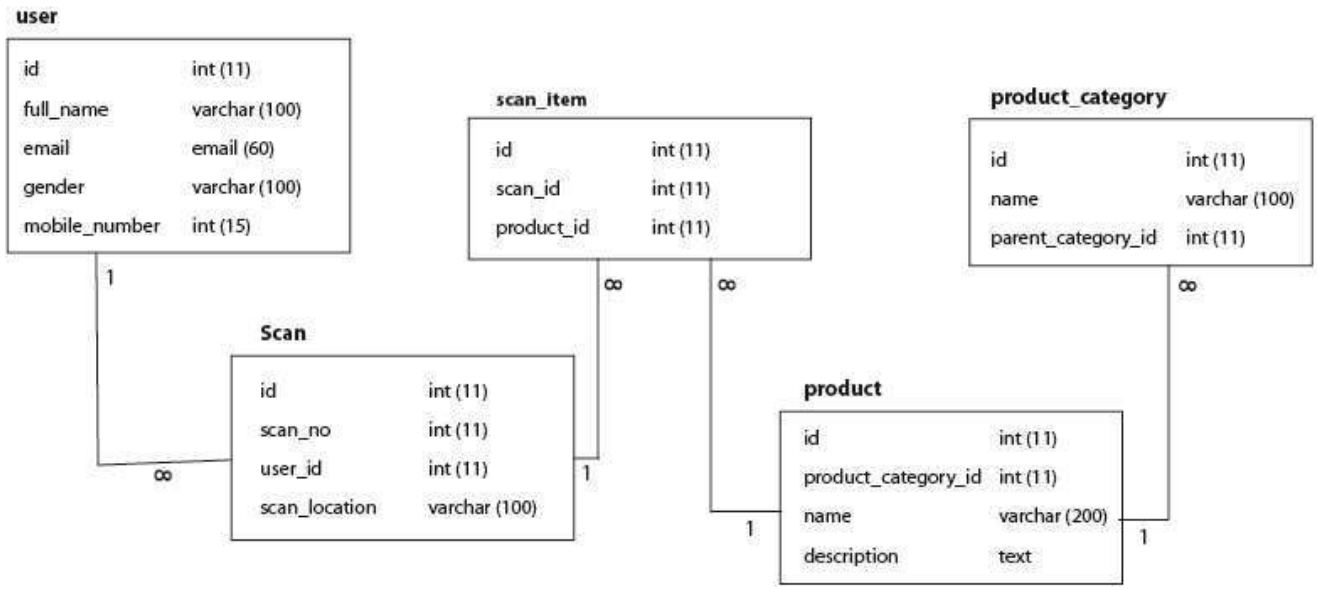


Figure 4.17: The Database Schema

4.4 Systems Architecture

The developed application implemented the Client Server Architecture. The client side consisted of the Android application that interact with GIS and GPS software modules embedded in the mobile device. User interacts with the application by scanning on items (drugs) purchased at a shop/pharmacy. Through an INTERNET connection the application verifies with the KEBS database to confirm whether the item scanned is genuine or counterfeit. If the item is genuine the user will clearly see the KEBS logo, a tick and the words "Genuine Product". If the item is counterfeit the user will get a response with a large crosses mark "X", with the words "Counterfeit Product". The user will also have an option to report the item by pressing a button that will appear at the bottom of the screen. On pressing the button, information on the date, GPS location of the instance of scanning will be sent to the KEBS server.

The application server verifies if the item scanned is genuine. It also collects feedback on location and date of scanning if an item has been reported as counterfeit. A system administrator has access to the application server and can manipulate data for secondary reporting.

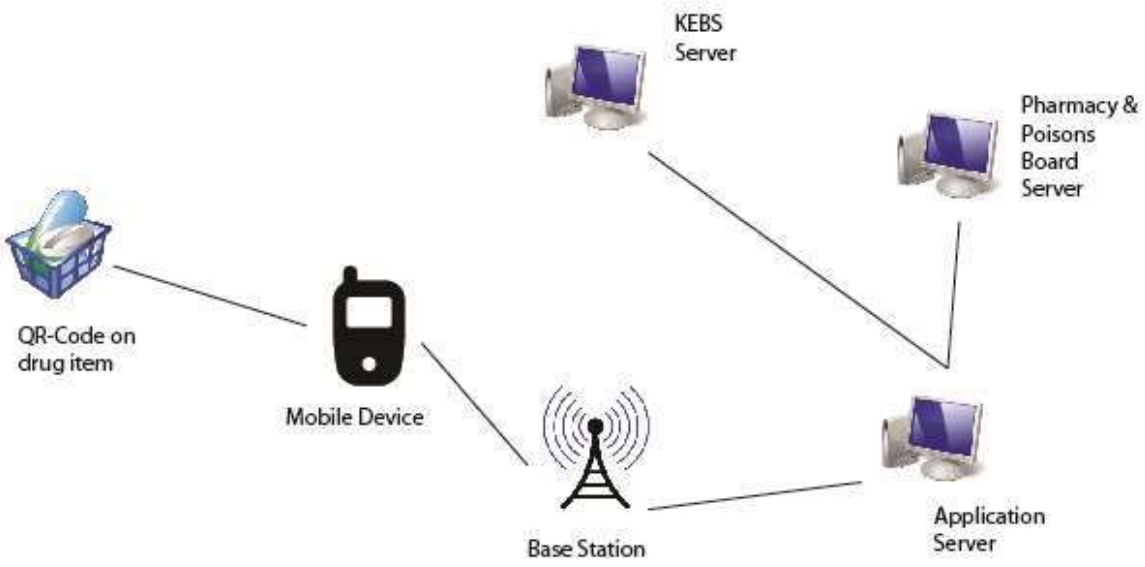


Figure 4.18: Mobile Network Architecture

Figure 4.18 shows the Mobile Network Architecture of the proposed system. This includes a mobile device, servers QR-Codes attached to drug items and a supporting mobile telecommunication service network such as SAFARICOM, AIRTEL and YU.

4.5 Mobile Application Wireframes

Mobile application wireframes were used to give a visual guide presenting a skeletal framework of the application. They guided the researcher through arrangement of elements to achieve the goal of this research. Figures 4.19 and 4.20 show the wireframe designs of the Splash Screen and Login Screen respectively. More Splash Screen designs and the backend wireframes can be viewed in Appendix B.

Home Screen

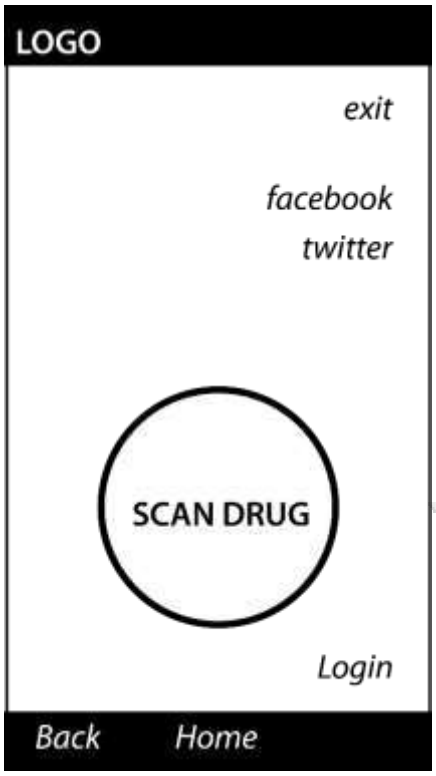


Figure 4.19: The Home Screen

Report on Genuine Drug Item

Figure 4.20: Report on Genuine Item

Uncertified Drug Item

Figure 4.21: Report on Uncertified Item

Feedback on successful report

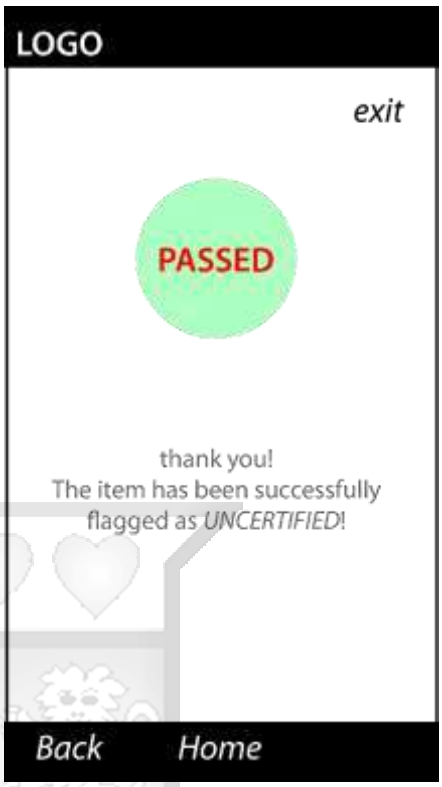


Figure 4.22: Feedback on Successful Reporting

CHAPTER 5: SYSTEM IMPLEMENTATION AND TESTING

5.1 Introduction

This chapter constitutes implementation of the proposed application. Chapter 4 section 4.2.5 (B) gave the system functional requirements which the prototype functionalities incorporated.

The implementation environment for the mobile application, web application and database will be described in this section to give a clear understanding of the actual implementation of the prototype. The implementation details provides descriptions of major system components and explanation of implementation procedures.

The chapter also provides the system testing procedure. Tests performed were:

i) Functional testing; where the system functionality was tested against the functional requirements.

ii) Compatibility testing; where the applications were tested against different platforms and browsers.

iii) Usability testing; which was conducted by potential users and their feedback analyzed.

5.2 Implementation Environment

5.2.1 Mobile Application Prototype

The Operating System for the mobile application implementation was Android. The source code was written in Java, utilizing android classes. The application was compiled and tested using the android Software Development Kit (SDK) emulator and an android device. The application is optimized for android version 4.4.2 compatible with android devices on minimum version 2.0 and maximum version 4.4.4. JSON was used as the web service that provides the interface between the android application and the database. Reasons for choosing android as the client application include: flexible SDK, availability of Android Development Tools (ADT) and availability of abundant support from online developer communities.

