2016

QR-based mobile payment application for Public Service Vehicles

Irungu, A. N.
Faculty of Information Technology (FIT)
Strathmore University

QR-Based Mobile Payment Application for Public Service Vehicles

Alex Ng'ang'a Irungu

Master of Science in Mobile Telecommunications and Innovation

2016

QR-Based Mobile Payment Application for Public Service Vehicles

Alex Ng'ang'a Irungu

Submitted in partial fulfillment of the requirements for the Degree of Masters of Science in Mobile Telecommunication 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 or a diploma 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.

Name: Alex Ng'ang'a Irungu

Signature: …………………..

Date: ………………………..

Approval

The dissertation of *Alex Ng'ang'a Irungu* was reviewed and approved by the following:

Dr. Humphrey Njogu
Faculty of Information Technology
Strathmore University

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

Professor Ruth Kiraka
Dean, School of Graduate Studies
Strathmore University

ACKNOWLEDGMENTS

I would like to express my gratitude to my supervisor Dr. Humphrey Njogu for his tireless support and guidance throughout the research process. I would also like to appreciate Mr. Martin Kabachia and Mr. Dominic Kanake for their invaluable assistance during the project work. In addition, thanks to my family and friends for their love and support during this period.

Finally, I would like to appreciate my classmates for their motivation to see me deliver a quality dissertation.

ABSTRACT

Transportation plays an imperative role in economic growth. Moreover, a well-organized transport sector is characterized by how people, goods and services are moved from one place to another in a speedily and efficient fashion. Nairobi provides a varied public transportation means of getting in and out of the city; some of these motorized transport means include buses, matatus, rick shaws, motor bikes, taxis, and limited commuter train.

About 10 percent of the revenue generated in public transport sector is lost. The income loss is attributable to staff theft, corrupt practices, inadequate bookkeeping procedures and other operational expenditures. Likewise, the commuters are exposed to risk of carrying cash, arbitrary hiked fares and delay. To reduce these exposures a cashless payment system needs to be adopted to improve efficiency and accountability in public transport sector.

A survey carried within PSVs in Nairobi to access the type of phones owned and mobile operating systems available indicated that: nearly 78% of the respondents own a smart phone. In addition, most respondents particularly the commuters were receptive to use of a mobile application to pay fare (87%) and Android platform was found to be common. Consequently, the study determines a suitable mobile solution that was developed using Water Fall Model, which is a simple implementation approach, requires minimal resources and its preferred where quality is paramount. A third party subjected the mobile solution to functional test which ascertained that various mobile functions worked as expected. The mobile application was also subject to rigorous quality assurance test which showed that software metric such as reliability, speed, scalability and accuracy were upheld. Results based on post-test indicated that there was a high user satisfaction on the solution on aspects such as usability and user experience.

The mobile application also known as “KommutePal” runs on a platform that takes advantage of the readily existing infrastructure and overcomes the challenges in cash payment method to improve accountability and reduce risks associated with the said system.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

3G	Third Generation cellular technology
3GPP	Third Generation Partner Project
APK	Android Application Package
CA	Communication Authority
CRUD	Create, Read, Update and Delete
DBMS	Database Management System
EDGE	Enhanced Data rates for GSM Evolution
EMV	Europay, MasterCard and Visa
ETSI	European Telecommunications Standard Institute
GDP	Gross Domestic Product
GPS	Global Positioning System
GSM	Global System for Mobile communication
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
IMSI	International Mobile Subscriber Identity
KBS	Kenya Bus Service
LTE	Long Term Evolution
ME	Mobile Equipment
MNOs	Mobile Network Operators
NFC	Near Field Communication
NTSA	National Transport and Safety Authority
POS	Point of Sale
PSVs	Public Service Vehicles
RFID	Near Field Communication
SACCO	Savings and Credit Cooperative Organisation
SIM	Subscriber Identity Module
WIFI	Wireless Fidelity

DEFINATIONS OF TERMS

Android Linux based mobile operating system developed by the technology company Google.

E-Payment Card It is an electronic payment card that is used by cardholder and acceptable to merchant for purchase payment or other in payment obligations.

Matatu It is a low-capacity public service vehicle which has a capacity to carry about 14 passengers.

QR Code Quick Response code is a 2-D barcode. The code is made up of black square dots on a white background that are arranged in square grid and can be read using a camera. Data is efficiently stored on the QR code through standardized encoding modes (alphanumeric, byte/binary, numeric, and kanji).

Stakeholder This refers to anyone i.e. a person, group or organisation that has interest or concerns in an organisation.

Synchronizing Refers to the process of uploading income earned data that is pooled from scanned electronic tickets as payment to a remote server. Thereafter these data is logged onto an appropriate account for reporting.

CHAPTER ONE: INTRODUCTION

1.1 Background

According to Zuidgeest (2005), transport system plays an important role by providing mobility and accessibility which has major impact in shaping countries. Consequently, he indicates that transport system will also influence the location of social and economic activity, the form and the size of cities, the style and pace of life through trade facilitation, allow access to people and resources and lastly, enable greater economies of scale, worldwide and throughout history. Further, transport is also a key ingredient in social-economic progress of a geographical area. It contributes to well-being of citizens by providing access to employment opportunities, security enhancement in isolated area, and jobs creation in the sector (World Bank, 2002). Kenya's public transport sector is worth 2 billion dollars (Nyasetia, 2013) which accounts to 5 per cent of the country's GDP (World Bank, 2014). It has created 300,000 jobs namely: fare collectors, drivers, bus stop attendant and many other positions (Leis & Baghudana, 2015). Accordingly, the role of the public transport segment to the economy cannot be underestimated.

The operation of Matatu as PSV provider can first be traced in the 1950s (Khayesi, 1999). In 1973, the Matatus were officially allowed to operate following a presidential decree (Ommeh, McCormick, Mitullah, Orero & Chitere, 2013) and compete with a formal bus company (Eric, Chavis, Li. & Daganzo, 2009). Graeff (2009) indicates, that the presidential order allowed matatus to operate without any licensing obligation. In addition, Graeff notes that, the main rationale behind the order was to increase and make mobility of people efficient and create jobs in the informal sector. Back then passengers used and even now settle commuter fee via cash. Further on, in the late nineties the KBS Company pioneered and introduced a commuter season ticket famously known as "Megarider". This was the first noble attempt to introduce a prepaid cashless commuter card.

Most PSVs operate using inappropriate and unreliable bookkeeping procedures for revenue collected; with an exception to a few companies namely KBS Company, Double M and Citi Hoppa that adopted paper tickets. Therefore, the lack of an apt accounting method has exposed the transport operators to losses and the passengers to varying fares. Khayesi (1999) alludes that, fares are normally adjusted without any formal notice. He further reveals that, the fare disparity is influenced by the time of the day, weather condition and prevailing transport demand. In an attempt to regularize public transport the Government issued an order to all PSVs to implement and operate a cashless payment system ("The National Transport and Safety Authority Act", 2012). The new traffic act has since been enforced but the industry players have been slow to take up the cashless payment systems. There are immense gains that come with implementation and adoption of a cashless system. Both the transport operator and the commuter will avoid the risk associated in carrying cash. Likewise, e-payment system will guarantee that the fares are generally standardized and hence allow commuters to plan.

The nature of business in public transport has similarities to a Check-out counter system in retail market stores. An individual picks an items and take it to the station which herein is referred to as a checkout counter/cashier stand ("What is Point of Sale (POS)?," n.d.). Similarly, a passenger pays for services rendered by remitting cash to the conductor. Specific POS can be deployed to facilitate the transaction process. A mobile application is well suited for the scenario highlighted herein.

1.2 Problem Statement

Public transport in towns and cities in Kenya faces a lot of challenges. Some of these challenges include: inadequate public transport system, increase in cost of transportation, pollution, prolonged travel time and long travel distance. In addition, the bulk of the PSVs operators in Nairobi accept hard cash for fare settlement and utilize unsuitable bookkeeping procedures to account for revenue collected. In view of that, the current system is open to abuse as there is no proper documentation to account for the income generated leading to revenue loss. Transport operators also incur expenditures associated with handling and securing hard cash. Equally, the commuters are exposed to varying fares, risks associated with carrying hard cash and delay in cases where the conductor has insufficient change.

1.3 Research Objectives

The main objective of the study is to examine and deliver a mobile payment application that will streamline public transport in Nairobi. The precise objectives of this study include:

i. To review the existing systems used to settle fare in PSVs.
ii. To design a mobile application that will help in payment and collection of fare, and track revenue collection in PSVs.
iii. To develop a mobile platform prototype to aid in transformation of PSV's operations.
iv. To test the mobile payment application.

1.4 Research Questions

The research questions of the study are:

i. What are the existing systems used to settle fare in PSVs?
ii. What are the design requirements for a mobile application that will be used in payment and collection of fare, and track revenue collection in PSVs?
iii. Do the stakeholders in public transport segment have mobile phones with the minimum features to support the functionalities in the proposed solution?
iv. How usable is the developed solution?

1.5 Assumptions

i. A mobile application will add value in PSVs.
ii. There exists an enabling environment to make use of the proposed mobile solution in the public transport sector.

1.6 Justification

The study suggests a secure mobile payment application that will facilitate speedy and efficient way through which passengers will settle fares in PSVs. The mobile application will safeguard the investor from revenue loss and provide audits of cash collected daily. Moreover, passengers will not be exposed to sudden fare hikes as they will only pay for stipulated fares and risk associated in carrying cash. Furthermore, the mobile payment application will make the experience of a commuter much better and also safeguard the interest of all public transport stakeholders and also streamline the operations of public transport sector. The interoperable mobile application will provide the ability to leverage on cashless payment systems that exist and provide integration to the same. These cashless payment systems range from mobile money services to card-based payment systems.

1.7 Scope Limitation

The research will be limited to Nairobi due to time constraints. In addition, the capital city has a well-established and a vibrant public transport sector that provides a varied transportation means to its residents. This mix provides a platform to carry out a well-informed research. Further, Nairobi County has been selected because it is convenient to the researcher.

1.8 Organization of Dissertation

The study consists of eight chapters. In chapter two, appropriate empirical literature is reviewed and literature overview is presented. Research design, selected software development methodology, sample size determination and sampling, data collection procedures and ethical measures are covered in chapter three. Chapter four covers the research findings and the discussion for the presented findings while chapter five covers the system architecture, architectural components of the system, data and process models for the proposed system, security and development. Chapter six presents detailed system implementation, functional test results, usability and user experience results, compatibility test results and system deployment. Chapter seven covers the discussions and key findings based on the objective questions for the study. Lastly, chapter eight highlights the summary, conclusion, and recommendations for further research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The intention of this literature review is to explore existing electronic payment solutions that have been adopted in public transport. Further, recommend suitable techniques to develop a QR based mobile solution that will handles electronic payments securely.

The chapter begins with an overview of public transport in Nairobi, reforms in public transport subsector and type of data required in public transport. Thereafter, the chapter highlights a detailed interrogation of QR Code technology.

2.2 Transportation in Nairobi

The Oxford Learner's Online Dictionaries (n.d) defines transportation as a system that is used to carry people or goods from one place to another by use of vehicles, roads, and further describes public transport as a system of buses, trains, etc. provided by either private companies or by the government and used by commuters to move from one place to another.

Omwenga (2011) indicates that, Nairobi is served by two key urban transport infrastructures these includes road and railway. Besides, he also states that, the local road network in the city is dense with integration to national and regional roads like Mombasa, Nakuru/Uganda, and Thika super highway. Rail is nearly nonexistent (Otieno, 2015) with commuter rail service limited to a number of areas in the city served by four different lines ("Commuter Train Service in Nairobi," 2011). Nevertheless, it is estimated that there are 80,000 matatu vehicles in Kenya where about 20,000 or more operate in Nairobi, hence underscoring the fact the public commuter fleet is composed of a substantial part of matatu vehicles (Khayesi, Muyia & Kemuma, 2015). Moreover, most paratransits are owned and managed by diverse groups which are organized into SACCOs (Mccormick, Mitullah, Chitere, Orero, & Ommeh, 2011) and private companies (Otieno, 2015). Furthermore, this kind of association allows some form of self-regulation in that matatus ply on allocated routes; crew wear uniform; fares are controlled based on time (Otieno, 2015). Conversely, the mode of transport to the city is diverse. Figure 2.1 summarizes how people commute in Nairobi.

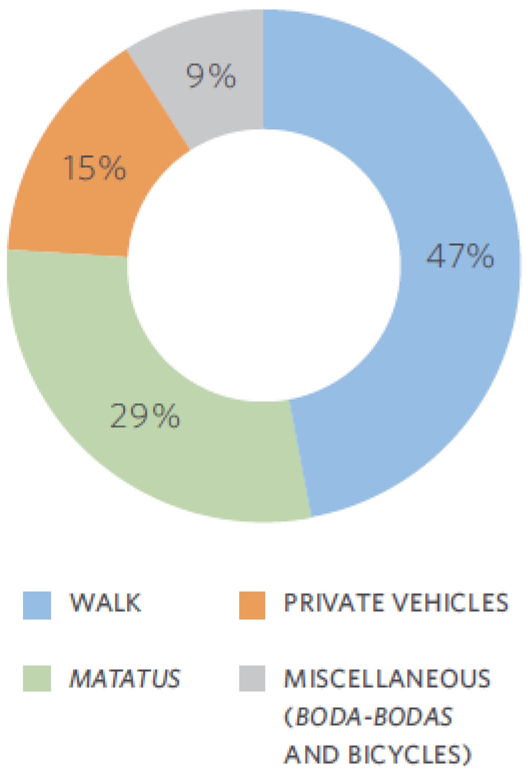


Figure 2.1 Modal Split in Nairobi
Source: Leis & Baghudana, 2015

Omwenga (2011) reveals that, Nairobi like several other cities in developing countries is grabbling with rapid population growth which is expanding at the rate of 4.5 per cent to 4.8 per cent every year. He further states that, this population growth is above that of both the developing countries whose annual growth stands at 3.4 per cent and the world urban population growth rate of 1.8 per cent annually. The projected population of Nairobi for years between 2000 and 2025 is summarized in table 2.1.

Table 2.1: Nairobi Population Projection

YEAR	2000	2010	2020	2025
POPULATION SIZE	2, 233, 000	3, 363, 000	4, 881, 000	5, 871, 000

Source: UNHABITAT

Omwenga (2011) alludes that, the spill effect of rapid population increase in Nairobi has led to rise in vehicle population and ownership; the ownership is skewed in favour of private vehicles compared to public transport. As a result, Omwenga suggests that, the high use of private cars has led to traffic congestion and increased cost of transport. In addition, the city of Nairobi is facing the following transport challenges:

1. Prolonged travel time and long commuter travel

Omwenga (2011) reveals that, the rapid expansion and spread of urban settlement in and around Nairobi has resulted in increased commuter distance. Additionally, he notes that, the commuter average distance which was 0.8km in 1970 has presently grown to 30-40km. Equally, travel time has become longer mainly because of long commuter distances and heavy traffic congestion (Omwenga, 2011).

2. Increase in cost of transport

Omwenga notes that, transport cost in Nairobi is relatively high compared to average per capita income where the average fare for 0-10km, 10-50km is Ksh 50 and Ksh 100 respectively at peak hours. He reveals that, public transport is costly in comparison to minimum employee wage which is about Ksh. 10,954 per month which translates to Ksh. 527 per day according to Kenya Gazette Supplement No. 91 (2015).

3. Pollution and urban environment degeneration

According to Omwenga, (2011), poor transport system in the city of Nairobi has led to both high level of air pollution and environmental degradation. He concurs with the statistics on air pollution in Nairobi which indicates that the average daytime concentration of fine particles range from 10.7µg/m3 at the edge of the city to 98.1µg/m3 on a central business district sidewalks accordingly the quality of urban health and environment has deteriorated

4. Inadequate public transport system

Public transport in Nairobi is inadequate to meet the ever raising demand this is evidently typified by public system that has long delays and heavy congestions (Omwenga, 2011).

2.3 Public Transport Policy Reforms in Kenya

Graeff (2009) notes that, for a long time public transport sector has operated in an environment where the relevant ministries and organizations are either corrupt or weak. Moreover, he suggests that, the industry can be described as structured chaos. The first transport reforms with fairly significant impact were spearheaded by the late John Michuki who was the transport minister in 2003. The Legal Notice No. 161 of October 2003 which amended the Traffic Act Cap 403 of the Laws of Kenya provides: seatbelts shall be fitted in all motor vehicle, speed governors shall be fitted in all PSVs and commercial vehicles that weight more than 3,048 kilograms, a continuous yellow band shall be painted on both sides and on the rear of all PSVs, the owners' names and the postal address will be indicated on the body of the vehicle, and lastly uniforms and a special identification budge will be worn by PSVs drivers and conductors (Asingo & Mitulla, 2007). "Who We Are" (n.d.) indicates, that in an attempt to further streamline public transport an Act of parliament was passed leading to establishment of NTSA; a government agency with the mandate to enforce transport safety policies and regulations already formulated. Likewise, NTSA is mandated to ensure that transport service is reliable, efficient and safe to commuters and as well as handle other functions within their mandate which are related to road transport and safety ("Who We Are," n.d.).

The National Transport Safety Authority Act (No.33 of 2012) Legal Notice No. 219, Section 7 (f), published on 17th December, 2013 by the Ministry of Transport and Infrastructure provide a directive to all public transport operators to ensure that commuters are issued with receipts for fare paid, and by 1st July, 2014 operate a cashless payment system ("The National Transport and Safety Authority Act," 2012). The order aims at facing out hard cash for payment of fares with an electronic cashless platform. As a result, different players consisting of banks, independent firms and telecos have rolled out different cashless solutions.