5.2.2 Web Application

The web based application was developed using Hypertext Preprocessor (PHP). The website was hosted on an online Apache HTTP server. Reasons for using PHP were; it is an Open Source platform, it is platform independent; it supports all major webservers and databases; it has multiple layers of security to prevent threats and malicious attacks.

5.2.3 Database

The database was developed using the MySQL database. The reasons for using MySQL were; it is an open source platform; it is fully compatible with PHP and other platforms; it is secure in that all passwords are encrypted before storage restricting unauthorized access to the database.

5.3 Implementation Details

5.3.1 The Mobile Prototype

The prototype was designed to run on an Android Operating System device compatible with android devices with minimum version 2.0 and maximum version 4.4.4. The device running the application relied on an active INTERNET connection and a working camera. Full functionality of the application required interaction with a QR-Code reader and an application that managed data manipulation and interaction with a backend server.

QR-Codes attached to drug items are captured by the mobile phone camera. A QR-Code reader application is used to analyse and generate a QR-Code number stored in the items QR-Code. The QR-Code number then used as the unique identifier of a drug item.

A unique QR-Code number is used to identify whether the item exists in the database or not. During an instance of scanning, the location of the device during a scan can be picked (this is only if the location service has been enabled) and stored in the database. Other information captured during a scan include; User information (if the user has logged into the application), time and date information. User experience was enhanced by providing functionalities in a simple but sleek manner. Also flow of the process was presented in a logical and easy way providing relevant data constraints in textboxes.

Components of the system

Some of the core components of the system are as follows:

The Home Screen

Figure 5.1 shows the Home Screen of the application. This is displayed upon launch of the application. A user doesn't necessarily have to login to use the application but can proceed to scan items upon pressing

on “Scan Drug”. Users looking for more meaningful interaction with administrators of the system and to acquire feedback such as viewing a history of all drugs scanned will have to register and login in.

Home Page

Figure 5.1: Home Screen

Home Page after Login

Figure 5.2: Home Screen after Login

Figure 5.2 shows a screenshot of the Home Screen after successful Login. The User Login interface allows a user to input his/her username and password. Users who may have lost their login credential have the option of resetting the username and password from this interface.

Figure 5.3 shows a screenshot of the QR-Code Screen Capture. A user will scan directly onto a visible QR-Code using the mobile phone camera.

QR-Code Scanner Interface

Figure 5.3: Screenshot of the QR-Code Scanner

Feedback on genuine drug item

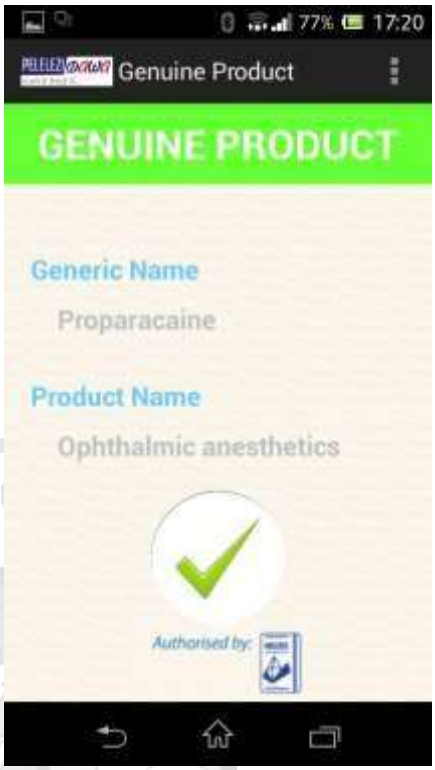


Figure 5.4: Screenshot of Genuine Item Report

Figure 5.4 shows a screenshot the feedback acquired upon scanning a genuine product. The product and generic name are shown with a mark of quality from KEBS.

Feedback on scanning drug items

Figure 5.5 presents a screenshot of the feedback acquired upon scanning a non-registered or counterfeit product. Details of the product don't show the generic and product name since the product is alien to the database. The mark of quality from KEBS is also not visible. A user has the option of reporting an Uncertified or Unregistered drug item as in Figure 5.6.

Figure 5.7 shows the feedback received upon successful reporting of an unregistered drug item. Figure 5.8 shows a history of scanned drug items. Users can only view the items after successfully login into the application prior to scanning items.

Feedback on uncertified drug item

Figure 5.5: Screenshot of Uncertified Item

Reporting Interface

Figure 5.6: Screenshot of Reporting Drug Interface

Feedback after reporting drug item

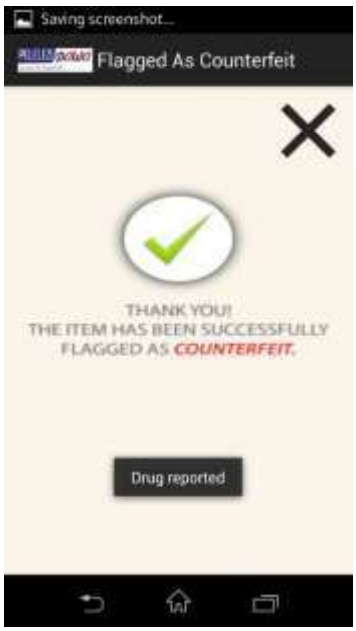


Figure 5.7: Screenshot on Successful Reporting

View List of Scanned Items

Figure 5.8: History of Scanned Items

5.3.2 Web Application

The web application's main function was to retrieve and receive information sent by the developed mobile phone application to the database. This application resides in the HTTP web server and is directly linked to the drug item's management database. The web application was designed for use by administration to manage users, generate and view reports. The reports generated included: a report to view the number of registered users using the application; Scan location of registered users using the application; Number of scans performed by each registered user; Total number of scans performed by all registered users.

System components

The main components of administrative users of the Web Application components are:

Administration Login

To gain access to the web application system users have to login using a unique Username and Password. Once the Username and Password have been issued by the user, they are authenticated for protection.

User Management

This component offers user management roles. It allows an Administrator to View registered users scanning activities, to edit user profiles as activate and deactivate a user, View and edit location names of geographic coordinates picked by registered users who have used the application and to finally manage user levels. A screenshot of the User Management Interface is below.

Scanned Drugs Report

This component allows an Administrator to view details of all scanning activities in the system. It gives a report of the user and scan details including time of scan, location of scan, drug item scanned and whether the scanned item was registered or not.

Registered Drugs Report

This component allows an administrator to view details of all drugs registered in the system. They can edit, add and delete drugs through this interface. Figure 5.9 gives a screenshot of registered drug items existing in the database.

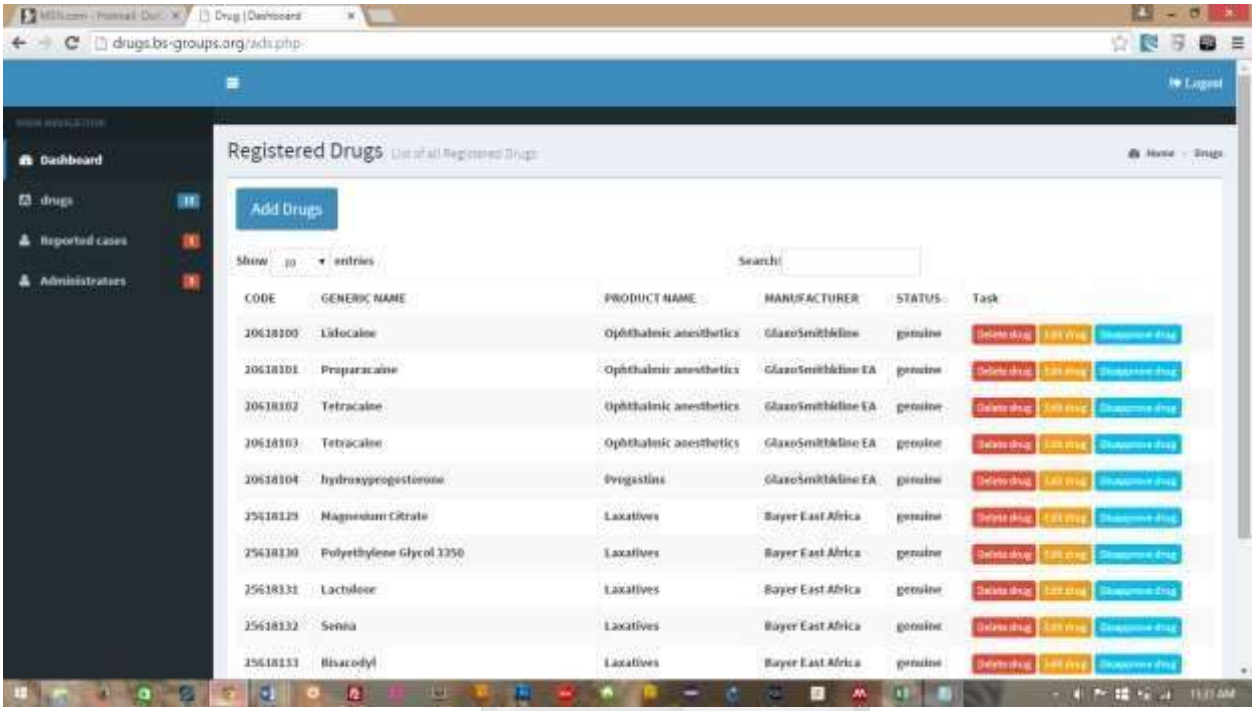


Figure 5.9: Screenshot of Registered Drug Items in the Database

5.4 System Testing

5.4.1 Introduction

This section describes tests performed on the mobile and web application. Tests were done against Functional and Non-functional requirements of the application.

5.4.2 Functional Testing

Functional tests were done based on use cases to determine success or failure of the system implementation and design. For each use case testing measures were set with results being considered successful or unsuccessful. Below are tables showing some of the major use cases and their test results.

Test Identifier 1: To Login or Logout

Table 5.1: Test Identifier 1 (To Login or Logout)

Utilised Use Case	Logging in or out of the system
Test Parameters	Login with correct username and password pair/Logout
Expected Behavior	Successful login and access granted/ Successful logout
Observed Behavior	Successful login and access granted / Successful logout
Test Outcome	Pass

Table 5.1 shows results of test identifier one who's main assessment was to check for correct login and logout functionalities of both mobile and web application. The observed and expected behaviour were consistent. Test Identifier one passed the trial and outcome was deemed successful.

Test Identifier 2: To Scan a drug item

Table 5.2: Test Identifier 2 (To scan a drug item)

Utilised Use Case	Scan Drug Item
Test Parameters	Expected response from server
Expected Behavior	To successfully report that a scanned item is genuine or uncertified
Observed Behavior	Successful report of both scenarios (genuine of uncertified product)
Test Outcome	Pass

Table 5.2 shows results of test identifier two whose main assessment was to check for correct behaviour and feedback from scanning a registered and non - registered drug item. The observed and expected behaviour were consistent. Test Identifier two passed the trial and outcome was deemed successful.

Test identifier 3: To view a history of scanned items by a registered application user

Table 5.3: Test Identifier 3 (View History)

Utilised Use Case	View Scanned Items
Test Parameters	A history of scanned items can only be viewed by a registered user
Expected Behavior	Successfully view the history of scanned drug items by a user
Observed Behavior	Successfully viewed a history of scanned drug items by a registered user
Test Outcome	Pass

Table 5.3 shows results of test identifier three whose main assessment was to view a history of already scanned drug items by a registered user. The observed and expected behaviour were consistent. Test Identifier three passed the trial and outcome was deemed successful.

Test identifier 4: To view a list of scanned items by an administrator

Table 5.4: Test Identifier 4 (View a list of Scanned Items)

Utilised Use Case	View Scanned Items
Test Parameters	Only scanned items by registered users should be visible
Expected Behavior	Successfully list scanned items by registered users
Observed Behavior	Successfully listed scanned items by registered users
Test Outcome	Pass

Table 5.4 shows results of test identifier four whose main assessment was to view a list of scanned drug items stored in the backend web interface by an administrator. The observed and expected behaviour were consistent. Test Identifier four passed the trial and outcome was deemed successful.

Test identifier 5: To Edit Users and User profiles

Table 5.5: Test Identifier 5 (To Edit Users and User profiles)

Utilised Use Case	Edit Profiles
Test Parameters	Edit user profiles by administrator only
Expected Behavior	Successful modification of user profiles by administrator
Observed Behavior	Successfully modified user profiles by administrator
Test Outcome	Pass

Table 5.5 shows results of test identifier five whose main assessment was to edit users and user profiles. Observed and expected behaviour were consistent. Test Identifier five passed the trial and outcome was deemed successful.

Test identifier 6: Modify Drug Details

Table 5.6: Test Identifier 6 (Modify Drug Details)

Utilised Use Case	Modify Drug details
Test Parameters	Drug Details can only be modified by an administrator
Expected Behavior	Successfully modification of scanned drug items
Observed Behavior	Drug details can be successfully modified by and administrator
Test Outcome	Pass

Table 5.6 shows results of test identifier six whose main assessment was to check for the ability to modify drug item details by an administrator. The observed and expected behaviour were consistent. Test Identifier six passed the trial and outcome was deemed successful.

Test identifier 7: Modify the location name of coordinates picked from a scan

Table 5.7: Test Identifier 7 (Modify Location)

Utilised Use Case	Modify Scanned location name
Test Parameters	Location name from scan coordinates can only be modified by a system administrator
Expected Behavior	Successful modification of location name picked from scan coordinates modified by a system administrator
Observed Behavior	Location name from a scan coordinate modified by the system administrator only
Test Outcome	Pass

Table 5.7 shows results of test identifier seven whose main assessment was to modify the location name of coordinates picked from a user's scan location. The observed and expected behaviour were consistent. Test Identifier seven passed the trial and outcome was deemed successful.

5.4.3 Compatibility Testing

Compatibility was done to ensure that the mobile and web applications were compatible with the available platforms. The mobile application was tested against the predefined available Android platforms while the web based application was tested against available web browsers.

Compatibility Testing on the Android Platform

The table 5.8 shows tests conducted on predefined and locally available Android platforms.

Table 5.8: Predefined Available Android Operating System Platforms

Android Platform	Compatible
Android 5 (2.0)	Yes
Android 8 (2.2)	Yes
Android 9 (2.3.1)	Yes
Android 10 (2.3.3)	Yes
Android 11 (3.0)	Yes
Android 12 (3.1)	Yes
Android 13 (3.2)	Yes
Android 14 (3.3)	Yes
Android 15 (4.0.3)	Yes
Android 16 (4.1.2)	Yes
Android 17 (4.2)	Yes
Android 19 (4.4)	Yes

Web Browser Testing

The table 5.9 shows testing done on available and commonly used web browsers.

Table 5.9: Test done on Available Browsers

Browser types	Compatibility
INTERNET Explorer (versions 4 and above)	Yes
Firefox (version 8.0 and above)	Yes
Chrome (All versions)	Yes

5.4.4 Usability Testing

End users of the application were involved in usability testing. This group defined the target population available to use the system. A total of 36 respondents carried out the user testing practice giving appropriate feedback for the research. 36 respondents were used as these were the only individuals who created time to visit a stand and participate in the process of scanning. User testing was done to achieve the following objectives:

i) User friendliness

ii) functionality

iii) Aesthetics

iv) Acceptance

This section will focus on each of the mentioned objectives in detail. The findings will be presented graphically for an elaborative visual presentation.

User Friendliness

78% of the potential users indicated that the application was easy to use and learn. They managed to use the application without prior training. 12 % of the respondents found the application fair to use meaning it was neither easy nor hard to learn and user, they needed the intervention of a trainer in some cases to confirm that what they were doing was right. 10% of the respondents found that application difficult to use. These were individuals who had just acquired a data enabled device. Others claimed to have used the phone camera for another use from the norm which was to scan on a QR-Code and note take a picture! Figure 5.10 shows a summary of the results.

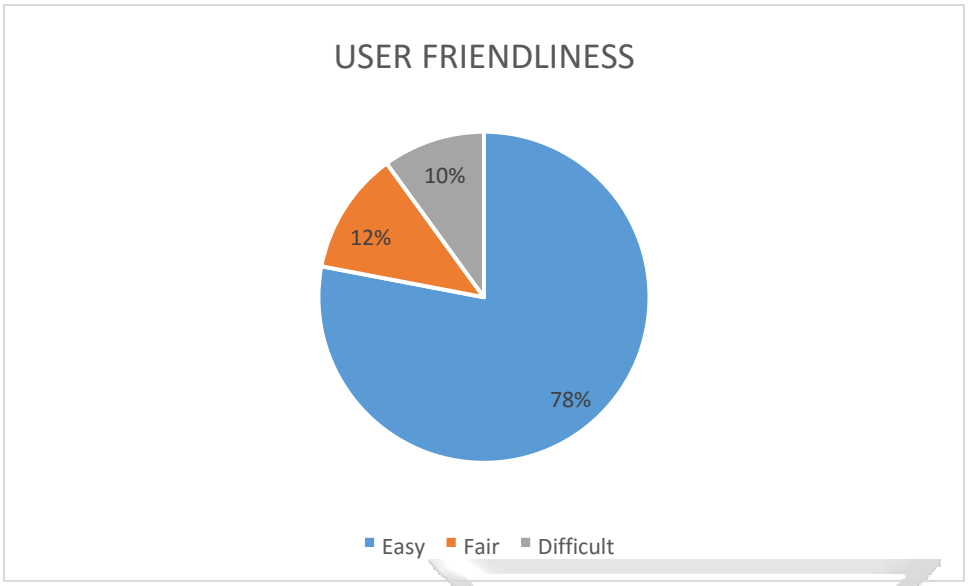


Figure 5.10: Test Results on User Friendliness

Functionality

Users of the application tested system functionality to verify whether they responded to their expectations. 75% of the respondents indicated that the applications functionality was commendable. 15% of the respondents indicated that the functionality was average meaning that some functional aspects of the application weren't satisfactory. 10% of the respondents indicated that the systems functionality did not meet its intended goal. The overall result collected was used to refine the application up to the level of acceptance. A summary of the result can be viewed in Figure 5.11.

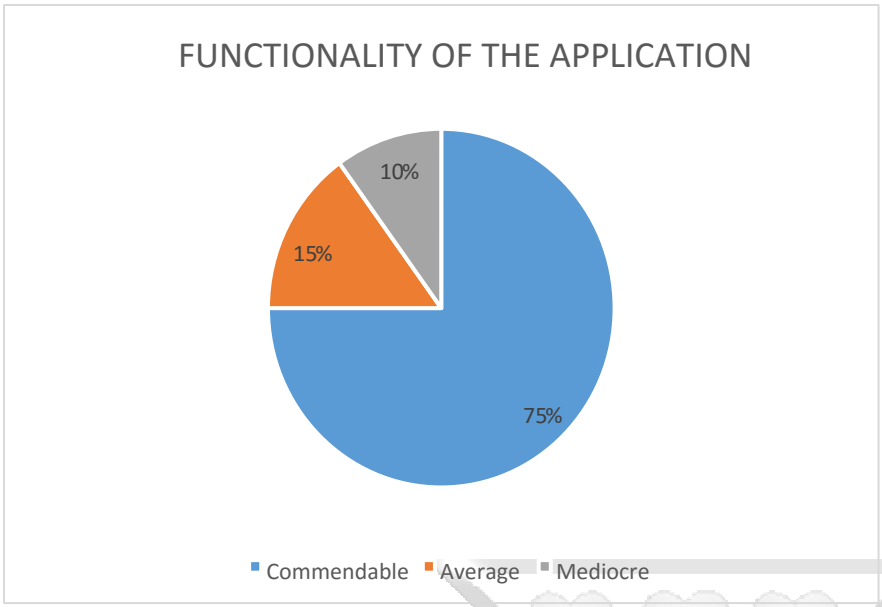


Figure 5.11: Test Results on Functionality of the Mobile Application

Aesthetics

User interface aesthetics is defined by the look and feel of the application design and flow to its users. 84% of the respondents indicated that the application had an attractive presentation. 14% of the respondents indicated that the application was acceptable while the remaining percentage indicated that the application was not pleasing to the eyes. A summary of the results can be viewed in Figure 5.12.