2.4 Data Required in Public Transport

Sengupta, (2015) asserts that, one of the primary requirements of humanity is mobility. At the same time, he suggests that mobility with a shared transport modality is without a doubt the best socially, economically and environmentally without forgetting that information is key to an effective means of public transport that is shared.

Transit data refers to spatial data, metadata and related attributes that can be utilized to largely illustrate elements used in public transport system. Each type of data that constitute transit data include: stops, interconnection, facilities, route, transport modes and many other (National Spatial Data Infrastructure Framework Data, n.d.). Transit data can be categorized based on the needs below:-

1. Service data for planning

According to Sengupta (2015), service data for planning consist of data on station, bus stop, route, timetable, fare chart and geographical alignment. He also notes that, this dataset provides information on transit service that can be gathered with ease to plan a journey.

2. Real-time data

The data consists of maintenance issues, route changes, arrival time estimates that is up-to-date, and last minute cancellations (Boyd, 2014).

3. Statistical and Operational data

Sengupta, (2015) article indicates that, operational data is made up of ticket data, resources like buses, depots, crews, workshops and operation infrastructure data etc. He notes that the digital method of managing these data is becoming a trend and also makes a good alternative to regularly publish them at an interval as these data is valuable for city planner to evaluate the city's commute trends and make knowledgeable decision. Accordingly, the infrastructure of the city can be planned to adjust it towards needs and demands of transit while transport agency will gain by exhibiting transparency and accountability (Sengupta, 2015).

2.5 Technology Advancement in Public Transport

Communication Authority of Kenya (2015) report shows that, mobile services uptake has continued to grow with mobile penetration standing at 88 per cent in September 2015. The report indicates that, during the same period mobile data subscription constituted 99 per cent of all the internet subscriptions. The upward trend in data and internet subscription is propelled by demand for internet services and considerably reduced cost of data enabled devices (Communication Authority of Kenya, 2015). Besides, a report titled "The growth of smartphone market in Kenya" published by an online retailer Jumia estimates that about 1.8 million smartphones were sold which constitute about 58 per cent of all unit sold (Zab, 2015). This represent a sale increase of 112 per cent compared to 3.6 per cent growth recorded in basic phone category (Sunday, 2015). Likewise, Safaricom the leading telecommunication company in Kenya had awhile back revealed that 67 per cent of all the mobile phones sold locally are smartphones and further, indicated that over a 100,000 new smartphones are shipped to customers monthly (Fripp, 2014).

There has been a notable advancement and use of technology in public transport to improve efficiency. According to Newcombe, (2015), smartphone applications have been incorporated to plan for trips and pay for fare. In addition, he suggests that, commuters will be able know the next bus arrival to their stop through the use of a phone, a tablet or a computer while other forms of automation which include GPS, mobile computing, social media and data analytics have opened new ways to improve services in public transport. Nevertheless, the increase in use of intelligent systems has streamlined and improved fare collection, routing and scheduling of transit services (Newcombe, 2015).

According to the economist Jeffery Sachs "cell phones are the most transformative technology for development" (Carmody, 2012). Therefore, this kind of advancement presents an opportunity to develop a solution that will address specific challenges in PSVs. Further, the availability of smartphones is an enabler to build a mobile application which rides on INTERNET access to transform lives.

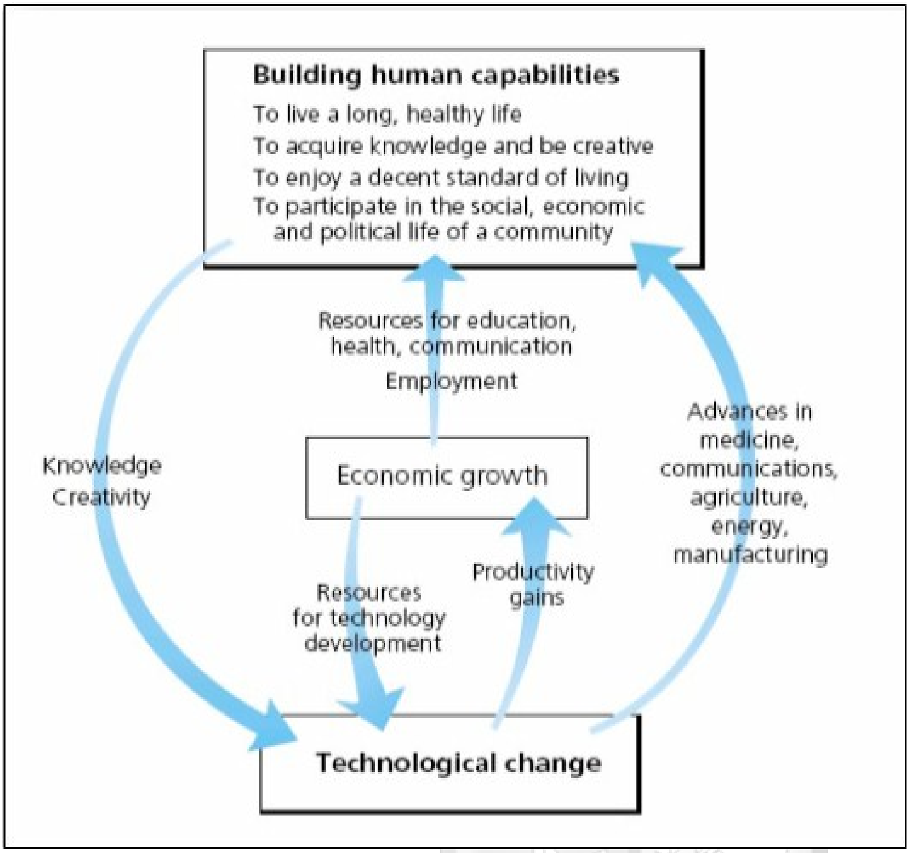


Figure 2.2 Link between Technology and Development
Source: Manica & Vescovi, 2009

There is a close relation between technology advancement and human development as depicted in Figure 2.2. Besides, in a research document titled "Mobile Telephony in Kenya … is it "Making the life better?" carried out by Manica and Vescovi (2009) explains that there is a direct link between technology innovation and human capabilities. They further allude that technology do present an opportunity to develop solutions that solve and make every-day life of a Kenyan easier. Similarly, new technology devices such as a smartphone device offers an environment through which a mobile solution can be developed to address process gaps in a business which then spins off the benefit to both the business and the user.

2.6 Cashless Systems in Public Transport

The study categorizes the cashless systems into two broad categories. The one unique feature that draws that distinction is a 2 dimensional matrix barcode hence the two classifications that includes: Non-QR Technology and QR Technology.

2.6.1 Non-QR Technology

There are several technologies that are already operational in public transport that use different techniques in provision of cashless systems. These technologies includes: RFID, NFC, EMV and SIM Tool kit.

2.6.1.1 RFID

According to tags Briseno et al. (2012), RFID is a communication technology that uses radio waves to both store and retrieve data from identification chips that are known as RFID. The technology is widely used in several applications for the industry that includes access control, security, supply chain tracking, and transportation (Briseno et al, 2012). Want (2006) states that, there are two classes of RFID devices namely active and passive where Active RFID tags needs to be powered while Passive RFID tags do not need batteries or maintenance and have indefinite operational life. He reveals that, there are two design approaches that transfer power from the reader to the tag: electromagnetic (EM) wave capture and magnetic induction. In Addition, the two designs utilize the EM properties that are related to an RF antenna (Want, 2006). Smiley (2014) explains that, inductive coupling is used in near-field antennas where magnetic field will energize the RFID tag while the RFID antenna is allowed to energize the tag when a magnetic field is created in a near-field region thus generating a disturbance in the magnetic field which is picked up by the reader to decode. Similarly, far-field antenna will use capacitive coupling which propagates RF energy from RFID reader's antenna where the same energy is used to energize the tag and a portion of the RF energy will be send to the reader's antenna as response by the tag (Smiley, 2014).

2.6.1.2 NFC

The NFC is a wireless short-wave high frequency communication technology that is designed to exchange data between devices which are about 10 centimeters apart (Briseno et al, 2012). An NFC device is unique in that it can either act as a NFC reader or a tag, this feature allows NFC devices peer-to-peer communication (Thrasher, 2013). In addition, both NFC and RFID technologies use the same working standard which makes NFC compatible with RFID (Briseno et al, 2012). NFC is considered secure in transmission of data because NFC devices have to be in close proximity of each other to communicate, at the same time NFC is founded on RFID standards and turns the drawbacks of its frequency into near-field communication's unique feature (Thrasher, 2013). Moreover, Briseno et al. (2012) states that an NFC device is able to read four basic types of tags based on ISO 14443 types A and B that corresponds to contactless smart cards and FeliCa smart cards. In addition, Briseno affirms that the NFC specification defines a common data format to exchange and store information using NFC devices and tags.

NFC technology is versatile as it offers a wide range of uses, thus with an NFC enabled phone an individual can do everything ranging from purchase of tickets, smart posters data translation, and other tasks from a single device (Wozniaki, n.d). Secondly, NFC technology is considered to be safe. Viswanathan, (2014) confirms that, the use of a mobile wallet to some extend is safer compared to use of a physical credit cards. In addition, he states that, the merchant will not have physical access to buyer's card information while using NFC payment system.

NFC technology has some drawbacks which potentially would impact its use. NFC works within a short distance which in itself is a security feature, however there are security concerns to possibly steal data from an NFC system from a greater distance (Simard, 2012). Such security fears would hamper both the users and companies from taking up this technology (Viswanathan, 2014). Another potential threat to NFC technology is malware or spyware interference. The man-in-the-middle attack poses a security concern; a hacker who gains access can transfer a malware or spyware onto the phone during an interaction with an NFC device which later would affect other devices that comes in contact with it (Simard, 2012). Lastly, the adaption of NFC may prove to be expensive to companies to buy and maintain related machines and equipment (Viswanathan, 2014). Majorly, the expenses stems from both software and hardware development which can be expensive ("Near Field Communication: Advantages and Disadvantages," 2012).

2.6.1.3 SIM

According to Gielen (2012), a SIM card is a special smart card that connects to and use GSM network. He further confirms that, a standardized SIM card has a unique subscriber number (IMSI), the authentication secret key, and other properties required for both network authentication and card owner identification. GSM divides the MS into a SIM card that hold network information related to a subscriber and ME, the phone's physical hardware that is common to each subscriber while the SIM Toolkit is largely one of the key features to be added on the SIM card alongside additional new functions (Gielen, 2012). Authentication take places when the mobile station is turned on and with each inbound call or outbound call (Van & Jorstad, 2005). Figure 2.3 shows the mobile phone with its components and functions.

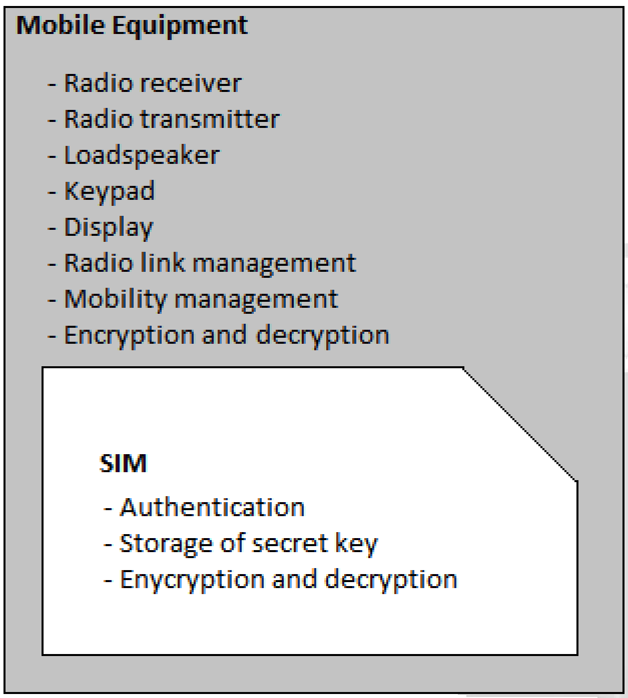


Figure 2.3: Mobile Phone with its Components and Functions
Source: Van & Jorstad, 2005

2.6.1.3.1 SIM Toolkit

The ISO/IEC 7816-3 specifies the protocol that defines the communication between the ME and the SIM (Van & Jorstad, 2005). "SIM Toolkit (STK)" (n.d.) states that, the SIM Toolkit is a GSM standard which consists of several proactive commands which are defined by ETSI and 3GPP standards for mobile equipment that can be activated through the actions of the user or network event. In addition, the "SIM Toolkit (STK)" explains that, standards allow integration of value addition and other functionalities onto a SIM card to provide mobile device with customized interface and menus from which users are able to access services provided by MNOs or other service providers via commands that enable the SIM card to initiate actions. The SIM

Toolkit which is modeled on client-server approach affords the means for the application to operate and interact with a compatible device while the operation of SIM Toolkit is phone independent ("SIM Toolkit (STK)," n.d.). The features of the SIM toolkit are classified into the following categories namely: man machine interface control, management of the accessory, communication services, management of the menu and control of the application and lastly miscellaneous (Van & Jorstad, 2005).

2.6.1.4 EMV

According to Puhe, Edelmann, and Reichenbach (2014) EMV is acronym for Europay, MasterCard and Visa and refers to Integrated Circuit Card specifications for Payment System (EMVCo, 2011). The main rationale behind EMV specification was to promote universal interoperability for chip based payment (Puhe et al., 2014). "The Migration to EMV Chip Technology," (2011) indicates that, the EMV is founded on strong symmetric and asymmetric cryptography approach and an intricate key management technique that makes it considerably more secure compared to magnetic cards. Transaction integrity is guaranteed by digitally signing payment data and use of dynamic data where each transaction carries a unique stamp to prevent reuse of data in cases where data is stolen from the database of either the processor or the merchant as alluded in the article titled "The Migration to EMV Chip Technology". Murdoch and Anderson, (2014) indicates that, an EMV transaction is made up of 3 stages; the first stage involves card authentication where the chip in the card confirms to the terminal that the card is valid while the next stage involves cardholder verification; the customer enters a PIN or signs for the transaction. Lastly, in transaction authorization as highlighted by Murdoch and Anderson, one or more message authentication codes will be generated by the card that will use symmetric key shared between the card and the issuing bank and will only be confirmed if the terminal is online.

2.6.2 QR Code Technology

According to "QR Code® Essentials" (2011), QR Code it is a matrix code that is two dimensional and belongs to a group of machine readable codes that are often referred to barcodes. Furthermore, Tarantola, (2012) reveals that, the QR Code was originally developed in

1994 by Denso Wave, which is a subsidiary of Toyota and the initial application of the QR Code was to track vehicles as they were assembled and facilitate high speed scanning of components. The QR is an acronym for "Quick Response" an indication to speed at which data they hold can be decoded using a scanner ("QR code, How to Get it," n.d.). Interestingly, Denso Wave the patent holder of this technology has allowed the QR Code to be used freely by everyone (Tarantola, 2012). Moreover, use of QR Code has overtime gained acceptance in varied industries some of these includes transportation, healthcare and manufacturing ("QR Code® Essentials," 2011). Besides, smart phones have been seen as a catalyst in accelerating use of QR Code (Gura, O'Shea, Reddy, & Sabatté, 2011) which has been instituted as an ISO standard and defined under ISO/IEC18004 specification (Briseno et al., 2012). Figure 2.4 depicts an image representation of a QR Code symbol.

Figure 2.4: QR Code Symbol
Source: Tarantola, 2012

Kieseberg et al. (n.d.) indicates that, the classical one dimensional barcode has overtime lost its popularity in some areas of application mainly because a QR Code is able to hold a maximum of 7,089 characters while a typical barcode can only hold a maximum of 20 digits. Further, a QR Code provides diversity and extendibility which lacks in a barcode accordingly this makes the use of the latter more appealing (Kieseberg et al., n.d.).

The process of encoding a QR Code involves the following steps.

i. Data analysis

Eby (2015) indicates that, text can be encoded in four modes which define the QR standard and these include alphanumeric, numeric, byte, and Kanji. Further, she states that, each of the modes will use appropriate method of converting the text to bits thereby ensuring encoded data is optimized with the shortest bit stream. Data analysis is the first step and should be performed to determine whether text can be encoded using the suitable QR standard and the most optimal mode is used (Eby, 2015).

ii. Data encoding

When a proper text encoding mode is selected, the next step is to encode the text which results in a string of bits that is divided into codewords that are 8 bits long data blocks (Eby, 2015).

iii. Error correction

According to Eby, (2015), this step involves use of Reed-Solomon error correction process to generate error correction codewords after a string of data bits has been created that represent an input text. She states that, a QR scanner will be used to read both the codewords and the error correction codewords which will be compared to ensure data is correctly read. “QR Code® Essentials” (2011) reveals that, there are four levels of error correction which are defined from the lowest level to the highest level as shown in figure 2.5. The greatest error correction is achieved when a higher level is selected resulting to a larger QR Code version as stated in “QR Code® Essentials”.