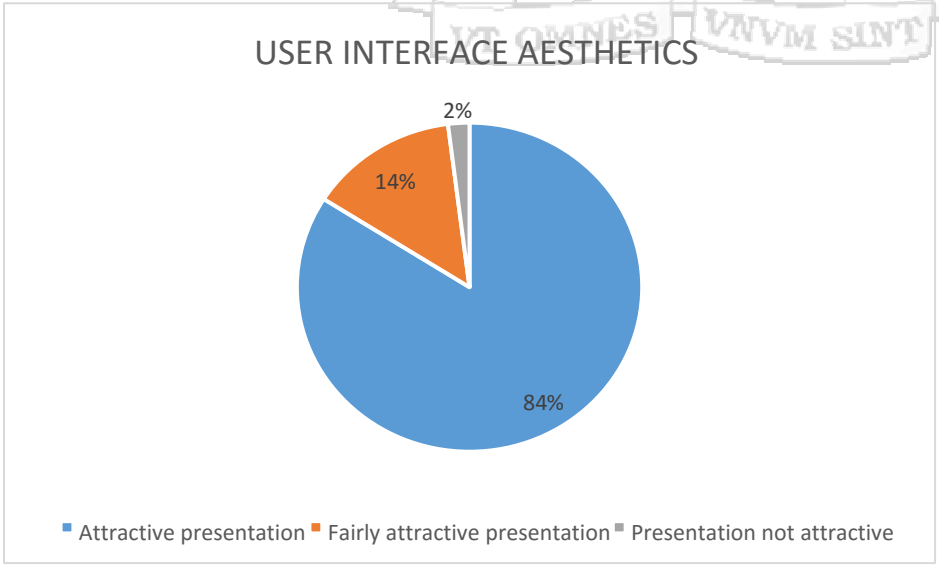


Figure 5.12: Test Results on User Interface Aesthetics

Acceptance

The acceptance test was done to find out whether the application can be incorporated for use by its target users. 88% of the respondents found the application useful. 6% of the respondents were reluctant in accepting the application while the remaining 5% would not use the application. A summary of the result can be viewed in Figure 5.13.

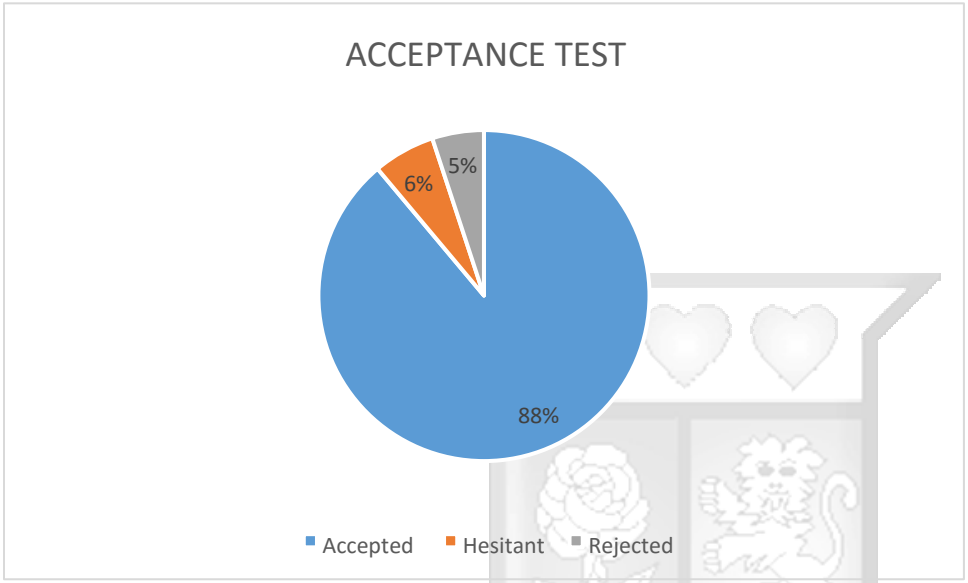


Figure 5.13: Test Results on Acceptance

Below are responses from the Survey in relation to the research questions:

There was evidence of the existence of counterfeit items in Kenya: a majority of the respondents felt that counterfeit/uncertified drugs items were in distribution all over the country. Respondents felt that having stickers with a mark of quality assurance from KEBS attached to products gave them confidence on legitimacy of products but were skeptical about sources of the sticker.

Effects of consuming uncertified drug items were evident: a majority of users claimed that consumption of drug items that were perceived not to be genuine hardly solved medical problems intended for. Money seemed to be wasted on such drugs.

There was no evidence of the existence of any technology that the public could use to identify and report existence of counterfeit drug items: Majority of the respondents were not aware of any technology that they could use to identify and report the existence of genuine and counterfeit products in the Kenyan market.

The mobile application was beneficial for its intended purpose: From the usability testing 78% of the respondents indicated that the application was user friendly in that it was easy to learn and use. 75% of the respondents indicated that the applications functionality was commendable. In terms of aesthetics 84% of the respondents indicated that the application had an attractive presentation and finally 88% of the respondents found the application useful and acceptable.

5.5 Summary

Fundamental information used in the system implementation stage was provided by system requirements formulated in the requirements gathering and analysis stage. Research objectives and questions were also put into consideration in ensuring that the system was implemented to achieve user requirements provided by targeted users.

The overall project adhered to a majority of the proposed objectives. The research was completed in ample time for testing and getting feedback from the application. The mobile application was developed to run on the Android platform. The mobile application consisted of a QR-Code reader and an inbuilt system for information recording and display. The web based application was developed entirely for user management, data generation, data reporting and data manipulation.

System testing was done in three phases: *Functionality Testing;* was done to ensure user requirements were met, *Compatibility Testing;* was done to test the mobile application to the Android platform and the web based application to web browsers, *User Testing;* was done to test User Friendliness, Application Functionality, Interface Aesthetics and User Acceptance of the prototype.

CHAPTER 6: DISCUSSION OF RESULTS FROM THE TESTING

6.1 Introduction

The research was done with the aim of investigating current technologies that have been implemented to try and systematically identify and report counterfeit or uncertified drug items. An appropriate technology was therefore identified and developed from the research findings. The technology comprised of a mobile and web based application. The mobile application was strategically developed for use by the general populace who had access to a data enabled phone with a camera and running an android operating system. The web application was developed for management by administrators and could be accessed using a standalone computer, laptop or mobile device. This chapter describes research findings and achievements, how research objectives were obtained and provides a review of the application developed citing advantages and limitations of the developed application.

6.2 Findings and Achievements

Kenya has no systematic method of identifying and reporting suspected drug items. Drugs can be traced in the market after reports of having substandard value or observation, while others are encountered in the course of quality control. The literature review pointed out some of the techniques that have been used internationally and locally to help identify and report on uncertified or counterfeit drugs. The techniques include the use of technologies such as RFID, SMS and QR-Codes.

RFID application is a reliable technology in identifying and tracking items in large organization having enormous supply chain management systems. Considering the region of research, it would be too expensive a venture to follow. The RFID chips and readers are expensive when considering that each drug item needs to tagged with a unique RFID chip.

SMS application is an expensive and so far the predominantly used technology to check the legitimacy of drug items by the public in emerging markets such as Africa, the Middle East and Asia. Multinational drug companies such as GlaxoSmithKline and Bayer Pharmaceuticals own the biggest market share in the manufacture and distribution of drug items in such markets. This gives these companies the financial muscle to implement such systems with ease restricting implementation by local manufacturers. SMS based applications are also limiting in that they are restricted in interactivity with users.

The use of QR-Codes emerging as the next best technology to advertise and collect other information such as market behavior towards certain products in the market. With the availability of data enabled mobile

devices cheaply to the public, the use of QR-Codes will be the preferred technology for automatic identification and data capture. The technology proves to be simple, universal and affordable to use and implement.

The research was carried out outside a local supermarket in Nairobi County. The target population for this study were consumers who shopped at a local supermarket, QuickMatt supermarket located in Rwaka Township, Nairobi. A total of 25 respondents were interviewed daily for a span of 7 days. The total number of respondents interviewed were 175 individuals. The local supermarket was selected because of its strong presence within the area of research.

The findings indicated that majority of shoppers were aged 25-35 years with a number of 96 respondents. 36-45 years were 41. The group of 15-24 years were 22, and the group of 46-55 years were 27 and finally 56+ were 14. Additionally, females formed majority of shoppers with a total of 112 compared to 88 for men. Moreover, most of the shoppers were married persons and also who were employed. A high number of respondents with data enabled mobile devices were found to own devices that run on the Android Operating system. Lastly, majority of the shoppers were people with educational level above form four level.

The findings collected from the research led to the development of a mobile based solution used to identify and report existence of counterfeit or uncertified products by scanning QR-Codes attached to them. The registering body in this case was the Kenya Bureau of Standards. The technology comprised of a mobile and web based application. The mobile application was strategically developed for use by the general populace who had access to a data enabled phone with a camera and running an android operating system. The web application was developed for management by administrators and could be accessed using a standalone computer, laptop or mobile device.

Cumulative research findings indicated that a majority of the users found the application beneficial for its intended purpose. From the usability testing 78% of the respondents indicated that the application was user friendly in that it was easy to learn and use. 75% of the respondents indicated that the applications functionality was commendable. In terms of aesthetics 84% of the respondents indicated that the application had an attractive presentation and finally 88% of the respondents found the application useful and acceptable.

6.3 Review of Research Objectives in Relation to the Mobile Application

Research objectives acted as guidelines to developing the mobile and web application.

The first objective was to investigate the prevalence of counterfeit drug in Kenya and internationally. This was achieved by review of relevant literature from other countries on the effects of counterfeit drugs to the economy and population. The study showed that all countries experience the problems of dealing with counterfeit products. Governing bodies in countries play the leading role in regulating the importation, manufacture and distribution of such products to their population. Third world countries were most affected by infiltration of counterfeit products in their markets due to weak legislative laws. Governments in these regions were at task to ensuring that there was proper control of legitimate drugs within their borders. Locally it was identified that there was no systematic way of identifying counterfeit/registered drugs. Usually drugs would be traced in the market after reports of having substandard value, by observing the drug physical appearance, while others were encountered in the course of quality control. All in all the objective created a need to have a solution to alleviate the problem of dealing with counterfeit products.