Error correction functionality	Level L	Approx. 7% of the symbol area restored at maximum
	Level M	Approx. 15% of the symbol area restored at maximum
	Level Q	Approx. 25% of the symbol area restored at maximum
	Level H	Approx. 30% of the symbol area restored at maximum

Figure 2.5: Error Correction Levels
Source: Soon, T.M., 2008

The environmental conditions and the size of the QR Code determine which level of error correction is selected (“QR Code® Essentials,” 2011). The error correction level of 15% is frequently used, however error correction of 7% is used in clean environment while error correction levels of 30% and 25% respectively are used in factories or places where the QR Code is likely to be damaged or become dirty (“QR Code® Essentials,” 2011).

iv. Structure final message

Eby (2015) explains that, at this stage data and error correction codewords spawned in the earlier step are properly re-arranged in the correct order. Further, she indicates that, for large QR both the data and error correction codewords are generated in blocks which are interleaved as per QR specification.

v. Module placement matrix

Eby (2015) reveals that, the codewords are arranged and specifically placed in a matrix. She states that, at this step patterns that are common to all QR Code for instance boxes on the three corners are also placed.

vi. Data masking

Eby (2015) indicates that, some patterns in the QR Code matrix can make it hard for a scanner to properly read the code. Accordingly, to counter this problem, Eby says that, the QR specification defines eight mask patterns that will alter the QR Code to a specific pattern which is then followed by the process to determine the results of these mask patterns in the QR Code with the least undesirable qualities based on four penalty rules. The final QR Code will use the matrix pattern with lowest penalty score (Eby, 2015).

vii. Format and version information

According to Eby (2015), both format and version information is added at the final step while the pixels are added in specific areas of the QR Code that are left blank. She indicates that, error correction level and mask pattern will be identified by format pixels while version pixels will be used in larger QR codes to encode the size of the QR matrix.

2.6.2.1 QR Code Structure

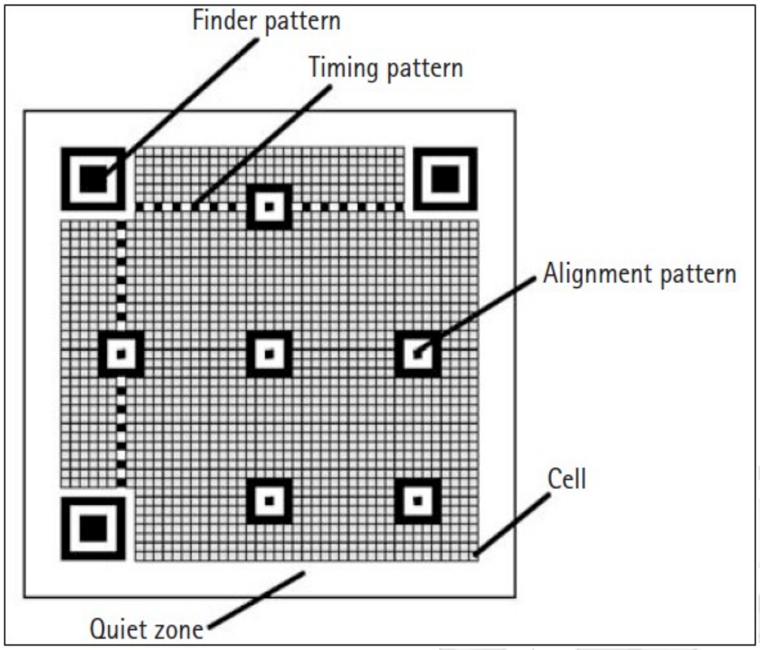


Figure 2.6: Structure of a QR Symbol
Source: Soon, T.M., 2008

Figure 2.6 above shows several elements that forms the QR Code symbol. Each element has a specific function in the QR Code as described:

a) Finder pattern

The position of a QR Code is detected using this pattern. Vanishree and Sunitha (2014) susgests that, by placing the finder pattern at the three corners of a symbol; the size, the position and the angle of the symbol can be detected. According to Vanishree and Sunitha, the finder pattern has a structure that can be detected in all directions.

b) Alignment pattern

Vanishree and Sunitha (2014) implies that, the alignment pattern is used for correcting the distortion of a QR Code hence it is particularly effective for correcting nonlinear distortion by identifying the central coordinate of alignment pattern to correct the distortion of the symbol.

Thus, Vanishree and Sunitha states that, for easier detection of the central coordinate a black isolated cell is placed in the alignment pattern.

c) Timing pattern

Vanishree and Sunitha (2014) indicate that, the timing pattern identifies central coordinate for each cell in a QR Code where black and white patterns are arranged interchangeably. They allude that, this pattern will be used for correction of central coordinate when the symbol is distorted or when the cell pitch has an error, and it is both vertically and horizontally arranged.

d) Quite zone

This is a margin space essential for reading a QR Code and more importantly the quite zone makes it effortless for the symbol read by the CCD sensor detectable from among other image (Vanishree & Sunitha, 2014).

e) Data area

Vanishree and Sunitha (2014) indicate that, the encoded QR Code data will be stored into the data area. According to Vanishree and Sunitha, these data is encoded into binary number of '1s' and '0s' that will be converted into well-arranged black and white cells and then incorporates both Reed-Solomon code for stored data and error correction function.

2.5.2.2 Benefits of QR Code

The QR Code offers numerous advantages and benefits these include:

1) High capacity encoding of data

A QR Code symbol is able to hold up to 7,089 numerals which about 200 times more than a conventional bar code ("QR Code® Essentials," 2011). Figure 2.7 illustrates this capability.

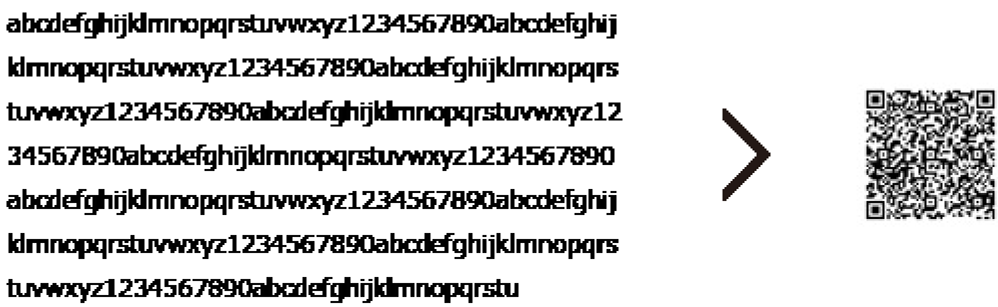


Figure 2.7: Symbol of this Size can Hold 300 Alphanumeric Characters
Source: "What is QR Code?," n.d.

2) Small printout size

In a QR Code information is held both horizontally and vertically as a result the QR Code is able to hold as much data contained in a 1-D barcode in a tenth the space ("QR Code® Essentials," 2011). Figure 2.8 below exemplifies this.

Figure 2.8: 1-D Barcode Fits in One Tenth the Space of a Symbol
Source: "What is QR Code?," n.d.

3) Several data types support

Different data types which include alphabetic characters, numerals, symbols, binary data, Japanese, and Chinese or Korean characters can be handled by the QR Code ("QR Code® Essentials," 2011). This is illustrated in figure 2.9.

Figure 2.9: Symbol Supports Different Data Types
Source: "What is QR Code?," n.d.

4) Damage and dirt resistance

The error correction capability enables the QR Code to restore data even when the QR Code symbol is damaged or partially dirty ("What is a QR Code?," n.d.) as shown in Figure 2.10. The QR Code symbol can be decoded even if when 30% of the same is damaged.

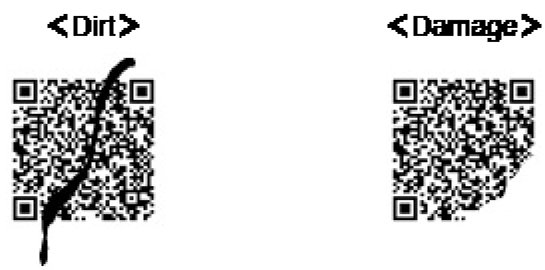


Figure 2.10: Dirty or Damaged Symbols
Source: "What is QR Code?," n.d.

5) Readable from any direction

"What is a QR Code?" (n.d.) indicates that, the QR Code is readable from any angle within 360 degrees; this is made possible by detection pattern located at the three corners of the symbol. Any background interference will be cancelled out by these position detection patterns thereby ensuring stable high speed reading as stated by “What is a QR Code?”. Figure 2.11 shows the position detection patterns for the said purpose.

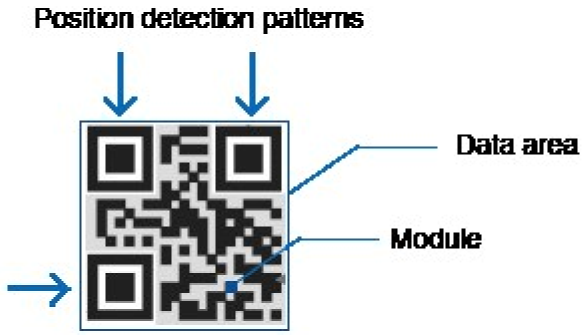


Figure 2.11: Position Detection Patterns in a Symbol
Source: “What is QR Code?,” n.d.

6) Linkability

The QR Code symbol can be split up to16 smaller symbols which can be placed in long narrow spaces which are then read as a single code from whichever order in they are scanned (QR Code® Essentials,” 2011). Figure 2.12 below illustrates this

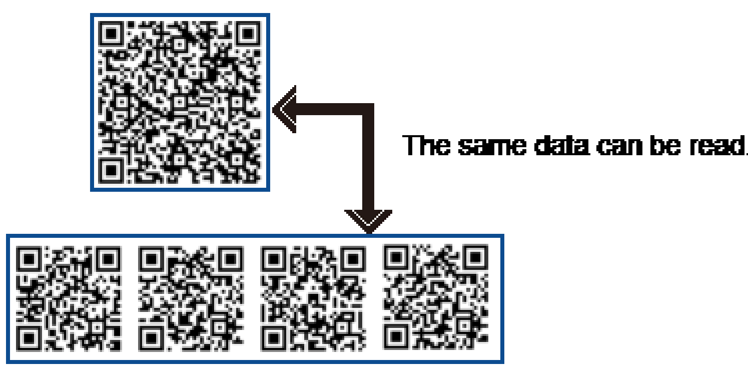


Figure 2.12: Linking the Symbols
Source: “What is QR Code?,” n.d.

2.7 Existing Systems

This section reviews several cashless systems that exists in the public transport domain and broadly categorise them into QR Based Systems and Non QR Based Systems.

2.7.1 Non QR Based Systems

Example of systems under this category include: Lipa na MPESA, KCB Pepea card, Co-operative Bank M-Nauli card, PesaPrint, My 1963 card, Tangaza PSV card, Abiria card, and BebaPay.

2.7.1.1 Lipa na MPESA

Lipa na MPESA is a mobile money service provided by Safaricom that allows business owners to accept payment for goods and services from their customers ("Lipa na M-PESA," n.d.). Customers are able to pay for goods and services via Lipa na M-PESA platform without being subjected to additional transaction fees (Tsiluma, n.d.). Likewise, payments of between kshs 10 to kshs 70,000 can be made by customers ("Lipa na M-PESA," n.d.). The Lipa na M-PESA has gained traction and has seen it adopted for payment of utilities bills, payment for shopping, and more recently payment within the transport industry ("Safaricom Introduces Lipa Na M-Pesa Service," 2013). There has been a sizable uptake of Lipa na M-PESA platform by transport players with registration of about 1,300 matatus and taxis (Mwaniki, 2014). Further, a commuter will be able to pay for fare through a till number provided and the funds collected can be withdrawn by the transport operator from the till to an M-PESA account (Sato, 2013).

2.7.1.2 KCB Pepea Card

Larbie (2014) indicates that, KCB Pepea Card is a prepaid commuter card and a product of KCB group. In addition, the cashless card doubles as a MasterCard debit card that is acceptable for payment of fare and other transactions. Secondly, the multi-purpose debit card incorporates NFC technology. Besides, the POS that supports KCB Pepea Card runs a standard digital device designed to read EMV ready card which offers interoperability to various cashless commuter cards thus making the Pepea platform unique compared to card-specific systems that are operational (Larbie, 2014).

2.7.1.3 Co-operative Bank M-Nauli Card

"Co-operative Bank Launches M-Nauli - It's Cashless System" (n.d.) states that, the Co-operative Bank of Kenya has launched a cashless commuter card dubbed "M-Nauli". The prepaid card incorporated NFC technology that allows a passenger to tap on an NFC enable device to pay for fare and be issued with a receipt. Interestingly, the card is fashioned like a tag that can be stuck conveniently on a phone, bag or a key holder (Wanzala, 2014). Moreover, the card is versatile and can be loaded with cash through Mobile Money Services, Co-operative's branches and Automated Teller Machines, and Co-operative's agents ("Co-operative Bank Launches M-Nauli - It's Cashless System," n.d.). The card contains a chip which permits "tap and go" technology and can work both online and offline hence avoiding delays (Herbling, 2014a).

2.7.1.4 PesaPrint

Kuria, (2014a) indicates that, PesaPrint the cashless platform developed by PesaPrint Limited operates multiple cards which include their own Metro Card, competitor's NFC-enabled cards such as Master PayPass or Visa PayWave, and payment by use of mobile money services such as Lipa Na M-PESA, Airtel Money, and Orange Money. Further, he states that, the integrated platform offers transport operators with extra features like route management which provide real time information on the location of a vehicle and pick up points. On the other hand, the platform also comes with a portable printer to print a paper receipt which contains the particulars of the vehicle route and registration number, the details of the payment card used and the supervisor's name (Mark, 2014).

2.7.1.5 My 1963 Card

According to Kihagi (2014) the collaborative effort between Fibre Space Limited, Matatu Owner's Association and Matatu Welfare Association has led to development of a cashless card named "My 1963". Moreover, the card is NFC ready and cash can be loaded on it via M-PESA (Akaki, 2014). Payment of fare has been simplified because commuters will only tap their cards against an installed terminal in PSVs (Kuria, 2014b). My 1963 cashless card affords a loan facility of an amount between kesh.50 to kesh.300 in the situation where a commuter who does not have enough fare while on the other hand every passenger earns a point for every kesh.10 spent on the card; the accumulated points are redeemable through promotions (Kihagi, 2014). "FAQ" (n.d.) shows that to register for the prepaid card a customer will be required to provide a national identification card, a mobile number and pay a minimum of 50 shillings for activation of an account once registered. "FAQ" indicates that, the prepaid card can be loaded with cash via agents or M-PESA platform at the same time customers will be able to check for the card balance through a USSD platform as well as through WhatsApp application.

2.7.1.6 Tangaza PSV Card

The prepaid card has been developed by Tangaza Pesa a local money service provider. Herbling (2014b) indicates that, the cashless platform is interoperable with authorized commuter cards from other providers. In addition, Herbling states that, passengers will settle their fares by tapping the card on a mobile phone or mPOS.

2.7.1.7 Abiria Card

According to Mwenesi (2014), the prepaid card was launched through the collaboration of KBS and KCB to facilitate cashless payment on commuter buses. Moreover, Mwenesi indicates that, the cashless card which is also a MasterCard and powered by TapToPay is acceptable for transit and payment of goods and other services in outlets that accepts MasterCard. "Abiria Card" (n.d.) indicates that, TapToPay is a Hong Kong based company providing an AFC solution to public transport operators through a partnership with local investors, a bank and a mobile service provider. As a result, the firm has picked Kenya Bus Service Management Limited to pilot the platform which allows the passenger to use NFC enabled cards by simply tapping the card once on to a validator installed in the bus to make payment as stated in "Abiria Card". To sign up for the card, an interested person presents an identification card and fills up a registration form after which the customer is required to load the card with a minimum of kshs.200 on receiving the card ("Abiria Card," n.d.).

2.7.1.8 BebaPay

"BebaPay: Launching Electronic Payments in Kenya" (n.d.) indicates that, Google and Equity bank teamed up to launch BebaPay, a cashless payment card that makes payment of commuter fare easy and convenient in public service vehicles. "BebaPay: Launching Electronic Payments in Kenya" reveals that, the prepaid card is powered by NFC technology, in addition to a software developed by Google. Furthermore, the cashless platform allows operators to use BebaPay application on their smart phones to accept payments from the BebaPay card holders after which an SMS receipts will be generated and send to commuters mobile phones hence making it easy to track usage and manage travel expenditures ("Equity Bank Partners with Google to Introduce a Cashless Solution," n.d.).

2.7.2 QR Based Systems

Examples of systems under this category include: Lufthansa Airline mobile boarding pass, TransGironde mobile ticket, and Edinburgh mobile ticket

2.7.2.1 Lufthansa Airline Mobile Boarding Pass

According to "The Mobile Boarding Pass - Check in On the Move and Save Time" (n.d.), the Lufthansa mobile application allow passengers to check in and reserve a seat upon which a mobile boarding pass is issued and then sent directly to the smartphone via email or SMS that contains the link to the pass. In addition, the mobile boarding pass resembles a QR Code ("Mobile Services of the Airline Company Lufthansa," 2013). After the boarding pass is received the management and use of the boarding pass can be done through the Lufthansa application, the android wallet for Samsung or the iOS wallet ("The Mobile Boarding Pass - Check in On the Move and Save Time," n.d.). The mobile boarding pass which contains the name of the passenger, flight number, take off and arrival time and confidential client information will be present for scanning ("Mobile Services of the Airline Company Lufthansa," 2013).

2.7.2.2 TransGironde Mobile Ticket

"TransGironde – Online reservation and QR Code tickets" (n.d.) article indicates, that the Gironde County Transport Authority implemented a system to book and purchase tickets via personal computer or mobile phone so as to handle an upsurge of visitors who were traveling to Gironde beaches during summer. According to "TransGironde – Online reservation and QR Code tickets" the ticket which is in the form of a QR Code can be printed or presented on the screen of a mobile device after which validation of the ticket is carried out by the driver while the passenger is boarding the vehicle.

2.7.2.3 Edinburgh Mobile Ticket

"Transport for Edinburgh Mobile Ticketing Terms & Conditions" (n.d.) indicates that, the m-ticket which is acceptable in both buses and trams is supported by Lothian Buses Limited and downloaded to a smartphone via Edinburgh m-ticket application. "Transport for Edinburgh Mobile Ticketing Terms & Conditions" states that, the ticket is bought in advance before travel and one needs data connection in order to make payment and download the ticket, though the purchased ticket can be used offline however periodic connection to the server is required by the m-ticket application for security purpose and a notification will be raised when required. "Transport for Edinburgh Mobile Ticketing Terms & Conditions" also specifies that, payment for the ticket can be made via VISA, MasterCard, and other credit cards and at the same time the ticket will automatically expire after the 180 days from the date of purchase. In addition, the m-ticket is locked to the ID of the purchasing smartphone and interestingly the said ticket can be sent to another user using a share ticket operation provided on the mobile application through Bluetooth, social media, email as highlighted in "Transport for Edinburgh Mobile Ticketing Terms & Conditions". The ticket will have to be activated prior to boarding and displayed on the smartphone screen and shown to the driver or tram ticket assistant ("Transport for Edinburgh Mobile Ticketing Terms & Conditions," n.d.). The activation of the ticket is done by scanning a QR Code situated at each tram stop thus an animated watermark is displayed on the ticket as prove the ticket has be authenticated (Boden, 2014).

2.8 Conclusion

NFC has been found to be secure because transmission of data happens within the close proximity of two communicating NFC devices. However, there are some setbacks that would impact its use. There has been security concerns to conceivably steal data from an NFC system even from a greater distance. On the other hand, it might prove to be costly for private bus companies and individual to take up NFC technology either through acquisition or maintenance of related machines and extra equipment. Majorly, most of the NFC-enabled cards rolled out in PSVs are locked to specific banks and do not provide interoperability to other payment services.

Thereafter, EMV is a standard for Integrated Circuit card for payment systems. The technology offers interoperability for chip based cards and it is more secure when it comes to securing data than magnetic strips. One downside of EMV technology is that it is expensive to purchase new terminal and POS systems. Moreover, EMV is vulnerable to fraud in case where the card credit number is stolen and used to buy items online. The PSVs investors will incur the huge cost of purchasing necessary equipment to make use of this technology.

RFID is well suited for large operation, and would somewhat be costly for small setup like an bus company that owns a small fleet of PSVs compared to technologies such as bar codes. In addition, RFID is dependent on RF strength which then means if the signal is weak then this would impact the use of an RFID devices. The technology has also been found to be susceptible to unauthorized reading of RFID devices.

Lastly, SIM Toolkit is considered secure and provides end to end encryption. The major benefit of STK is in form of identity identification and encryption. Nevertheless, STK can only be used in limited distribution environment as any STK changes would necessitate new SIM card to be issued. Furthermore, the use of STK is only appropriate where rich content and images is not an issue.

It can be seen therefore there are challenges in implementation of these cashless platform in PSVs. Majorly, cost has been a big obstacle especially to small investors in PSVs. On the other hand, lack of interoperability in most of the cashless systems has also made it hard for commuters warm up to the new system.

Consequently developing a cost-effective mobile solution will provide the best alternative to cash payment and also address the shortcomings of the non QR-based cashless platforms. Besides, the implementation of the mobile solution will not require acquisition of new software and hardware hence no extra cost will be incurred by the users. Lastly, the existence and application of QR-based system in other parts of the world confirms the credibility in use of QR Code technology to develop the proposed mobile solution.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is an orderly approach to solve a problem as well as a science of study on how research will be conducted (Rajasekar, Philominathan & Chinnathambi, 2013). This chapter provides an in-depth examination of steps, procedures and methodologies employed to design and develop the mobile solution.

The research questions highlighted below were the major guiding principle to developing the solution:

i. What are the design requirements for a mobile application that will be used in payment and collection of fare, and track revenue collection in PSVs?
ii. Do the stakeholders in public transport segment have mobile phones with the minimum features to support the functionalities in the proposed solution?

3.2 Research Design

The research design uses naturalistic techniques and survey to examine the present PSVs fare collection systems. Moreover, using transversal approach, data from the conductor, the passenger and the PSVs owner was collected.

It is estimated that about 10 per cent of the income generated in public transport is lost majorly due to cash pilferage and insufficient book keeping methods. Paying for fare using hard cash is popular and widely used method compared to the newly introduced cashless systems. Accordingly, this exposes both the PSV owners and the passengers to risk of carrying cash. More importantly the aim of this chapter is to design a comprehensive mobile solution that can be in used to address the highlighted operational challenges in PSVs. The mobile solution will provide a platform through which passengers will effortlessly buy tickets and settle commuter fees. In addition, the PSV owners will be provided with daily collection audit report while the conductors will have a tool to validate tickets and collect fare.

Overall, the waterfall model will guide the design, implementation and testing the proposed mobile solution. The architecture developed should be able to meet the expectations and needs of the PSVs owner, the passenger and the conductor.

3.3 Software Development Methodology

The study uses waterfall software engineering framework to structure, organization, and control the procedure to develop the proposed mobile solution. The model has been selected because of the following reasons:

i. Usability: By use of waterfall approach users' needs are well looked into.
ii. Reduce cost: Both the logical and physical system design is separated when using the waterfall approach. This means the development of system do not need to implement new hardware and software.
iii. Timelines: Allows good planning and management of the project.

Figure 3.1 illustrates a waterfall design model and each basic steps its covers in each phase. The waterfall model's framework is considered to be linear. This dissertation is divided into phases that are sequential where overlap and splash back between some phases is acceptable.

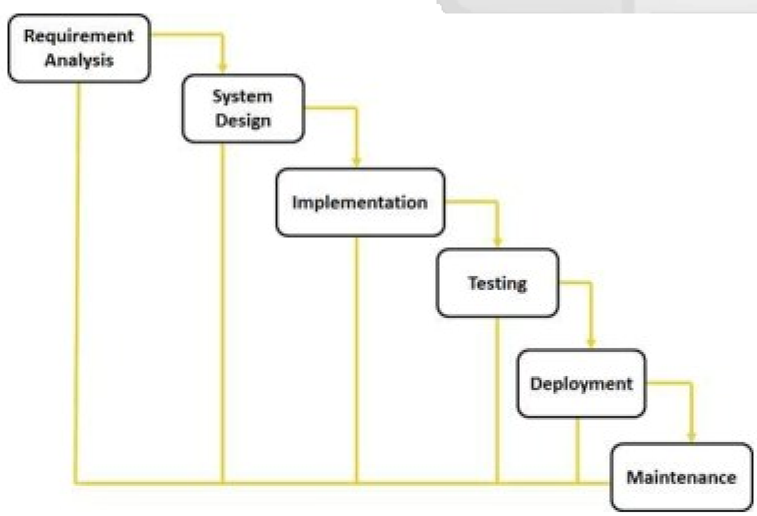


Figure 3.1: Waterfall Model

Tight control is upheld throughout the life of the project via use of broad written documentation, through official reviews and approval/signoff by the user and information technology management that occurs at close of most phases before commencing the next phase (Kawabata & Kasah, 2007, p.56). However, there are intrinsic bottlenecks in using the waterfall model as compared to other framework such as inconsistencies in requirements, missing system components, little room for iteration, and unexpected development needs that are mostly discovered during design and coding.

3.3.1 Requirements Analysis

The preliminary phase was meant to highlight the environment of the target audience, needs and capacity important for the proposed solution to be developed.

The researcher administered a questionnaire (Appendix A) to guarantee that it produces the preferred results essential for development of the mobile platform. The questionnaires provided sufficient quantitative data needed to understands challenges, user perceptions and current user's environment. These requirements were gathered from three sets of questionnaires that were given to each group namely: the PSV owner, the passenger and the conductor.

3.3.2 System Design

In system design phase the researcher studied the requirement specifications from the first phase and system design was prepared. During this phase the researcher also identified all the inputs, processes and outputs needed. Two design approach were considered. Firstly, during the logical design the researcher designed the database, the interfaces, the forms and the reports. Secondly, in physical design approach the researcher selected appropriate specifications for both hardware and software which helped to define the system architecture.

3.3.3 Implementation

The implementation of the mobile solution commenced in the third phase of the waterfall model where the construction of the new system and delivery of the same into production was executed. The researcher carried out the actual writing of the code based on the designs from the previous phase. Code was broken into small module rather than coding the whole solution. These small modules are were integrated in the next phase and subjected to unit testing.

3.3.4 Testing

The fourth phase was software testing. The researcher used a third party who conducted a functionality and usability test on the developed mobile solution. In addition, the post-test survey was carried out to ensure the following objectives were met:

i. To test the vital functionalities of the mobile solution.
ii. To measure the ease of use of the mobile solution.
iii. To measure acceptance rates of the mobile solution.

3.4 Target Population

It is estimated that there are about 20,000 PSVs that operates daily (McGregor & Malingha, 2015) in the city of Nairobi. At the same time, the number of commuters that enters or leaves the city daily is about 2.6 million (Kiarie, 2015).

3.5 Sample Size Determination

Taro Yamane (1967) recommended an easy formula to calculate the sample sizes; a confidence level of 95% and P = 0.5, would be calculated using the formula below (Israel, n.d.).

Formula: $$n = \frac{N}{1+Ne^2}$$ Yamane (1967)

Where:

n – The sample size

e^2 – The acceptable sampling error

N – The population size

Further, by substituting in the formula above where **N** = 2,640,000 with a precision level **e** = 10%. The sample size was estimated to be **n** = **100**.

Assumption: *Each vehicle is assigned 1 driver and 1 conductor has hence the total number of personnel that works in the PSVs is 20,000 x 2 = 40,000*

3.5.1 Sampling

Based on the sample size determined using the Yamane formula in Figure 3.1. Purposive sampling was used to select 2 matatu routes (Lopha Traveler Sacco 11c route-Pangani and Lopha Traveler 11b route-Ruaka) in Nairobi as representative sample. This sampling technique was opted for due to researcher's familiarity with the routes. Stratified sampling involving 26 passengers per route making a total of 52 passenger respondents was used. These passengers were randomly selected and given a questionnaire each to complete. Stratified sampling involving 12 PSV owners per route making a total of 24 PSV owner respondents was used. The PSV owners were randomly selected and given a questionnaire each to complete. Lastly, stratified sampling involving 10 conductors per route making a total of 20 conductor respondents was used. The conductors were randomly selected and given a questionnaire each to complete. The total number of respondents used was 100.

3.6 Data Collection Procedures

The questionnaires were administered personally by the author to the participants in each group who were identified and were willing to take part in the survey. The filled questionnaires for both the PSV owners and the passengers were collected at a later date while the questionnaire given to the conductors was collected immediately after engaging the participant.

3.7 Data Analysis

The study combined both quantitative and qualitative data. Statistical Package for Social Sciences (SPSS) was used to check, code and analyze the collected data. The data was then summarized and presented in Microsoft Excel suite. Charts were used to present the visual findings.

3.8 Validity and Reliability

The study will safeguard that the results obtained can be replicated in other trials. The solution was meticulously developed to closely replicate a real application that PSVs would want to adopt. In addition, the developed application will assist to understand and validate the conclusion that will be made later in study. It is hoped that the result findings will help answer the research questions

3.9 Ethical Measures

The process undertaken in the study ensured that all measures were taken to protect intellectual property that might be stumbled upon, avoid harm to participants by getting consent before administering the questionnaires. The privacy and confidentiality of data was maintained and protected when conducting the study. Lastly, no personal data was collected to protect the respondents.

CHAPTER FOUR: DATA ANALYSIS AND INTERPRETATION

4.1 Introduction

The analysis of data collected from sample population of 52 passengers, 24 PSV owners, and 20 conductors picked from two matatus routes in Nairobi namely: Lopha Traveler Sacco 11c route-Pangani and Lopha Traveler 11b route-Ruaka is handled in this chapter. The purpose of this analysis is to explore the level of readiness in PSVs to accept and use mobile application technology in order to develop a cashless payment system. Varied variables will be carefully selected in an attempt to answer the research questions that had been set.

4.2 Survey Information

30 out of the 52 sampled passengers who received the questionnaires returned their survey, 12 out of 20 sampled conductors who received the survey questionnaires returned their survey, and lastly, 16 out of 24 sampled PSV owners who received the survey questionnaires returned their survey. Thus a total of 58 respondents returned their surveys.

4.2.1 Respondent Composition

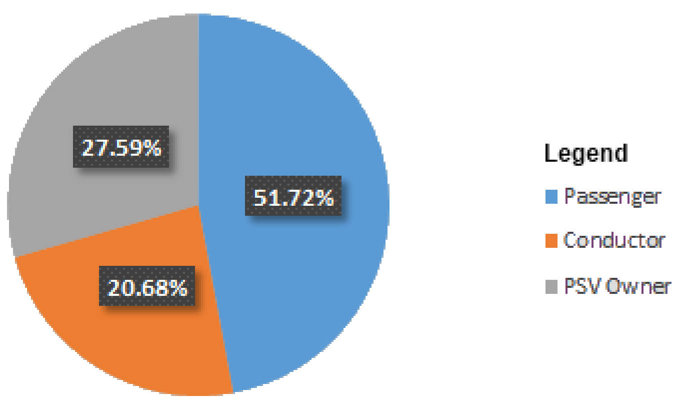


Figure 4.1: Respondent Categories

Figure 4.1 above shows the distribution of respondents that took part in the survey. 51.72 percent of the respondents were passengers, 27.59 percent were PSV owners and lastly, 20.68 percent were conductors.

4.2.2 Challenges of Using Hard Cash

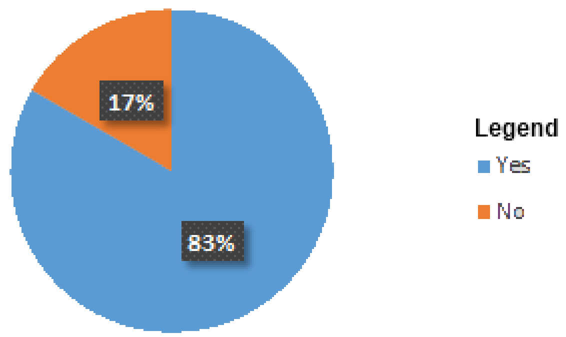


Figure 4.2: Challenges of Using Hard Cash

Figure 4.2 above illustrates that 83 percent of all the respondents that were surveyed confirmed to have had challenges with cash payment in PSVs. A partly 17 percent did not experienced any problems with cash payment method.

4.2.3 Familiarity with Cashless Systems

Figure 4.3 shows that a majority of the respondents i.e. 89 % had knowledge to existence of cashless systems while 11 % of the respondents surveyed were not familiar with to the same.

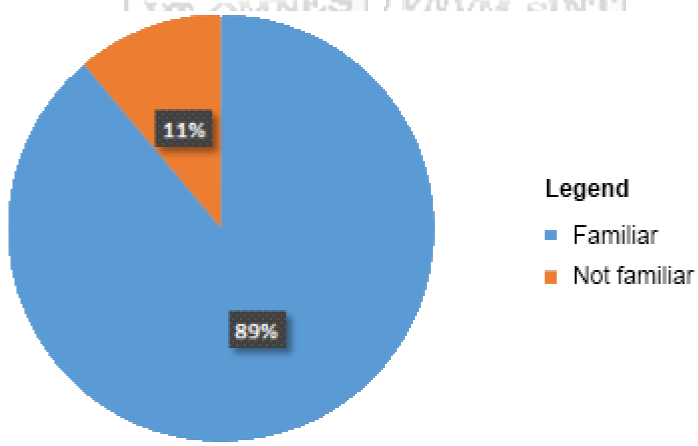


Figure 4.3: Familiarity with Cashless Systems

4.2.4 Cashless Systems to Streamline PSV Operations

There is a firm agreement that the cashless systems will streamline PSVs' operations. 44 percent of the respondents agree to use of cashless systems to streamline operations in PSVs while 17 percent also strongly agree with the same. 28 percent and 5 percent of those surveyed strongly disagree and disagree to application of cashless systems to streamline operations in PSVs respectively. 6 percent of the respondents remained neutral on the subject question. Figure 4.4 demonstrates this.

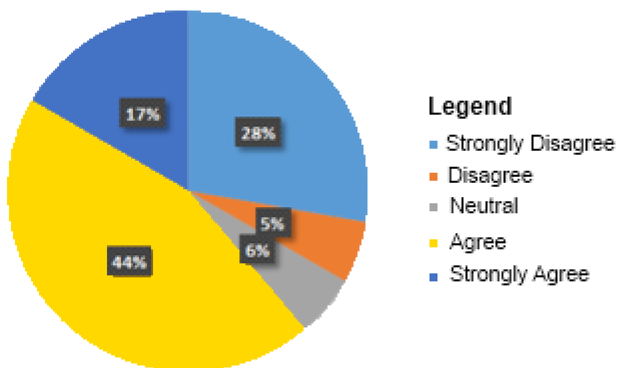


Figure 4.4: Cashless Systems to Streamline PSV Operations

4.2.5 Types of Mobile Phones Owned

Figure 4.5 below shows the type of phone owned by the respondents surveyed. 78 percent of those surveyed owned smartphones while the remaining 22 percent surveyed own basic phones.

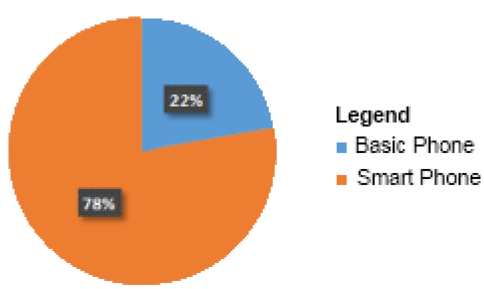


Figure 4.5: Type of Mobile Phone Owned

4.2.6 Distribution Spread of Mobile Operating System

Figure 4.6 illustrates the mobile operating system spread according to the respondents surveyed. 72 % of the respondents own Android smart phones while 6 % and 5 % own Symbian and iOS smart phones respectively. Lastly, 17 % of the respondents owned phones that had other operating systems.