The second objective which was to investigate current technologies used to track and report existence of genuine and counterfeit products in the market aided in giving the researcher an understanding of techniques that are already used in the market. Strengths and weaknesses were identified for each technique and the best was chosen for adoption. Techniques used included the use of SMS based applications and serial numbers attached to drug items, use of RFID tags attached to drug items and finally the use of QR-Codes attached to the drug items. Based on the literature review, the use of QR-Codes emerged as the most efficient, reliable and current technique for implementation of the solution to the problem.

The third objective was to develop a mobile based application that can give information on genuine products and flag counterfeit products in the market through the use of QR-Codes. This was achieved through the design and implementation of a mobile application with a web application for administrative management of products and user responsibilities. The mobile application was developed to run on the Android Operating system while the web application was developed using PHP and MySQL.

The final objective which was to test the effectiveness and efficiency of the developed mobile application was achieved by doing different kinds of tests. Functional testing was done to test how operable the system was, compatibility testing was done to ensure that the application performed at its optimum on a variety

of Android versions with the web application tested on a variety of web browsers. Usability testing was finally done which confirmed user friendliness, aesthetics, user acceptance and functionality.

6.4 Review of the Application in Relation to Current Drug identification Techniques

The prototype was designed to run on an Android Operating System device compatible with android devices with minimum version 2.0 and maximum version 4.4.4. The device running the application needed INTERNET connection and a working camera. Full functionality of the application required interaction with a QR-Code reader and a records management application.

QR-Codes attached to drug items are captured by the mobile phone camera. A QR-Code reader application was used to analyse and generate a QR-Code number stored in the items QR-Code. The QR-Code number then used as the unique identifier of a drug item. A unique QR-Code number was used to identify whether the item existed in the database or not. During an instance of scanning, the location of the device during a scan was be picked and stored in the database. Other information captured during a scan included; User information (if the user has logged into the application), time and date information.

SMS application is an expensive and so far the predominantly used technology to check the legitimacy of drug items by the public in emerging markets such as Africa, the Middle East and Asia. Due to their high cost implementation was biased to a few multinational companies. SMS based applications were also limiting in that they were quite restricted in interactivity with users.

6.4.1 Advantages of the Application

Some of the advantages of the application in relation to current ways of identifying legitimate and counterfeit drugs in the market included the following:

i) Information about legitimate drugs registered by a standardization body such as KEBS was easily accessible.
ii) The application offered accuracy of information captured and retrieved.
iii) The application was real-time.
iv) Reporting was instantaneous.
v) Users who have logged into the system have a view history of drugs they have scanned.

vi) More information can be acquired from the application such as market behavior on the use of different drugs by the population.

vii) The application incorporates a web application that can be used for data manipulation and data representation.

viii) Reporting is location based thereby giving insight into the origin of drugs purchased by the population.

6.4.2 Limitations of the Study

The study has offered an evaluative perspective on an important national development strategy in fighting against counterfeiting of products. This has been achieved technologically by development of a mobile and web based application that identifies and reports existence of counterfeit products in Nairobi County, Kenya. Although this research was carefully prepared, limitations were encountered that have been highlighted below.

i) The application was biased towards users with mobile devices running on the Android Operating system. This greatly limited responses to a few selected individuals from an already downscaled populace. ii) The application requires the use of only data enabled phones with an embedded camera. INTERNET availability is mandatory for the application to run. Respondents with feature phones that without INTERNET connectivity and lacking an embedded camera were automatically disqualified from the exercise. This negatively affected prospective worthy responses from the populace.

iii) The application is independent of the cost of printing QR-Codes. This entirely leaves the cost of printing QR-Codes at the hands of sellers of drug items. This could negatively affect the exercise if sellers become unwilling to print and attached QR-Codes to specific drug items due to extra costs in printing.

iv) It was assumed that feedback from respondents was genuine and not biased. The researcher did not consider the socio-economic level of respondents as a criteria for allowing an interviewee to participate in the interview session.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions of the research described in this dissertation. The aim and objectives of the dissertation, outlined in Chapter 1, are reviewed and their achievements addressed.

Proposals for future work indicated by the dissertation are suggested.

7.1 Conclusions

The study was set out to explore on the prevalence, use and effects of counterfeit or uncertified drug items to the population in emerging or third world markets. This was coupled up by development of a Data Driven Mobile Phone Solution for Systematically Identifying and Reporting non-Standardised Drugs in Nairobi County, Kenya. The study also sought to know whether developed mobile application would be efficient in solving the stated problem and would be accepted by the population of the research study. The general theoretical literature on this subject in the context of Kenya is conclusive on successful implementation and use of the developed application as a tool for identifying and reporting existence of counterfeit/uncertified drug items. It is however inconclusive in the implementation of certain laws that ensure local and international manufacturers register each distributed item under a government quality assurance body such as the KEBS.

The developed application was aimed at ensuring: easy verification of the authenticity of drug items in the market, improve accuracy in drug items information, creating a sense of responsibility to the populace and reviewing drug items purchased by users.

System testing was performed, look and feel, ease of use, system functionality and acceptance was done.

7.2 Recommendations

Below is a list of recommendations of the developed application to other stake-holders such as governmental and non-governmental organizations that may use the application. Some of these organisations include the Pharmacy and Poisons Board or KEBS, health facilities at national, county, sub-county and local levels.

i) The government should adjust policies on drug items that direct local and multinational companies to register with quality assurance bodies in the country. This should enable manufacturers and distributors of drug items to issue unique QR-Codes for each item they sell in the market.

7.3 Suggestions for Future Research

The weaknesses and limitations of the proposed solution in the research study have indicated the following areas as recommendations for further work.

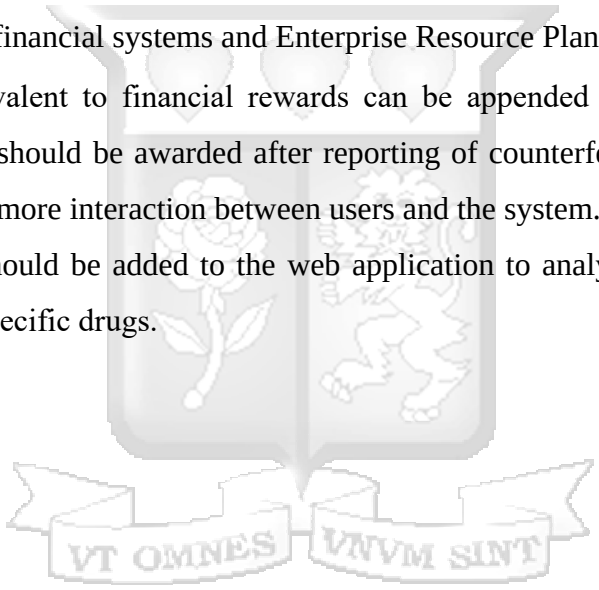
ii) The application should be developed to run on other platforms other than Android to incorporate users using phones running on different Operating Systems.

iii) The mobile application should be further developed to allow for persistent storage of data captured. This capability will make it possible for a user's mobile device to store data when there is no INTERNET connectivity. Data can then be transmitted to the server and response back to the mobile device immediately an INTERNET connection is established.

iv) There should be future research work done on how the mobile and web application can be integrated with other financial systems and Enterprise Resource Planning software.

v) Loyalty point's equivalent to financial rewards can be appended to the system upon use by consumers. Rewards should be awarded after reporting of counterfeit/uncertified items. This in effect will encourage more interaction between users and the system.

vi) More functionality should be added to the web application to analyse market behaviour of the population's use of specific drugs.



REFERENCE

Ahmed, P. I. (1985). *International Health Planning Methods.* Retrieved September 10, 2015, from International Health Planning Methods: http://pdf.usaid.gov/pdf_docs/PNAAH132.pdf

Akunyili, D. (2005, August 08). *Counterfeit drugs and Pharmacovigilance*. Retrieved March 16, 2015, from Counterfeit drugs and Pharmacovigilance: http://www.nafdacnigeria.org

Arnold , D. M., Burns, K. E., Adhikari, K. N., Khoe, E. M., Cook, D. J., & Meade, M. O. (2009). The Design and Interpretation of Pilot Trials. *Med*(1), 69-74. doi:10.1097/CCM

Beasley, D. M., Temple, W. A., Slaughter, R. J., & Schep, L. J. (2015, August 3). *Diethylene Glycol Poisoning.* Retrieved April 29, 2015, from Department of Preventive and Social Medicine, National Poisons Centre: http://www.ncbi.nlm.nih.gov/pubmed/19586352

Bell, D. (2004, February 16). *UML basics: The sequence diagram*. Retrieved July 17, 2015, from IBM Bluemix: http://www.ibm.com/developerworks/rational/library/3101.html

Burge, S. (2011). *The Systems Engineering Tool Box.* Retrieved August 04, 2015, from Context Diagram: http://www.burgehugheswalsh.co.uk/.../cd-tool

Business Daily Africa. (2013, April 24). *Politics and Policy.* (Xinhua, Ed.) Retrieved July 4, 2015, from Business Daily Africa: http://www.businessdailyafrica.com/Kenya-goes-digital-in-stemming-rising-fake-medicine//539546/1757018/-/4595eh/-/index.html

CA. (2015, January). *QUARTERLY SECTOR STATISTICS REPORT.* Nairobi: Communications Authority of Kenya. Retrieved from Communication Commission of Kenya: ca.go.ke/index.php/what-we-do/94-news/285kenya-s-mobile-penetration-hits-80-per-cent

Charlton, G. (2011, August 15). *The pros and cons of QR codes*. Retrieved August 23, 2015, from Econsultancy: https://econsultancy.com/blog/7884-the-pros-and-cons-of-qr-codes/

Ciuri, S. (2015, May 25). *Studies show counterfeit drugs hurt Kenyan lives, economy*. Retrieved from Business Daily: http://www.businessdailyafrica.com/-counterfeit-drugs-hurt-Kenyan-economy//1248928/2729206/-/64r3lc/-/index.html

College of Health Sciences. (2016, February 18). *Drug Analysis and Research Unit*. Retrieved from Department of Pharmaceutical Chemistry: http://pharmchem.uonbi.ac.ke/node/806

Collins, J. (2013, August 11). *Perfecting Just In Time Production*. Retrieved September 18, 2015, from RFID Journal: http://www.rfidjournal.com/articles/view?530

Counterfeit Medicine. (2015, June 8). Retrieved April 22, 2015, from U.S. Food and Drug Administration:

http://www.fda.gov/Drugs/ResourcesForYou/Consumers/BuyingUsingMedicineSafely/CounterfeitMedicine/

Database Schema. (2015). Retrieved September 18, 2015, from tutorials point: http://www.tutorialspoint.com/dbms/dbms_data_schemas.htm

Denso Wave. (2014). *About QR-Code*. Retrieved June 02, 2015, from About QR-Code: http://www.qrcode.com/en/

Diaz, V. (2015, August 3). *Fact Sheet Revised 2006, Counterfeit Medicines.* Retrieved May 05, 2015, from World Intellectual Property Organisation, Word Health Organisation: www.wipo.int/edocs/mdocs/enforcement/en/third_global_congress/third_global_congress_ref_z3.doc

Erwin , B. A. (2014). The Health and Economic Effects of Counterfeit Drugs. *Conference Correspondent, 7*(4), 218-219. Retrieved July 07, 2015, from http://www.ahdbonline.com/issues/2014/june-2014-vol-7-no-4/1756-the-health-and-economic-effects-of-counterfeit-drugs

Essential Medicines & Health Products – Counterfeit Medicines. (2015, March 15). Retrieved July 4, 2015, from World Health Organisation: http://www.who.int/medicines/services/counterfeit/impact/ImpactF_S/en/index1.html

Essential Medicines & Health Products. (2015, February 18). Retrieved June 25, 2015, from World Health Organisation: http://www.who.int/medicines/services/counterfeit/impact/ImpactF_S/en/index1.html

Generic versus Brand Medication. (2014, July 14). Retrieved from Health Smart: http://www.healthsmart.com/SmarterHealth/GenericVsBrandDrugs.aspx

Geo Tagged QR Codes. (2011, October 27). Retrieved August 25, 2015, from Geo Tagged QR Codes: https://qrd.by/geotags

Johnson, L. C. (2011, April 4). *Econsultancy*. Retrieved August 25, 2015, from Ten ways marketers can use QR Codes: https://econsultancy.com/blog/7368-ten-ways-marketers-can-use-qr-codes

KEBS. (2014). *PVoC Overview*. Retrieved August 20, 2015, from Kenya Bureau of Standards: http://www.kebs.org/index.php?opt=qai&view=pvocoverview

Kendall, K. E., & Kendall, J. E. (2013). Need for System Analysis and Design. In Kendall, *System Analysis and Design* (pp. 7-9). Prentice Hall.

Kenya Bureau of Standards. (2009). Focus on Standards. *KEBS fighter appointed to the Anti-Counterfeit Board(9)*, 10-13. (P. Kimanthi, Ed.) Retrieved September 06, 2015

Kevin, B., & Fenlon, W. (2007, November 05). *How RFID Works*. Retrieved September 12, 2015, from How Stuff Works: Electronics: http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/rfid3.htm

Kibwage, I. (2008). Counterfeiting of Drugs and the Necessity of Quality Control Systems in Developing Countries. *Interdisciplinary Courses on Development and Cultures, invitation of CADES*, (pp. 1-3). Katholieke Universiteit Leuven, Belgium.

Lapowsky, I. (2012, September 23). *At 28, Winning the War against Counterfeit Drugs*. Retrieved September 14, 2015, from 30 under 30: http://www.inc.com/30under30/issie-lapowsky/nathan-sigworth-founderpharmasecure.html

Larman, C. (2002). Applying UML and Patterns. In M. J., & O. J., *Applying UML and Patterns: An Introduction to Object-oriented Analysis and Design* (p. 128). Upper Saddle River: Prentice Hall.

Law, C.-y., & So, S. (2010). QR Codes in Education. *Journal of Education Technology Development and Exchange, 3*(1), 85 - 100. Retrieved October 08, 2015, from http://sicet.org/journals/jetde/jetde10/7-So.pdf

Laws of Kenya. (2012). *Standards Act.* Nairobi: National Council for Law Reporting.

Mackey, T. K., & Liang, B. A. (2011, June 22). The Global Counterfeit Drug Trade: Patient safety and public health risks. *Journal of Pharmaceutical Sciences, 100*(11), 112-115. doi:10.1002/jps.22679

Maitai, C. K., Kofi-Tsekpo, W. M., Wangia, C., Wakori, E., Mkoji, L., & Githiga, I. M. (1982). East African Medicine. *East African Medicine, 59*, 399. Retrieved August 09, 2015

Piasecki, D. (2012, December 16). *RFID Update: The Basics, The Wal-Mart Mandate, EPC, Privacy Concerns, and More*. Retrieved September 28, 2015, from Inventoryops.com: http://www.inventoryops.com/RFIDupdate.htm

Plank, J. S. (1997, September). A tutorial on Reed-Solomon Coding for Fault-Tolerance in RAID-like Systems. *Software Practice and Experience, 27*(9), 995-1012. Retrieved August 08, 2015, from http://web.eecs.utk.edu/~plank/plank/papers/SPE-9-97.html

RFID Journal. (2005, January 16). *The Basics of RFID Technology*. Retrieved May 27, 2015, from RFID Journal: http://www.rfidjournal.com/articles/view?1337

RFID vs Barcodes. (2012, April 16). Retrieved September 15, 2015, from Adaptalift: http://www.aalhysterforklifts.com.au/index.php/about/blogpost/rfid_vs_barcodes_advantages_and_disadvantages_comparison

Scrum. (2015, September 24). Retrieved September 06, 2015, from Mountain Goat Software: https://www.mountaingoatsoftware.com/agile/scrum

Scrum. (2015, September 24). Retrieved from Mountain Goat Software: https://www.mountaingoatsoftware.com/agile/scrum

Stechz. (2012). Retrieved June 15, 2015, from Stechz: http://www.stechz.com.hk/tech_2dbarcode.html

SurveyMonkey. (2015). *SurveyMonkey*. Retrieved September 06, 2015, from SurveyMonkey: https://www.surveymonkey.com/

Ukoh, A. (2015, February 25). *How Does Sproxil Create Value*. Retrieved August 07, 2015, from Sproxil: http://www.sproxil.com/blog/tag/anti-counterfeiting-measures/

Ullrich, J. (2011, August 03). *Malicious Images: What's a QR Code*, 1. Retrieved September 09, 2015, from Internet Storm Center: https://isc.sans.edu//diary/Malicious+Images+What+s+a+QR+Code/11305

UML 2 Case Diagrams: An Agile Introduction. (2014). Retrieved August 20, 2015, from Agile Modelling: http://www.agilemodeling.com/artifacts/useCaseDiagram.htm

Violino, B. (2004, March 01). *Farm Harvests RFID's Benefits*. Retrieved from RFID Journal: http://www.rfidjournal.com/articles/view?810

Violino, B. (2004, March 01). *Farm Harvests RFID's Benefits*. Retrieved August 26, 2015, from RFID Journal: http://www.rfidjournal.com/articles/view?810

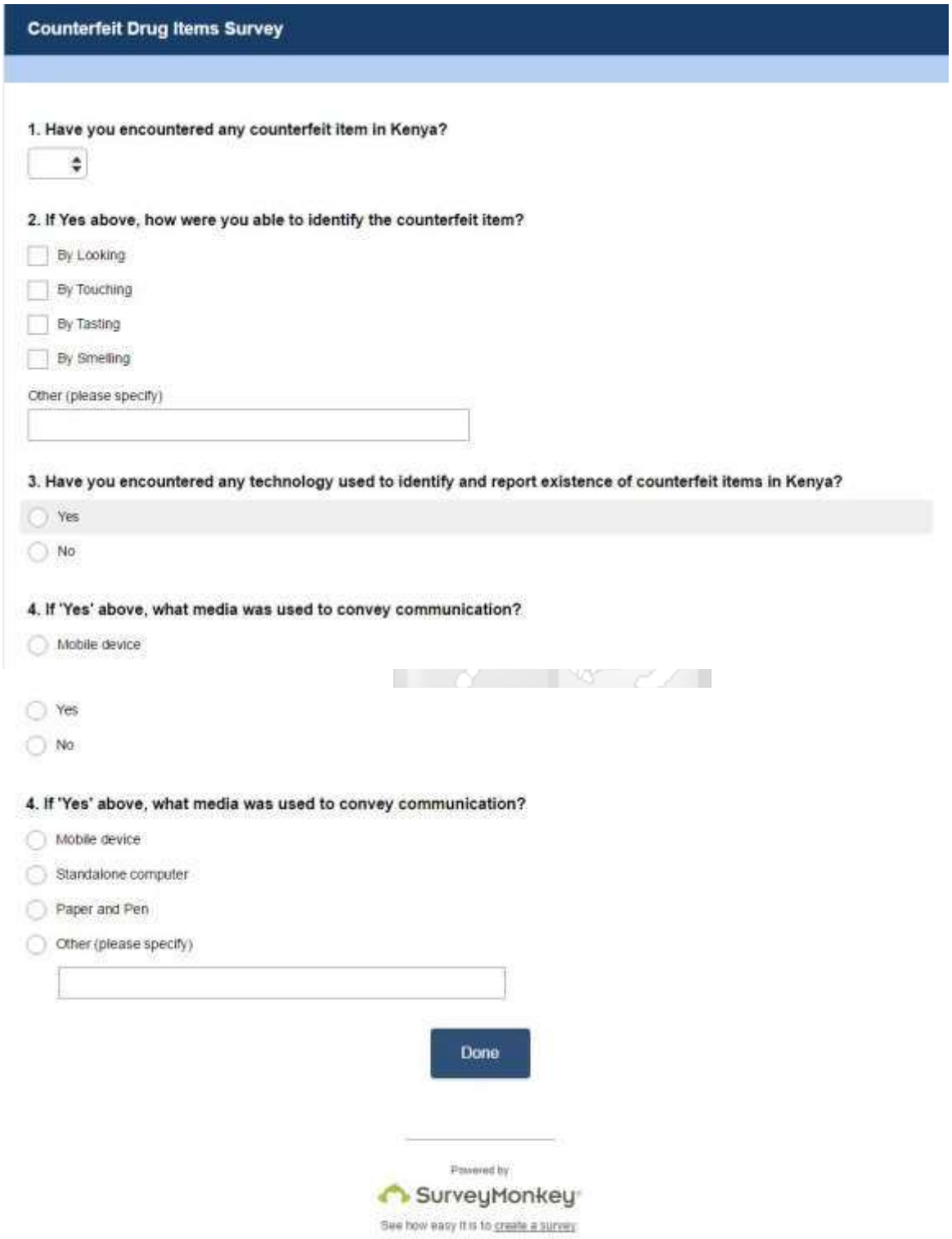
WHO. (2015). *Management of substance abuse*. Retrieved July 15, 2015, from World Health Organisation: http://who.int/substance_abuse/terminology/who_lexicon/en/