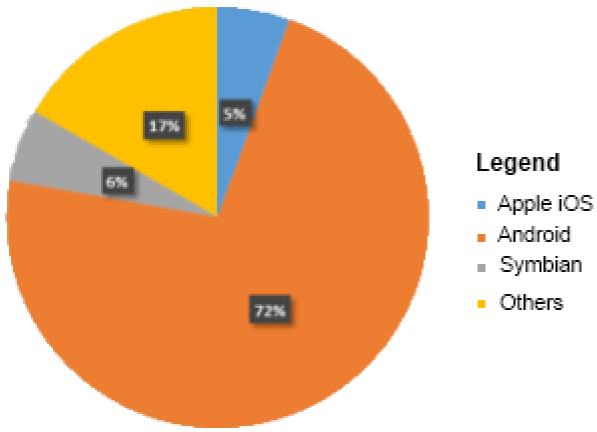


Figure 4.6: Distribution Spread of Mobile Operating System

4.2.7 Support the Use of a Mobile Application for Payment of Fare

Figure 4.7 illustrates that 87 % of the commuters would support the use of a mobile application to pay for fare. 13 % of the commuters did not support payment of fare via a mobile application.

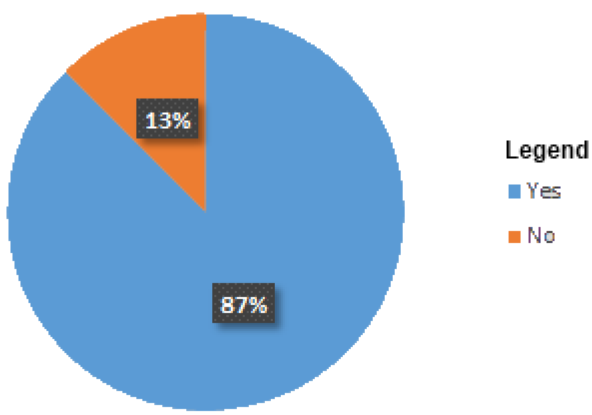


Figure 4.7: Support the Use of a Mobile Application to Pay for Fare

4.2.8 Support the Use of a Mobile Application to Collect Fare

Figure 4.8 illustrates that 80 percent of the conductors surveyed would not support the use of a mobile application for the purpose of collecting fare. Only 20 percent of the conductors surveyed supported the application of a mobile application to collect fare.

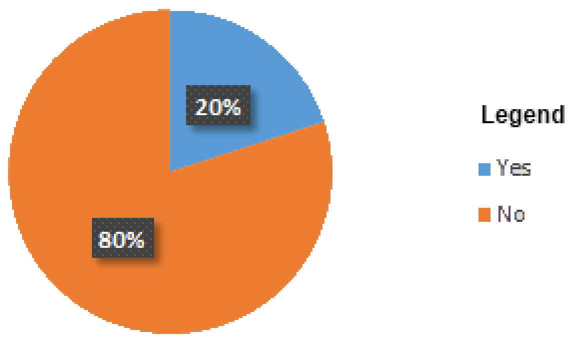


Figure 4.8: Support the Use of a Mobile Application to Collect Fare

4.2.9 Support the Use of a Mobile Application to Track Revenue Collection

The figure 4.9 below shows that 80 percent of the PSV owners surveyed supported the use of a mobile application to track income earned while 20 percent of the PSV owners do not support the use of a mobile application for the purpose of tracking collected revenue.

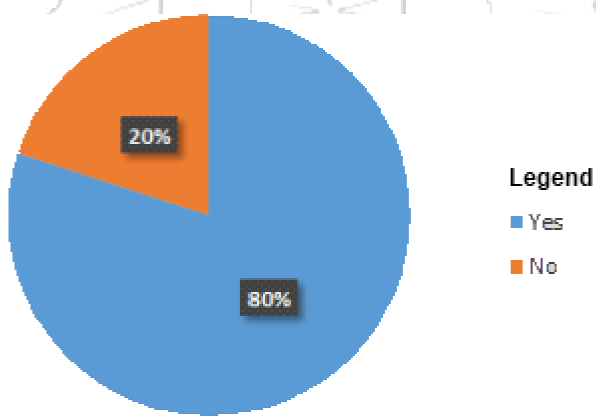


Figure 4.9: Support the Use of a Mobile Application to Track Revenue Collection

4.2.10 Problem with the Cash System

Most of the respondents surveyed confirmed to have experienced problems with use of hard cash in PSVs. Figure 4.10 shows that 65% of the respondents experienced delay in getting their change while 23% of the respondent surveyed did not get their change back. In addition, 10% of the respondents lost their cash through theft while a mere 2% attributed their problems to other factors.

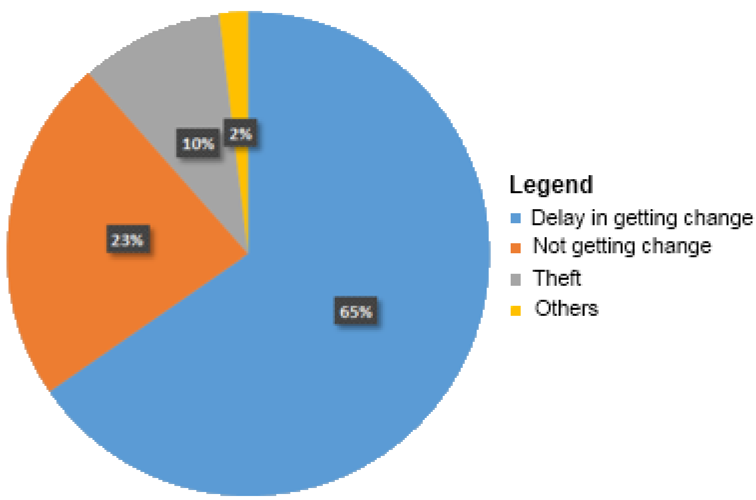


Figure 4.10: Problem with Cash Payment Method

4.3 Interpretation of Results

This chapter has presented the following key findings that are essential to the users:

i. Challenges of handling cash.
ii. Phone capabilities.

Challenges of Handling Cash

From the findings of the data analysis, it is quite evident that most of the respondents had in one way or another experienced challenges in use of hard cash. This therefore meant that a mobile solution was a feasible environment to suitably provide a cashless means to electronically pay for fare. Firstly, it would aid the commuters to avert risks associated with carrying hard cash and also delays in getting change. Secondly, the PSV owners would be able to track revenue collection and also reduce the overheads incurred while securing the hard cash. Thirdly, the mobile solution would assist the conductors to conveniently collect fare and also account for revenue collected.

Phone Capabilities

From the findings, the figure presented on the ownership of smart phones by the various stakeholders i.e. the passenger, the conductor and the PSV owner offers sureness for the appropriateness of the project in relation to the objectives set out by the researcher. Normally, dissemination of visual information such as reports in chart format, images i.e. for this case the QR Code image and graphical charts tend to be a difficult task to accomplish with a basic phone hence this limits what can be dispersed. Nevertheless, the result of the study has shown that a large number of the smart phone ownership among the stakeholders in Nairobi's public transport sector. Smart phones are loaded with better capabilities such as INTERNET access, allows installation of third party applications, greater memory, large screen, camera and other key features. Further, these capabilities would fit well in dissemination of purchased electronic tickets, presentation of graphical reports, and collection of fare by scanning the electronic tickets by means of a phone camera.

4.4 Discussion

From the result findings summarized in the graphical charts presented in this chapter there is a significant approval to use a cell phone through a mobile application for the purpose of paying fare. Most of the respondents surveyed owned an Android smart phone which presents a ready platform to develop the proposed mobile solution. Moreover, there is a small category of the respondents that own smart phones with other operating systems hence this group should also be targeted for inclusivity. On the other hand a good number of the PSV owners are in agreement that the proposed mobile solution would provide means to track income. Most of the passengers surveyed confirmed to have experienced challenges in use of hard cash while a substantial number of the conductors did not welcome the implementation and use of the proposed mobile solution. For a successful adoption of cashless systems, all the public transport stakeholders need to be sensitised about the benefits of taking up the said platforms. Moreover, incentives and support could extended by the government to the PSVs investors who take up the cashless platforms to encourage them push their use.

4.5 Summary

The findings gathered from the questionnaires provided a strong indication that indeed there was need for a solution that would streamline the PSVs operations. Most of the respondents welcomed the proposal of a mobile application that would be used for payment of fare, collection of fare and tracking of income.

Based on the findings, the following important design requirements become clear:

i. Most users have had an Android smart phone.
ii. Most users are using smart phone which are already internet enabled.
iii. Most users had smart phone that would thus support visual information such as charts, electronic ticket and scanning tickets.
iv. There was a need for mobile solution that would facilitate cashless transaction among the stakeholders in PSVs.

Most of the respondents were already familiar with cashless platforms in PSVs and they felt they would need an alternative cashless means through the use of a mobile application to pay for fare and for this they endorsed the need for a mobile solution.

CHAPTER FIVE: SYSTEM DESIGN

5.1 Proposed System

The mobile solution referred to as "KommutePal" is proposed to streamline the operations in PSVs. The solution will allow the passengers to settle fare via a smartphone; enable the conductors to validate and collect fare by scanning an electronic ticket presented on the commuter's mobile phone; lastly, provide the PSV owners with daily revenue collection breakdown.

5.2 System Architecture

The architecture for the mobile solution has been designed to accommodate several stakeholders namely: the passengers, the PSV owners, and the conductors. Furthermore, the system architecture has been design using the client-server approach. The client-server model breaks up workload between the service providers i.e. the hosting server, and requesters of the service i.e. the client. Both the passenger and the conductor will utilize a mobile device installed with the mobile application to communicate with the core system via the telecommunication network. Similarly, the PSV owner will access the resources the on the same server either via a browser on a mobile device or a personal computer. Figure 5.1 below illustrates the "KommutePal" system architecture.

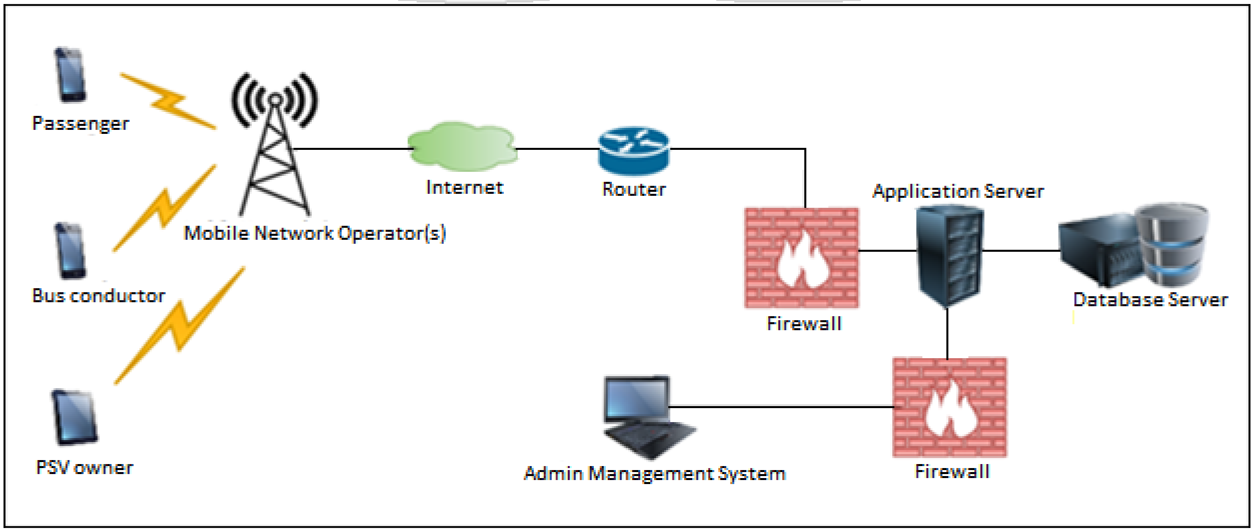


Figure 5.1: System Architecture

The communication between the users and the application server is through INTERNET. The application server handles the following roles namely: process and storage of information into the database server, and retrieval of information queried from the database server. Similarly, the MNOs routes the communication between the mobile phone and the application server which is achieved through the MNOs data services like EDGE, 3G and LTE while the communication which is dependent on HTTP protocol.

The components of the architecture include:-

5.2.1 The PSV Owner

The web application provides the PSV owner with an administrative management feature to create, modify, suspend or delete a user who is here-in referred to as the conductor. Further, the PSV owner will be able to set agreed collection targets, view summarized daily fare collections report.

5.2.2 The Passenger

Through the mobile application the passenger will be able to create a new user account, purchase a ticket, pay fare, view recharge wallet account details, and view summarized transactions breakdown.

5.2.3 The Conductor

The mobile application allows the conductor to collect fare by scanning the electronic QR Code tickets on the passenger's mobile phone. Moreover, the mobile application affords the conductor with a feature to synchronize offline transactions, scan and validate tickets, and view a graphical chart report of set target against revenue collected. Offline transactions will automatically be uploaded to the remote server every 45 minutes if not manually synchronized.

5.2.4 The Administration Management System

The administration management system allows setting up of transit data like route, bus stops, vendor information etc. via a web portal. An administrator is able to use CRUD operations to setup other information.

5.3 Web Server

The web server also referred to as the application server in the KommutePal system architecture uses HTTP to provide all the necessary services and resources to the client applications. The web services will handle the communication between the client applications and the server. Apache has been identified as the web server that will be used to host the resources and services needed.

5.4 Data and Process Modeling

This section describes the logical model of what the mobile solution will accomplish. The primary entities in the system include: the PSV owner, the conductor and finally the passenger.

5.4.1 Data Flow Diagram Models

The demonstration of how the data moves throughout the mobile application is shown through the use of data flow diagrams. Figure 5.2 illustrates the context diagram for the proposed solution in terms of inputs and outputs.

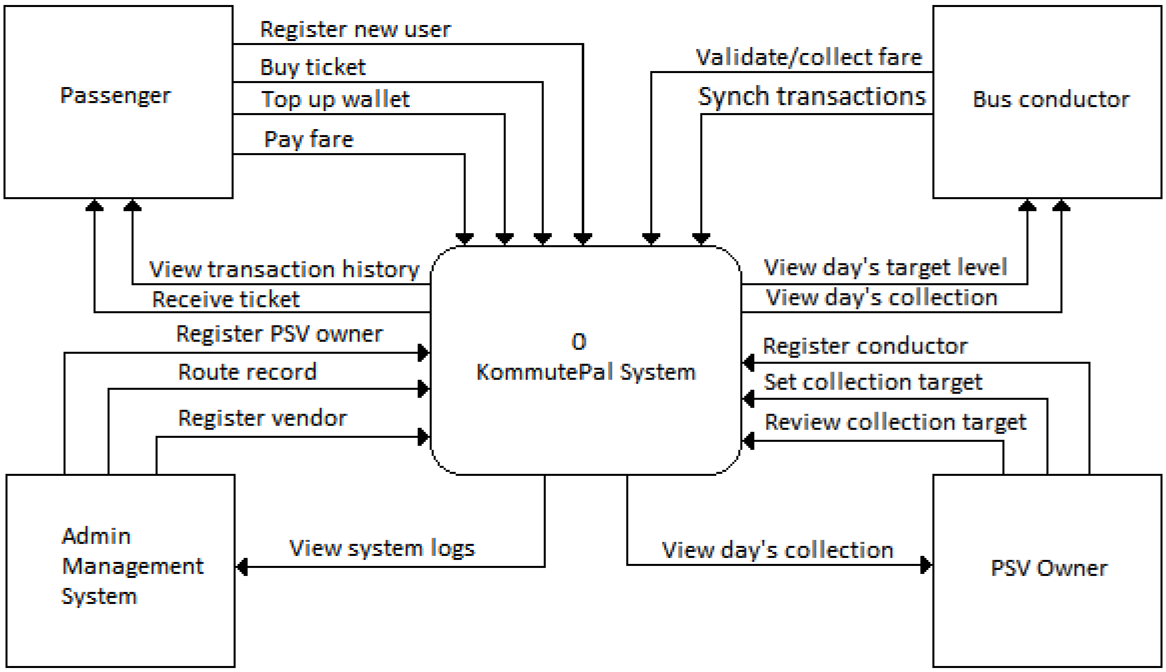


Figure 5.2: Context Diagram of KommutePal System

5.4.2 Level 1 Data Flow Diagram

Figure 5.3 and Figure 5.4 shows the data flow diagrams for both the passenger and the conductor respectively. The Level 1 DFD decomposes the processes in Level 0 to show all the sub-processes in the proposed mobile solution. Level 1 data flow diagram displays the major processes, data flows and data stores in the system.