Xhiang, Z., Wang, H., Shen, J., Huang, J., Song, S., & Gao, X. (2004). *An approach to security and privacy of RFID system for supply chain.* Beijing: IEEE . doi:10.1109/CEC-EAST.2004.14

Yepoka, Y. (2015, July 3). *The African Startup Using Phones to Spot Counterfeit drugs*. Retrieved September 04, 2015, from Bloomberg Business: http://www.bloomberg.com/news/features/2015-07-03/the-africanstartup-using-phones-to-spot-counterfeit-drugs

APPENDICES

A: ONLINE PRE – SURVEY QUESTIONNAIRE



Counterfeit Drug Items Survey

1. Have you encountered any counterfeit item in Kenya?

2. If Yes above, how were you able to identify the counterfeit item?

- By Looking
- By Touching
- By Tasting
- By Smelling

Other (please specify)

3. Have you encountered any technology used to identify and report existence of counterfeit items in Kenya?

- Yes
- No

4. If 'Yes' above, what media was used to convey communication?

- Mobile device

- Yes
- No

4. If 'Yes' above, what media was used to convey communication?

- Mobile device
- Standalone computer
- Paper and Pen
- Other (please specify)

Done

Powered by SurveyMonkey

See how easy it is to create a survey

B: INTERVIEW QUESTIONS

1. What is your Age?
2. What is your Gender?
3. What is your marital status Marital Status?
4. What is your education level?
5. What is your employment status?
6. How long have you owned a mobile phone, in years?
7. How many SMSs do you send per day?
8. Do you use any data enabled (e.g. Check email, play online games, WhatsApp) services?
9. Your frequency of 3G/GPRS/WAP use?
10. What operating System does your phone run on?
11. How many Data enables application services do you use?
12. Your frequency of using individual data application services weekly?
13. The average amount of time you spend using Data application services per week?
14. Your frequency of INTERNET usage?
15. Your frequency of mobile shopping services use?
16. Do you use most of the advanced features on your mobile phone/device?
17. How does the simplicity of using a mobile device to scan over a QR-Code affect your decision to adopt its use?
18. How many steps would you be willing to follow in order to confirm whether a product that you want to verify is legit or compromised?
19. Would you still adopt a mobile device scanning procedure to verify legitimacy of products even if you had to pay a premium for every transaction?
20. Would the ease-of-use associated with the developed application influence your decision to adopt the solution?
21. Would the convenience associated with the developed application influence your decision to adopt the solution?
22. Would the efficiency associated with developed application influence your decision to adopt the solution?
23. What is your current position?
24. How long have you worked in this position?

25. Do you think scanning of products to verify their legitimacy has been successful in Kenya? **[Yes] [No]**

26. Have you ever heard of the term QR-Code? **[Yes] [No]**

27. Is there a need for scanning products using mobile devices to verify the legitimacy of products? **[Yes] [No]**

28. Do you feel that the attributes Convenience, Ease-of-use and efficiency have affected mobile service adoption in Kenya? **[Yes] [No]**

29. What trust and security concerns do you think might affect consumer adoption of data enabled services?

30. Do you think consumers would rather use a trusted mobile device application to verify the legitimacy of a product rather than an attached paper stickers from a recognized body? **[Yes] [No]**

31. Have you ever encountered a mobile or standalone application that can be used to help identify and report any counterfeit product in the market? **[Yes] [No]**

32. Have you ever used any mobile device application to help you identify and report counterfeit products in the market? **[Yes] [No]**

33. What is your confidence level on the legitimacy of products you purchase that have been tagged with the KEBS sticker?

- Very confident
- Slightly confident
- Not sure
- Don't care

C: AUTHORISATION LETTER TO CARRY OUT RESEARCH

@iLab Africa

excellence in research

Our Ref.: iLab/PP/15/73

16 July 2015

The Director
Kenya Bureau of Statistics
Nairobi

Dear Sir/Madam,

Re: Mark Misiko - 008046

This is to certify that Mark Misiko is currently a student of Strathmore University undertaking a Masters degree Course – Master of Science in Mobile Telecommunications and Innovation (MSc.MTI) in the Faculty of Information Technology.

Mark is in his final (2nd year) of study and is seeking for approval from you to collect data for his research project.

As part of his studies, he is required to undertake an information research project prior to completion of his master's degree.

Any assistance given to him will be highly appreciated.

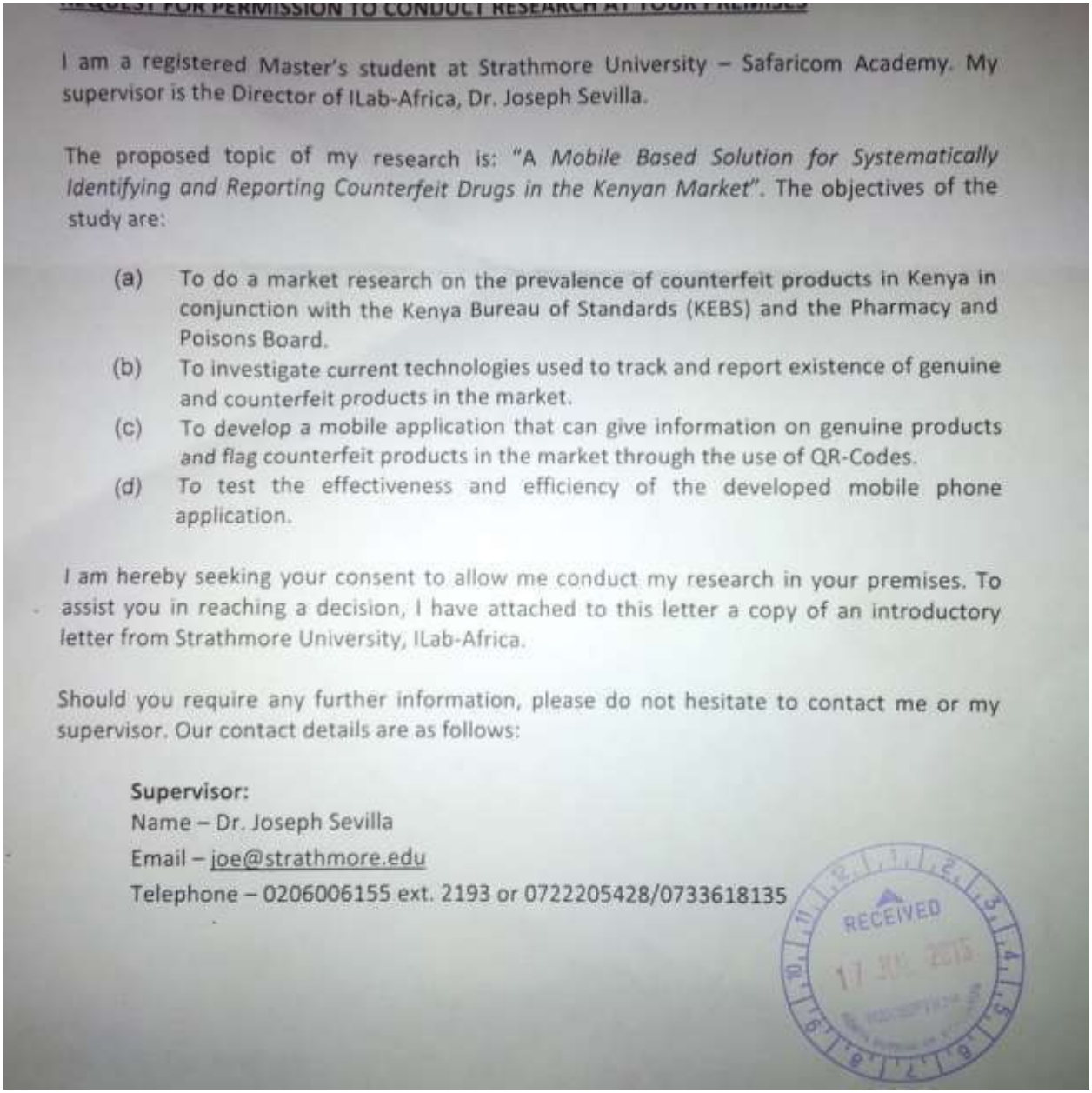
Please contact us in case of any further clarifications.

Yours faithfully,

STRATHMORE UNIVERSITY
@ILAB AFRICA
P.O. Box 59857
TEL: 0703 - 034000

Dr Everlyne Makhanu
Academic Director, @iLabAfrica
emakhanu@strathmore.edu

D: RECEIPT OF LETTER TO PERFORM RESEARCH AT KEBS



REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT YOUR PREMISES

I am a registered Master's student at Strathmore University – Safaricom Academy. My supervisor is the Director of ILab-Africa, Dr. Joseph Sevilla.