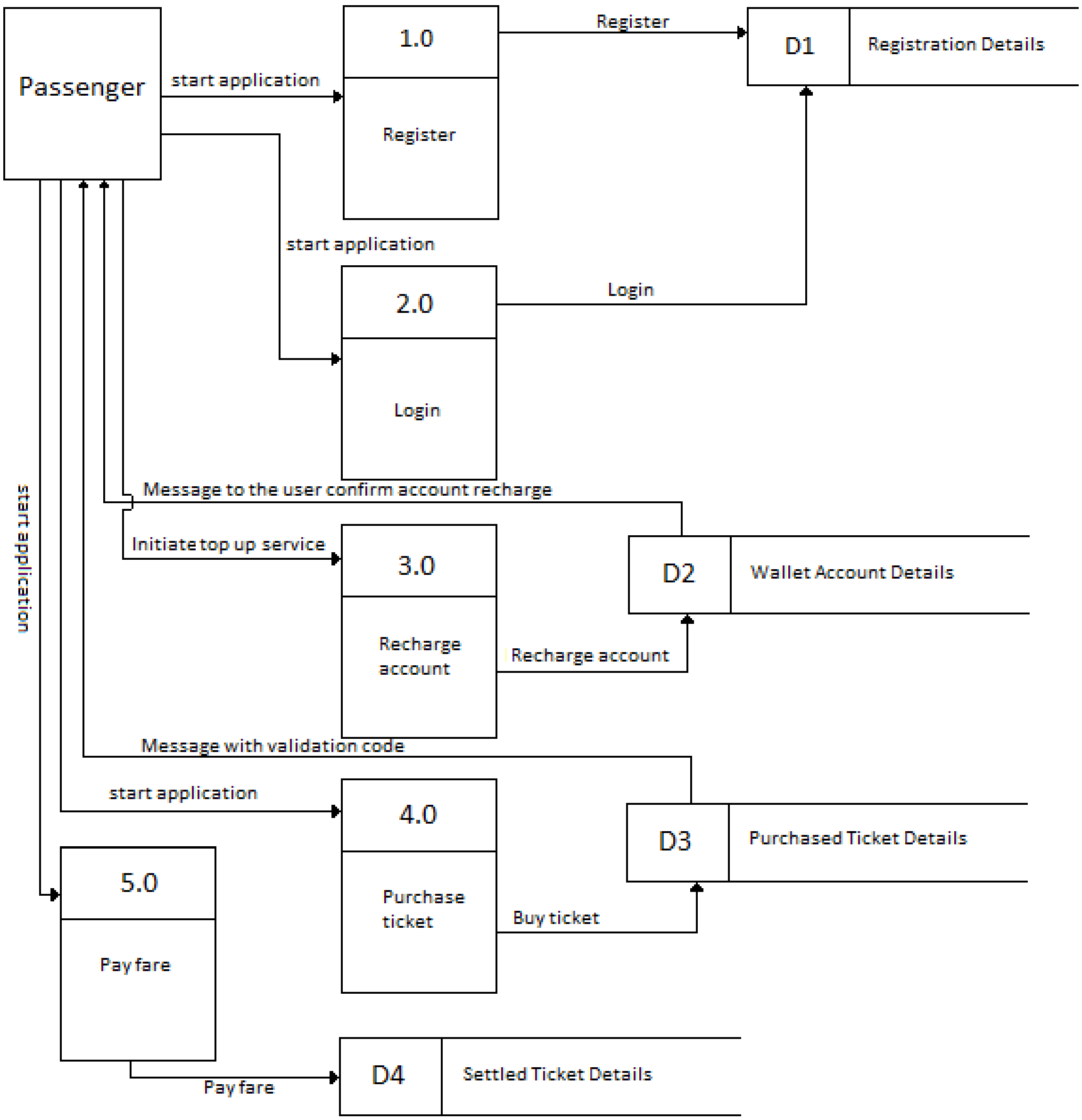


Figure 5.3: Level 1 DFD of KommutePal System - Passenger's Process

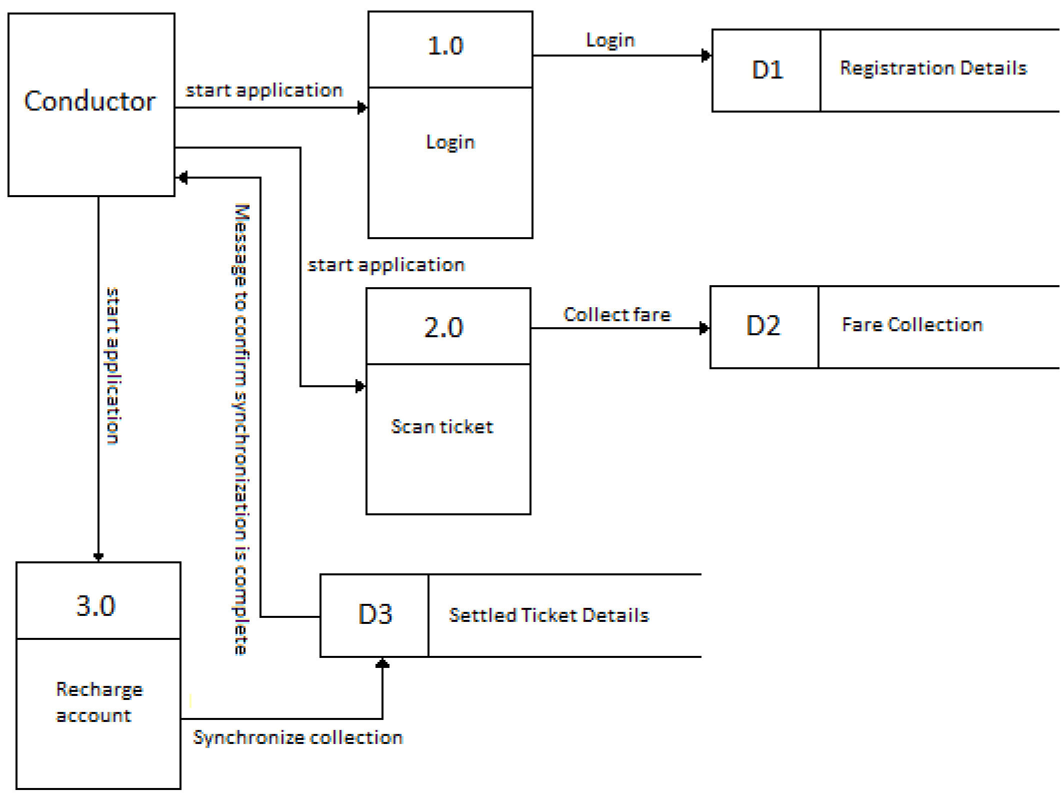


Figure 5.4: Level 1 DFD of KommutePal System - Conductor's Process

5.4.3 Use Case Diagram

The use case diagram illustrates interaction between external entities and the varied processes in the system. The main actors are the PSV owner, the bus conductor, the passenger and the admin management system as an external entity. Figure 5.5 depicts the use case diagram for the proposed system.

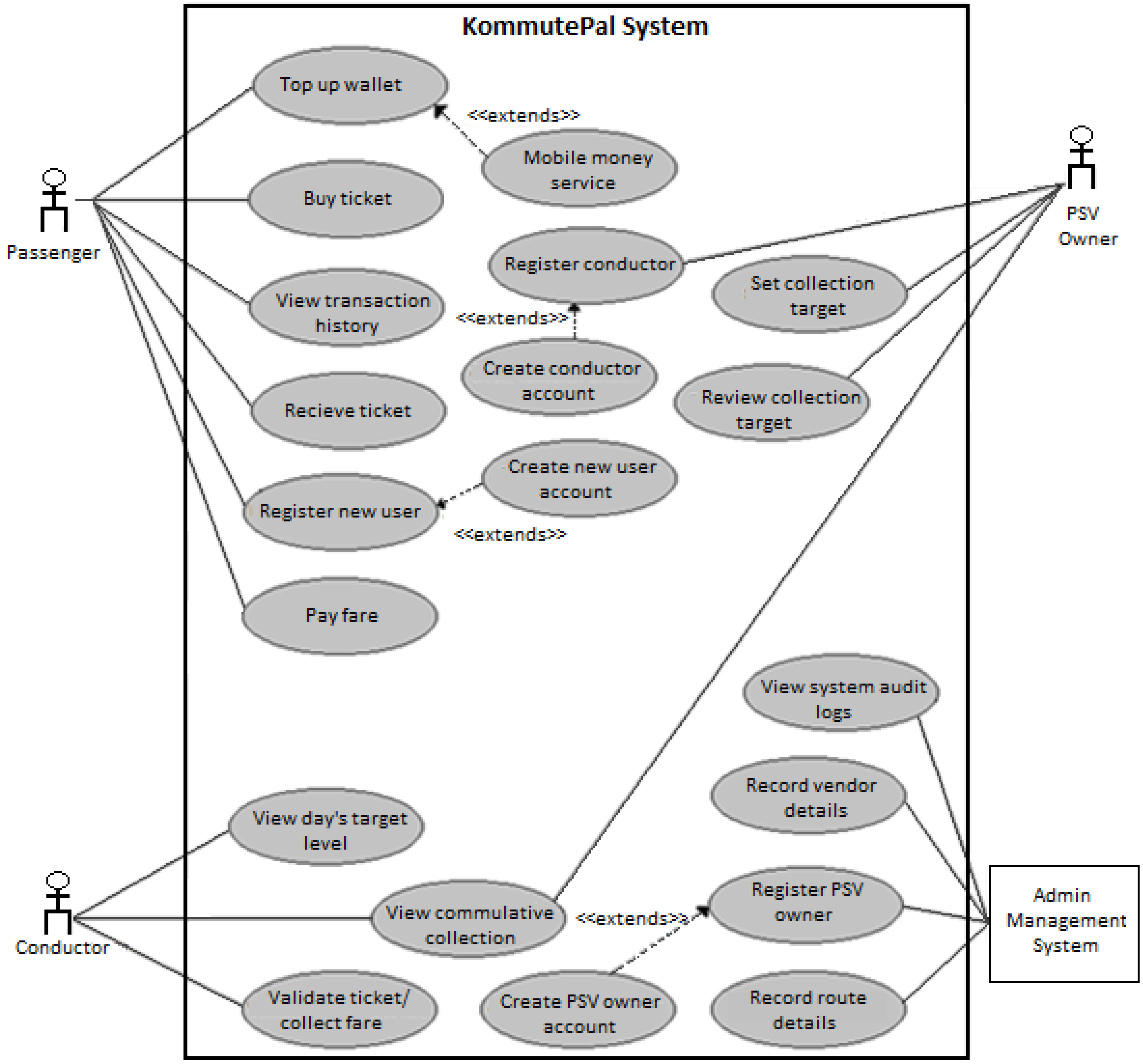


Figure 5.5: Use Case Diagram

5.4.5 Sequence Diagram

The sequence diagram majorly focuses on identification of behavior within the system. At the same time a sequence diagram shows object interaction arranged in time sequence. Figure 5.6 and Figure 5.7 illustrate the sequence diagrams for the passengers and the conductors respectively.

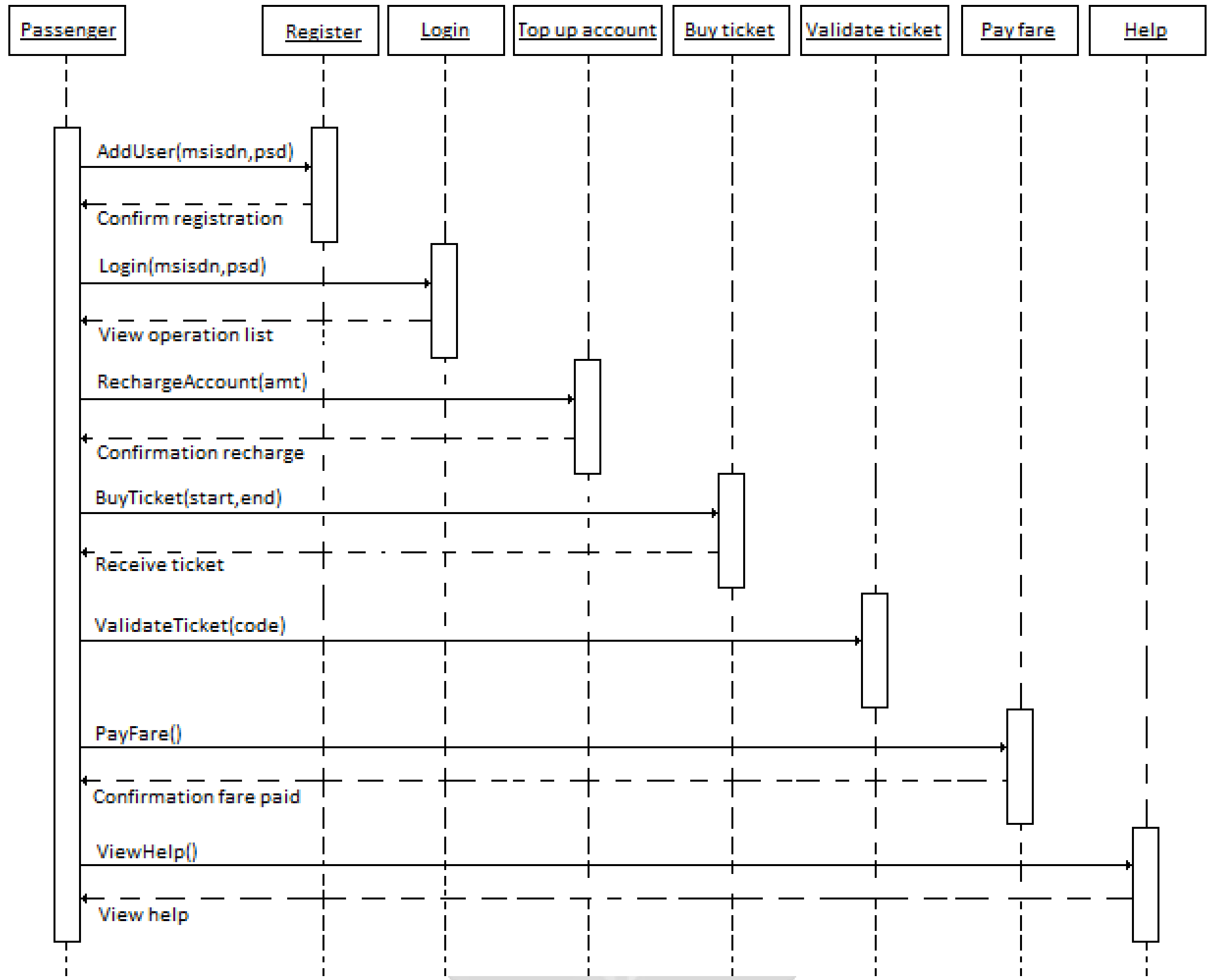


Figure 5.6: Sequence Diagram - Passenger

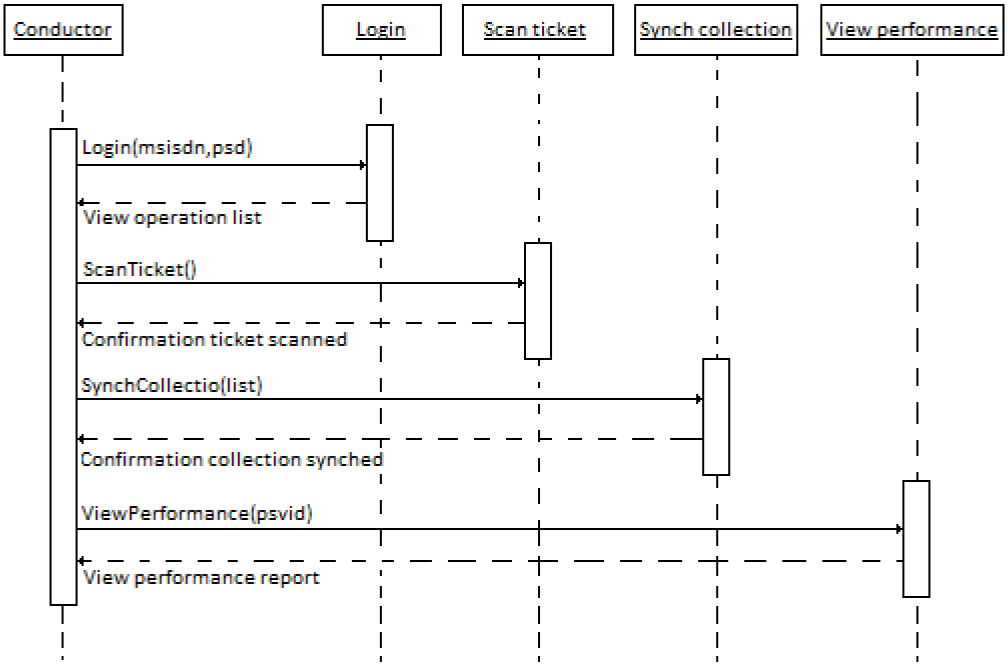


Figure 5.7: Sequence Diagram - Bus conductor

5.5 Entity Relation Diagram

The ERD in figure 5.8 shows the relationship between entities within the mobile solution in a detailed view.

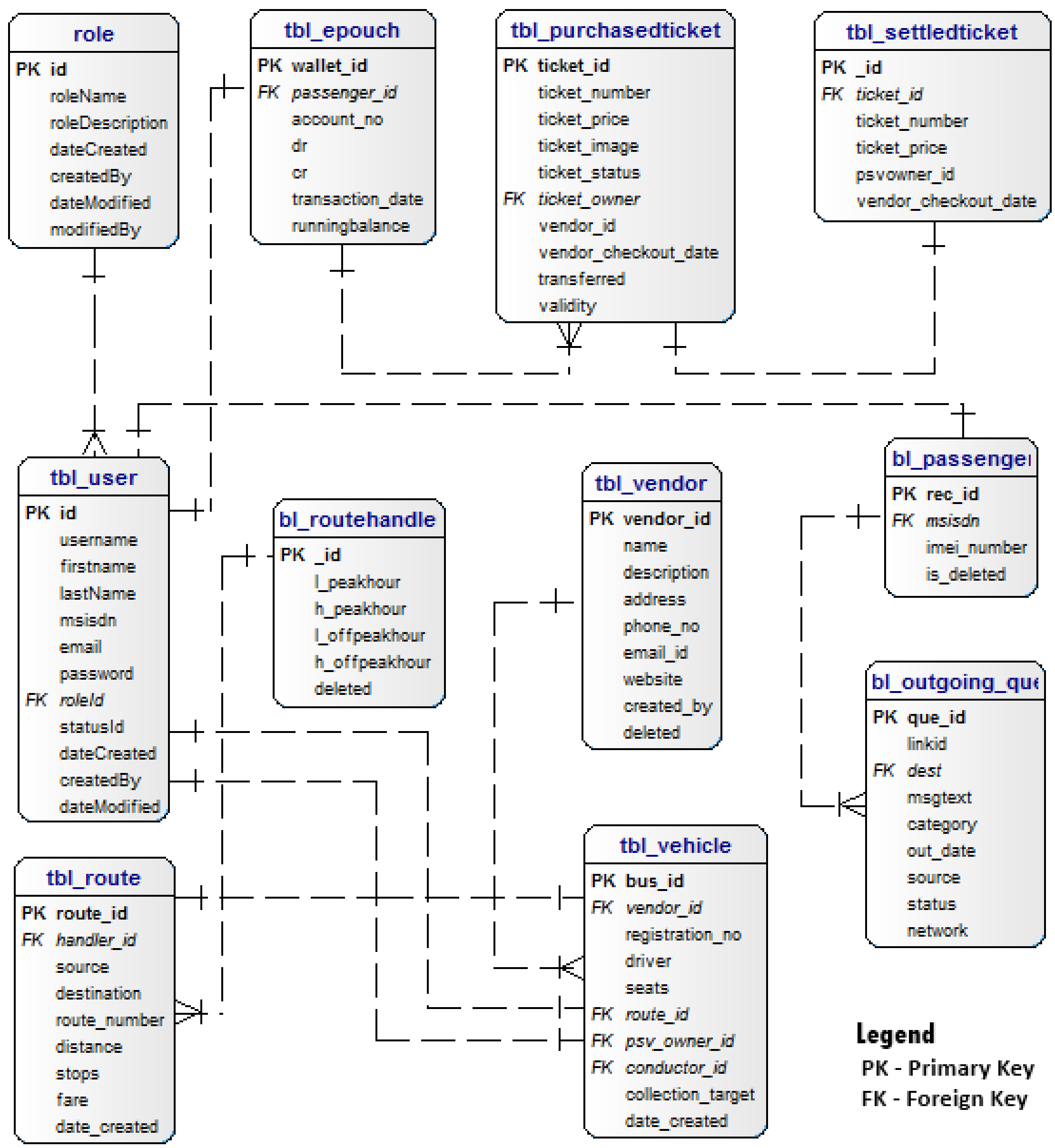


Figure 5.8: KommutePal System ERD

5.6 Database Schema

This section shows an impression of the tabular representation of the database schema that was used to model the mobile solution.

Vendor Table	
Column	**Type**
Vendor_id (**PK**)	int(7) auto_increment
Name	varchar(25) , Nullable
Description	varchar(60) , Nullable
Address	varchar(20) , Nullable
Phone_no	varchar(20)
Email_id	varchar(20) , Nullable
Website	varchar(20) , Nullable
Created_by	Timestamp
Deleted	char(1) , Nullable

Table 5.1: Vendor Table

Vehicle Table	
Column	**Type**
bus_id (**PK**)	int(7) auto_increment
vendor_id (**FK**)	varchar(7) , Nullable
registration_no	varchar(10) , Nullable
Driver	varchar(20) , Nullable
Seats	int(10) , Nullable
route_id (**FK**)	varchar(7) , Nullable
psv_owner_id (**FK**)	int(11) , Nullable
conductor_id (**FK**)	int(11) , Nullable
collection_target	double(6,2) , Nullable
date_created	Timestamp

Table 5.2: Vehicle Table

Route Table	
Column	**Type**
route_id (**PK**)	int(7) auto_increment
Source	varchar(20) , Nullable
Destination	varchar(20) , Nullable
route_number	varchar(10) , Nullable
Distance	varchar(2) , Nullable
Stops	Text
Fare	varchar(5) , Nullable
date_created	Timestamp

Table 5.3: Route Table

Route Handler Table	
Column	**Type**
_id (**PK**)	int(7) auto_increment
route_id (**FK**)	varchar(7)
l_peakhour	varchar(7)
h_peakhour	varchar(7)
l_offpeakhour	varchar(7)
h_offpeakhour	varchar(7)
Deleted	char(2) , Nullable

Table 5.4: Route Handler Table

Purchased Ticket Table	
Column	**Type**
ticket_id (**PK**)	int(7) auto_increment
ticket_no	varchar(20) , Nullable
ticket_price	int(11)
ticket_image	Blob
ticket_status	char(2)
ticket_owner (**FK**)	varchar(13)
vendor_id (**FK**)	char(20) , Nullable
vendor_checkout_date	datetime , Nullable
Transferred	char(2) , Nullable
Validity	datetime, Nullable

Table 5.5: Purchased Ticket Table

Settled Ticket Table	
Column	**Type**
_id (**PK**)	int(10) auto_increment
ticket_id	varchar(50)
ticket_no (**FK**)	varchar(20) , Nullable
ticket_price	int(11)
vendor_id (**FK**)	char(10) , Nullable
vendor_checkout_date	datetime , Nullable

Table 5.6: Settled Ticket Table

Epouch Table	
Column	**Type**
wallet_id (**PK**)	int(10) auto_increment
passanger_id (**FK**)	varchar(20)
account_no (**FK**)	Varchar(13)
Dr	varchar(10) , Nullable
Cr	varchar(10) , Nullable
running_balance	varchar(10) , Nullable
transaction_date	Datetime

Table 5.7: Epouch Table

User Table	
Column	**Type**
id (**PK**)	int(1) auto_increment
Username	varchar(45) , Nullable
Firstname	varchar(45) , Nullable
Lastname	varchar(45) , Nullable
Msisdn	varchar(13) , Nullable
Email	varchar(30) , Nullable
Password	varchar(128) , Nullable
roleid (**FK**)	int(11)
statusid (**FK**)	int(11) , Nullable
dateCreated	datetime, , Nullable
createdBy	int(11) , Nullable
dateModified	timestamp , Nullable

Table 5.8: User Table

Role Table	
Column	**Type**
id (**PK**)	Int(10) auto_increment
roleName	varchar(20)
roleDescription	Varchar(20), Nullable
dateCreated	datetime, Nullable
createdBy	int(11) , Nullable
dateModified	timestamp, Nullable
modifiedBy	int(11) , Nullable

Table 5.9: Role Table

Outgoing_que Table	
Column	**Type**
que_id (**PK**)	int(10) auto_increment
Linked	varchar(150)
dest (**FK**)	varchar(13), Nullable
Msgtext	varchar(160), Nullable
Category	varchar(50), Nullable
out_date	datetime, Nullable
Source	varchar(15), Nullable
Status	varchar(20), Nullable
Network	varchar(20), Nullable

Table 5.10: Outgoing_que Table

5.7 Security

The proposed mobile application has been designed to allow user authentication before the application on the mobile phone is loaded. The MSISDN was used to identify and authenticate the user. Since communication between the client applications and the server happens over a network, HTTPS is used to safeguard the security at all times. In addition, the forms which capture the user inputs were developed to prevent intrusion. Also a user input was sanitized to avert injections.

There are several users with different privileges that have been created on the core database. Each user plays a specific role and provides connection to the database engine. These users includes: root user, application user and web user have been created on MySQL with specific roles that grant each user with certain privileges to the database. The root user is created with extensive privileges and other management functions related to the database. The application user provides database access to the back-end web services while the web user provides the web application with access to the same database. The privileges are assigned to each user to ensure that specific functions get delivered by specific applications on the system hence providing some form of database security. The access to the core database is limited to these users and will not be available outside the system's network. Sensitive data like stored passwords will be encrypted.

5.8 Development

The proposed solution was developed to work on an Android mobile that will be used by either the passenger or the conductor while the web-based platform will be accessed and used by either the PSV owner or the system administrator.

Java for Android was used to develop the mobile application, while PHP was used to build the server side web service scripts and the web application.

CHAPTER SIX: SYSTEM IMPLEMENTATION AND TESTING

6.1 System Development Environment

Table 6.1 and 6.2 below illustrate the hardware and software components that were used to come up with the system and their justifications.

Table 6.1 Hardware Implementation

HARDWARE	JUSTIFICATION
Laptop: 1 HP core i5/4Gb Ram/500Gb	Used for dissertation documentation, design and development of the proposed mobile solution.
Huawei Y300-0100	The mobile phone is used for testing the mobile application.

Table 6.2 Software Implementation

SOFTWARE	JUSTIFICATION
Windows 7	Operating system used in computer
MS Word 2010	Used for writing the dissertation document
MySQL Server Workbench	Used for development of system database
Android Studio	Used to develop the mobile application
EditPlus	Used to write PHP scripts
Xamp	Used for testing the web service/web application
ZXing Library	Provide support decoding and generation of QR Code
Drop box	To back up the source code, dissertation document and other relevant resources.

6.2 System Implementation

The development of the system amalgamated at least two programming technologies i.e. mobile programming technology and web technology. Android was used to develop the mobile application while PHP was used to script the server-side web service/web application. The system database was build using MySQL DBMS. In addition, ZXing library which is implemented in Java was incorporated in the mobile application for the purpose of decoding QR Codes, while php-qrcode library was used on the server side to aid in generation of QR Code images.

6.3 Web Application

The web application is accessed and used by the system administrator to both manage the system and other related functions while the PSV owner will use the same web application for specific roles tied to the user. The web application allows the system administrator to manage transit data like route, bus stops, vendor information. Similarly, the PSV owner via the same web application will be able to review revenue collection targets, view summarized fare collections, create, modify and delete a user i.e. the conductor.

6.3.1 Login Page

The login page Figure 6.1 allows the user to login onto the web application. The login control ensures that no unauthorized user has access to the web application.

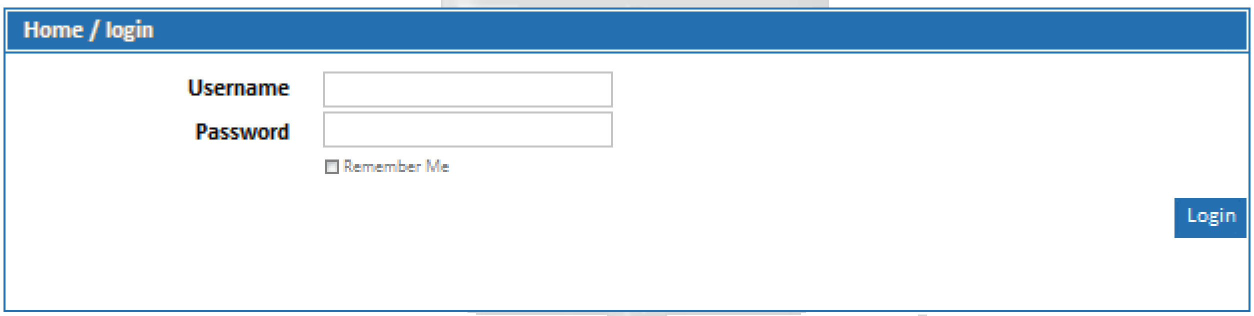


Figure 6.1: User Login Page

6.3.2 Change Password Page

The change password page Figure 6.2 allows the user change the old login password with a new password. Frequency to change the password has been left to the user's discretion as the system does provide notification to prompt for password change.

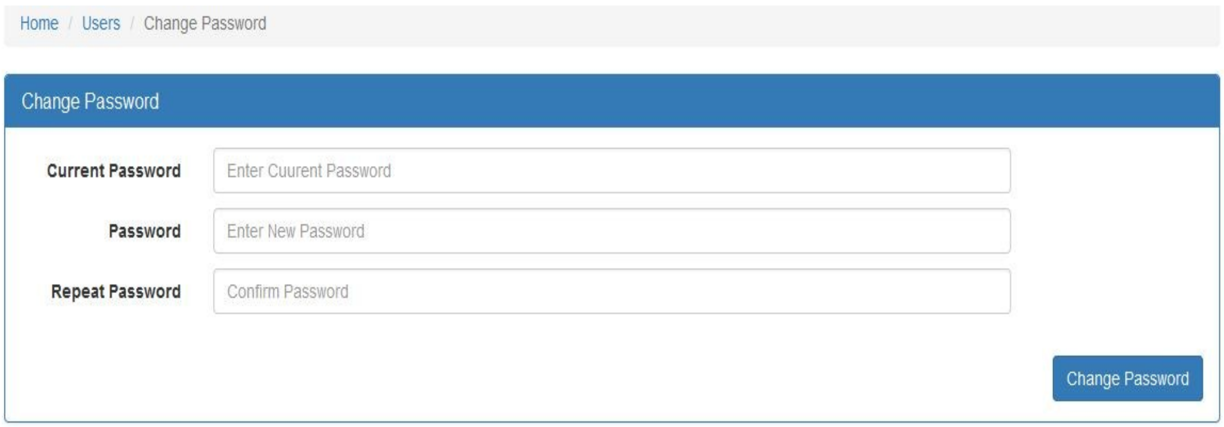


Figure 6.2 Change Password Page

6.3.3 Route Page

The page Figure 6.3 allows the administrator to add, modify and delete route details. Further, the page also provides a search function where route particulars can be searched by either source, destination or both. The route information outlines the stipulated fare for a journey thus safeguarding against manipulation by either the conductor or PSV owner. As a result, this afford predictable and stable commuter fares to the passengers.

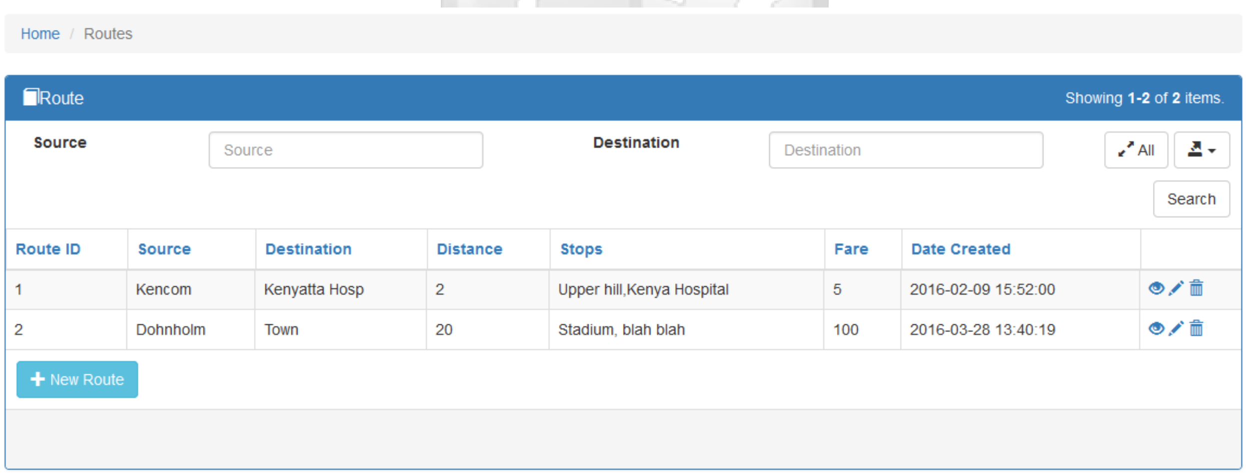


Figure 6.3: Route Information Page

6.4 Mobile Application: KommutePal

The mobile application is setup package that users install on their cell phones and the use of the application is tied to the role of the user. The commuter will use the mobile application to purchase an electronic ticket, view recharge wallet account details, and settle fare while the conductor will utilize the same mobile application to validate and collect fare, synchronize offline transactions and view a graphical chart report of set target against revenue collected.

6.4.1 Registration/Login Screen

The screen Figure 6.4 has two uses namely: registration and authentication. A new user creates an account by providing the registration details through the screen below. Likewise, an existing user will utilize the same registration/login screen to login onto the system. The authentication process allows only registered users to have access the mobile application. Upon successful authentication the user is presented with the main dashboard listing the specific operations available to the user.

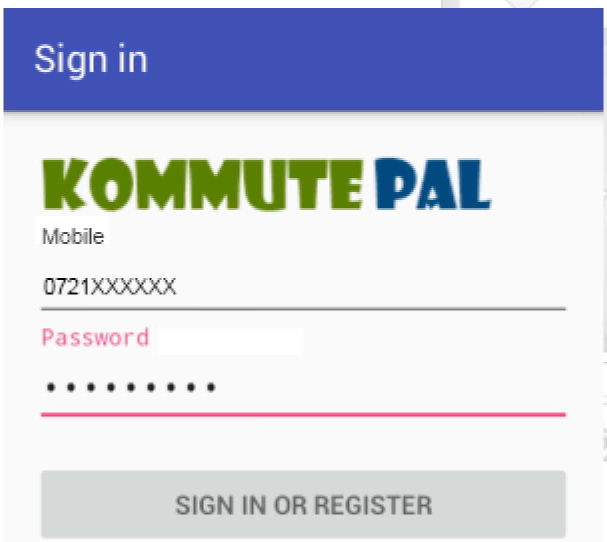


Figure 6.4: Registration/Login Screen

6.4.2 Main Screen

The main screen Figure 6.5 illustrates varied operations that are available to a passenger after successful authentication to the mobile application. The passenger is presented with the following operations:-

i. Purchase Ticket: The operation provides the passenger with a screen to select travel details namely: bus company, route, start point and destination in order to purchase a ticket against the selected travel information.
ii. Show ticket: The operation provides the passenger with a list of tickets bought in a list from which the passenger can select in order to display the ticket. A newly purchased ticket needs to be activated using a code shared via SMS.
iii. Recharge Account: The operation provides the passenger with instructions on how to recharge the electronic wallet account.
iv. Help: The operation provides the passenger with general information on how to use the mobile application and also provides help contact information through which assistance can be sort.