The proposed topic of my research is: "A *Mobile Based Solution for Systematically Identifying and Reporting Counterfeit Drugs in the Kenyan Market*". The objectives of the study are:

(a) To do a market research on the prevalence of counterfeit products in Kenya in conjunction with the Kenya Bureau of Standards (KEBS) and the Pharmacy and Poisons Board.
(b) To investigate current technologies used to track and report existence of genuine and counterfeit products in the market.
(c) To develop a mobile application that can give information on genuine products and flag counterfeit products in the market through the use of QR-Codes.
(d) To test the effectiveness and efficiency of the developed mobile phone application.

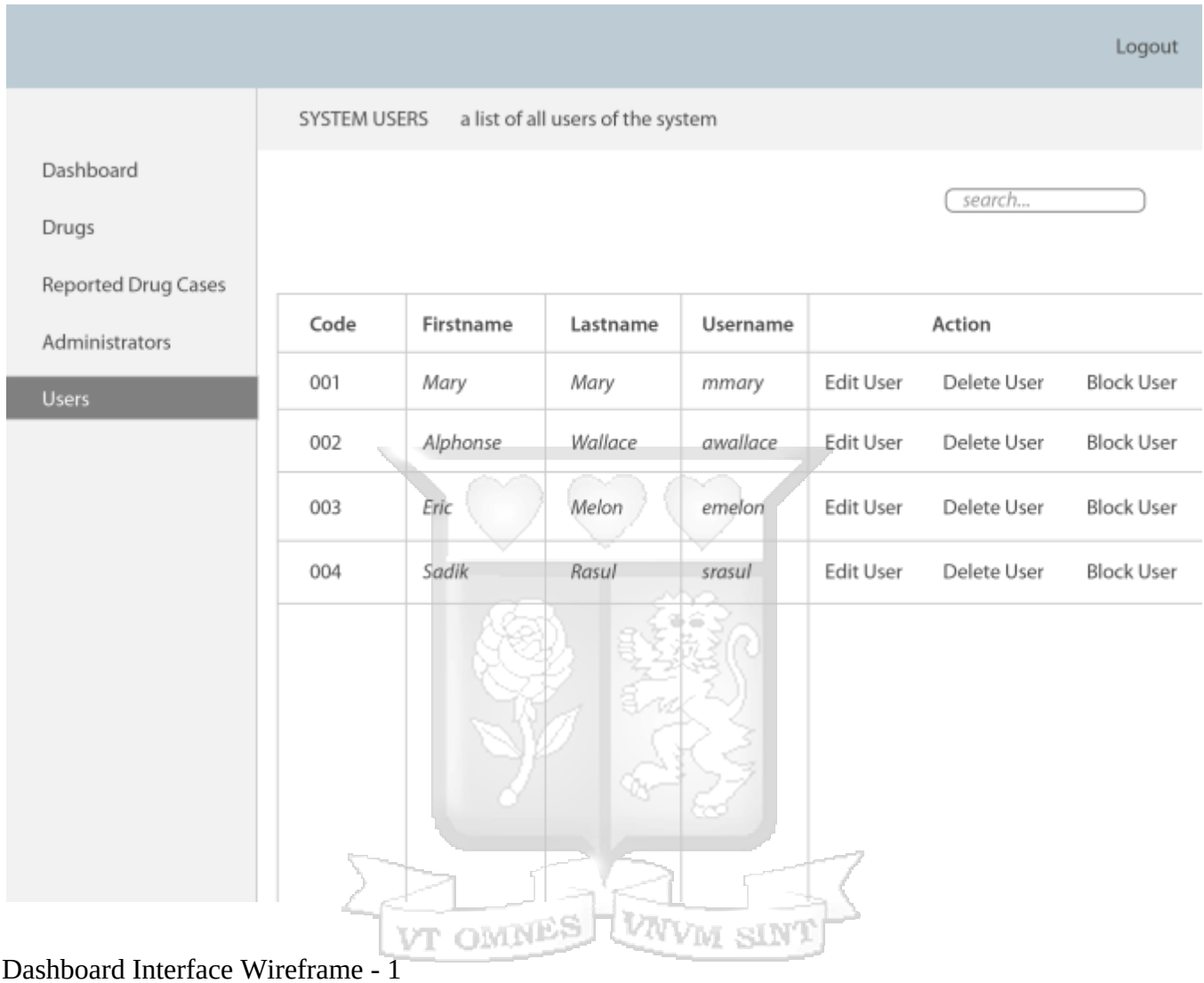
I am hereby seeking your consent to allow me conduct my research in your premises. To assist you in reaching a decision, I have attached to this letter a copy of an introductory letter from Strathmore University, ILab-Africa.

Should you require any further information, please do not hesitate to contact me or my supervisor. Our contact details are as follows:

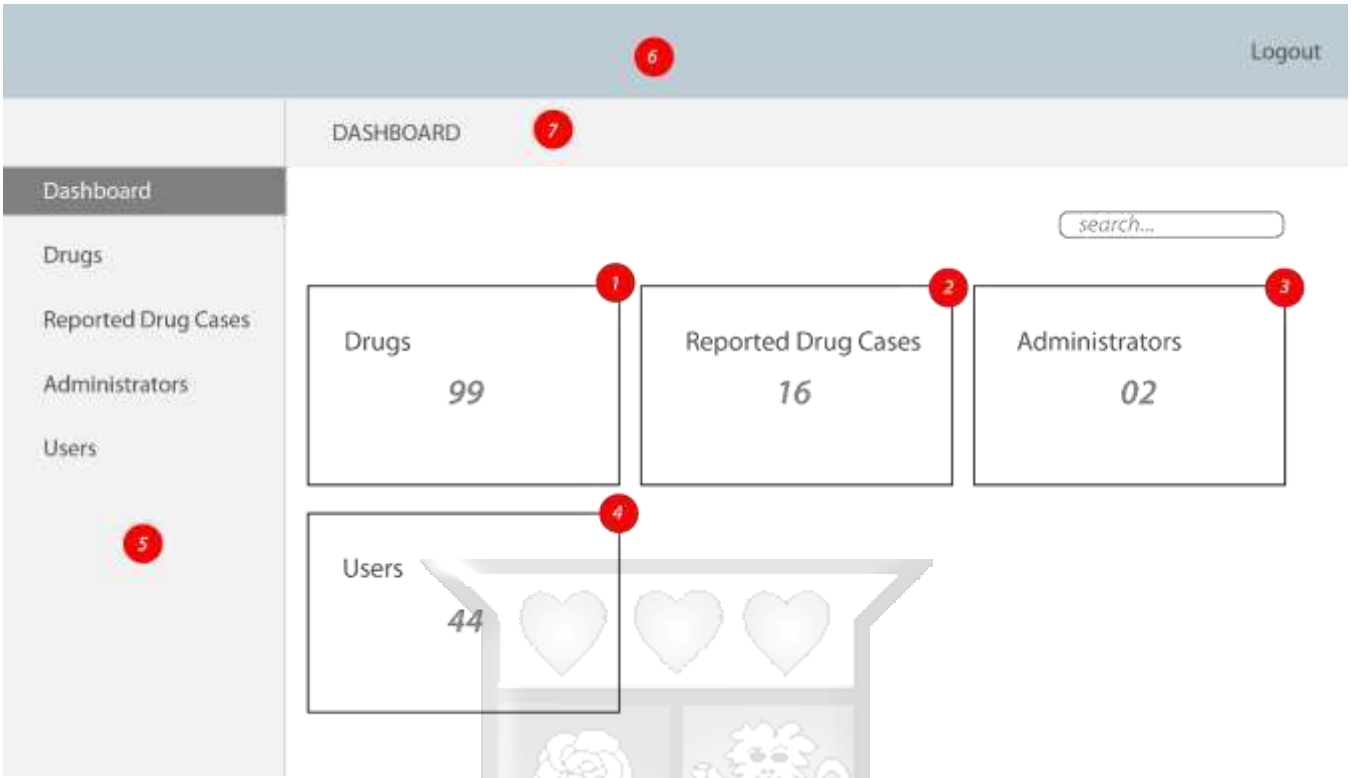
Supervisor:
Name – Dr. Joseph Sevilla
Email – joe@strathmore.edu
Telephone – 0206006155 ext. 2193 or 0722205428/0733618135

RECEIVED
17 JUL 2015

E: List of System Users Wireframe



Dashboard Interface Wireframe - 1



Dashboard Interface Wireframe - 2

1	A summary report on the number of drugs in the system server
2	A summary report on the number of reported drugs by users in the system server
3	A summary of the number of administrators in the system server
4	A summary of the number of users in the system server
5	A menu list of links to items in the system server
6	Top menu pane that allows a user to login and logout of the backend system
7	Title pane that shows a user the title of the current page. This is associated with the active link on the menu list

Wireframe of report on dashboard

F: BACKEND DATABASE AND TABLES

Database: pelelezi_dawa

Table Information

Name	Engine	Rows	Data Size	Index Size	Total Size
product	InnoDB	0	16 K	16 K	32 K
product_category	InnoDB	0	16 K	0	16 K
scan	InnoDB	0	16 K	16 K	32 K
scan_item	InnoDB	0	16 K	32 K	48 K
user	InnoDB	0	16 K	0	16 K

Database

Table: product

Column Information

	Field	Type	Comment
🔑	id	int(11)	
	product_category_id	int(11)	
	sku	varchar(200)	
	name	varchar(200)	
	price	int(11)	
	description	text	

Index Information

	Indexes	Columns	Index_Type
🔑	PRIMARY	id	Unique
	FK_product_category	product_category_id	

Product table

Table: product_category

Column Information

	Field	Type	Comment
🔑	id	int(11)	
	name	varchar(200)	
	parent_category_id	int(11)	

Index Information

	Indexes	Columns	Index_Type
🔑	PRIMARY	id	Unique

Product category table

Table: scan

Column Information

	Field	Type	Comment
🔑	id	int(11)	
	scan_no	int(11)	
	user_id	int(11)	
	scan_location	varchar(100)	

Index Information

	Indexes	Columns	Index_Type
🔑	PRIMARY	id	Unique
	FK_scan	user_id	

Scan item table

G: TURNITIN REPORT