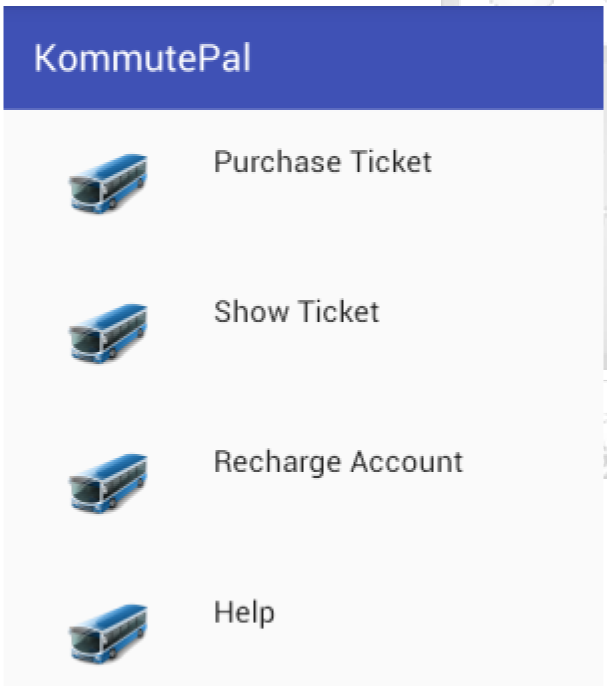


Figure 6.5: Passenger's Main Screen

Further, Figure 6.6 shows the resulting screens that are navigated to when each operation is selected by the passenger.

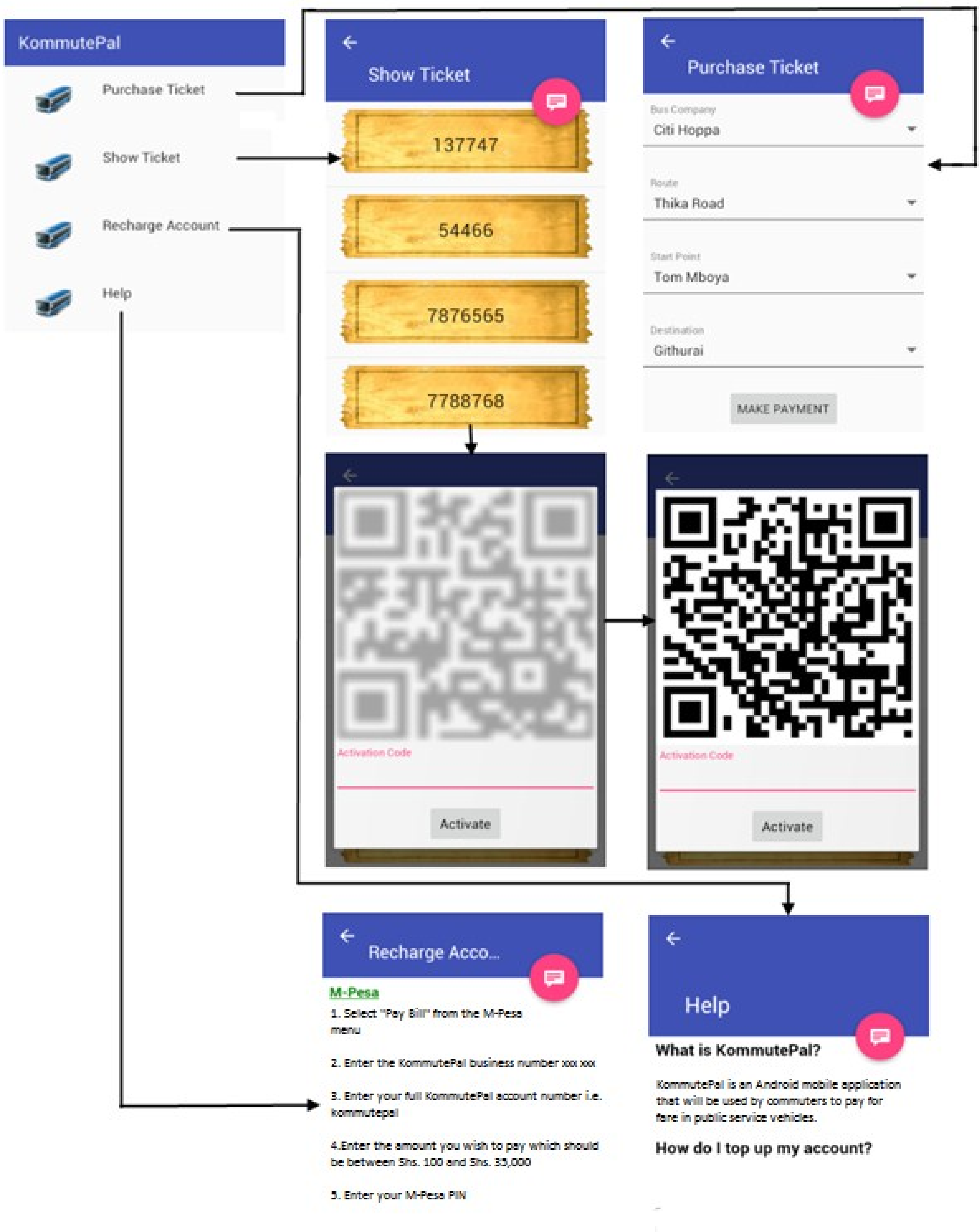


Figure 6.6: Passenger's Operations and the Resulting Screens

The conductor is also presented with several functionalities upon successful authentication to the mobile application. Figure 6.7 below shows the main screen presented to the conductor that has the following operations:

i. Scan Ticket: This operation provides the conductor with the ability to validate and decode a QR Code ticket using a camera on the cell phone.
ii. Synch Collection: This operation allows the conductor to upload the details of the electronic tickets that have been collected as payment on the mobile phone onto the remote server. Two approaches are used in revenue collection namely: manual synchronization that is initiated by the conductor and automated synchronization that is initiated by the application and regularly runs at an interval of 45 minutes.
iii. View Performance: This operation allows the conductor to view the report of the day's revenue collection against set target.

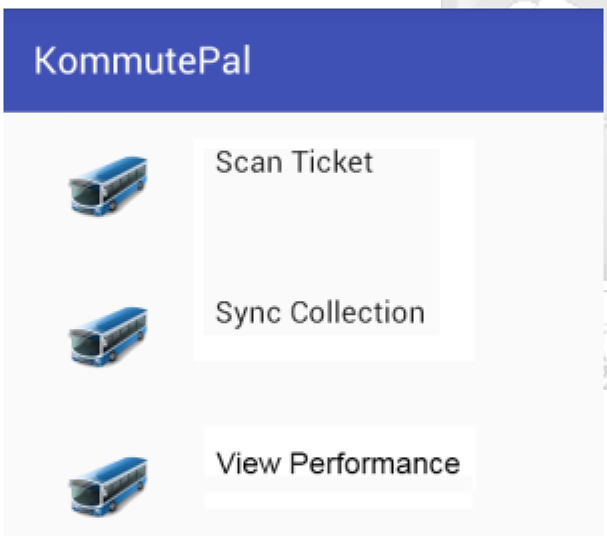


Figure 6.7: Conductor's Main Screen

In addition, Figure 6.8 shows the resulting screens that are navigated to when each operation on the main screen is selected by the conductor.

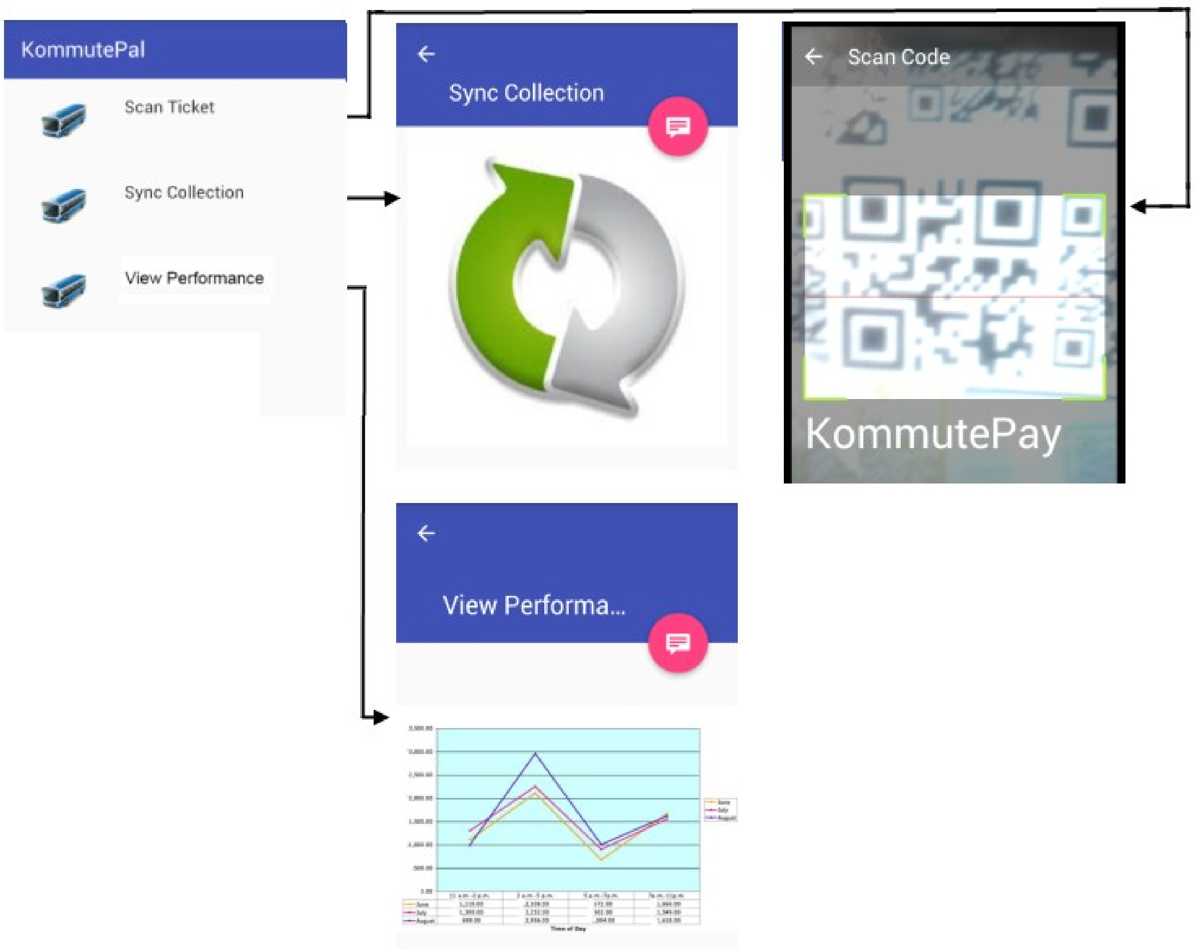


Figure 6.8: Conductors' Operations and the Resulting Screens

6.5 System Testing

The application was given to a third party, an expert in software testing and subjected to functional test, compatibility test and software metric test.

6.5.1 Functionality Test

The test was conducted to determine if all the mobile application functionalities worked as expected. Table 6.3 illustrated the test results. The mobile application functions were subjected to repetitive test and the results registered in the table. The functionality test was majorly conducted to ensure all bugs were fixed and certify that the key objectives of study are met. Also the functionality test was important to check that the user requirements are met.

Table 6.3: Functional Test Results

Test Case Name: **Functionality Test** Test Date: **20/03/2016** Tested By: **Martin Kabachia**					
Module Tested	**Description of Test Conducted**	**Expected Behaviour**	**Observed Behaviour**	**Error**	**Verdict**
Registration	Confirm whether registration is carried out	The application registers users and stores the user information into a database	The application registers users and stores the user information into a database	None	Ok
Login	Confirm whether only registered users has access	User is first verified before granting access to the system	User is first verified before granting access to the system	None	Ok
Purchase Ticket	Pay for ticket	Ticket is generated with correct information	Ticket is generated with correct information	None	Ok
Show Ticket	Display the ticket	The electronic ticket is correctly display on the mobile screen	The electronic ticket is correctly display on the mobile screen	None	Ok
Recharge account	Top up the account wallet	Correct wallet fund information is captured and in the right user account	Correct wallet fund information is captured and in the right user account	None	Ok
Scan Ticket	Collection of fare	Ticket fund information is correctly decoded and stored	Ticket fund information is correctly decoded and stored	None	Ok
Synch Collection	Synchronize collected fare information with the remote server	Stored collection is then posted in the right entities	Stored collection is then posted in the right entities	None	Ok

6.5.2 Software Metric Test

The quality assurance metric test was conducted to ascertain that the mobile application met the following software metrics which includes: reliability, speed, scalability and accuracy.

Table 6.4: Application Speed Test

Test Case Name: **Application Speed Test** Test Date: **25/03/2016** Tested by: **Martin Kabachia**					
Description: *The application was subjected to speed test to evaluate the time taken for each request.*					
Operations	**Time < 1mins**	**Time > 1mins < 2mins**	**Time > 2mins < 3mins**	**Time > 1mins < 3mins**	**Time > 5mins**
Login	×				
Recharge account		×			
Purchase ticket	×				
Pay fare	×				
Scan ticket	×				
Synchronize collection	×				
View help	×				
View collection target chart	×				
Installation	×				

The mobile solution was subjected to speed test as shown in table 6.4 above most operations were found to work within a couple of seconds. Delay was experience on recharge account operation which took about 1 to 2 minutes. Speed metric was met for most of the operations.

Table 6.5: Application Scalability Test

Test Case Name: **Application Scalability Test** Test Date: **26/03/2016** Tested by: **Martin Kabachia**		
Description: *The application was subjected to scalability test to evaluate whether it will handle extra users without breaking it. The number of users was increased gradually and the service quality evaluated.*		
Number of Users	**Result**	**Comments**
< 5 Users	Pass	None
> 5 Users < 10	Pass	None
> 10 Users < 50 Users	Pass	None

The number of users was gradually scaled up as shown in table 6.5 above and the mobile solution was able to handle the increase without any problem hence scalability metric was met.

Table 6.6: Application Accuracy Test

Test Case Name: **Application Accuracy Test** Test Date: **26/03/2016** Tested by: **Martin Kabachia**		
Description: *The application was subjected to accuracy test with focus on wallet information before and after the purchase of a ticket, recharge of the wallet account, fare collection information due to the PSV owner.*		
Item Tested	**Result**	**Comments**
Wallet account information after recharge of the account	Pass	None
Wallet account information after purchase of ticket	Pass	None
Revenue collection information due to the PSV owner	Pass	None

The mobile solution was tested for accuracy. Table 6.6 above illustrates specific items that were tested for accuracy. Wallet account information was tested for accuracy to safeguard against inaccurate account information. The account information in the wallet changes when either a ticket is purchased or when the account is recharged. Further, the collected revenue needs to be polled to the correct PSV owner.

The mobile solution has been seen to meet the three key software metrics namely: scalability, accuracy and speed hence it can be deduced that the mobile solution is also reliable.

6.5.3 Compatibility Test

This was carried out to determine if the mobile application works in different assortment of mobile phones. Three mobile phones were used for the test as shown in table 6.6.

Table 6.6 Compatibility Testing Results

Test Case Name: **Compatibility Test** Test Date: **21/03/2016** Tested By: **Martin Kabachia** Test Description: *The application was installed in three different mobile devices*.	
Phone	**Compatible**
Huawei Y300-0100	Yes
Samsung J5	Yes
Infinix Hot 2	Yes

6.5.4 Usability and User Experience

Post-test survey was conducted by the researcher on various users as shown in Appendix B. The test comprised of 40% (2) Female and 60% (3) Male respondents as shown in Figure 6.9.

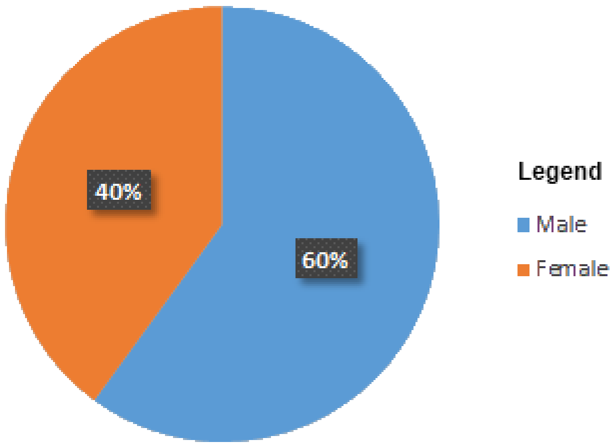


Figure 6.9: Gender Distribution

The table 6.7 below summarizes the user experience, usability and acceptance responses from the users who carried out the test.

Table 6.7 User Experience, Usability, and Acceptance

User Experience, Usability and Acceptance	N= 5		
	Yes	No	Neutral
Does the application look good?	80%	0	20%
Can you use the application without instructions?	100%	0	0
Would you use the application?	80%	20%	0

1. Ease of Use

   65% of the respondents felt that it was very easy to use the mobile application while 25% felt it was easy to use the application. This is illustrated in Figure 6.10.

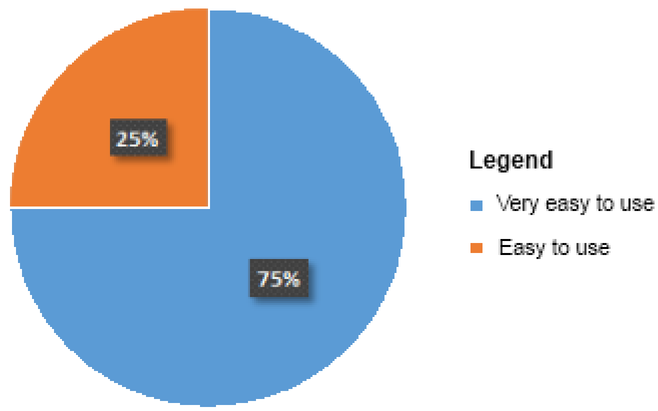


Figure 6.10: Ease of Use

2. Acceptance

   From the survey conducted by the research 80% of respondents would want to use the solution. Figure 6.11 illustrates the findings on how users felt in terms of user experience and usability of the application.

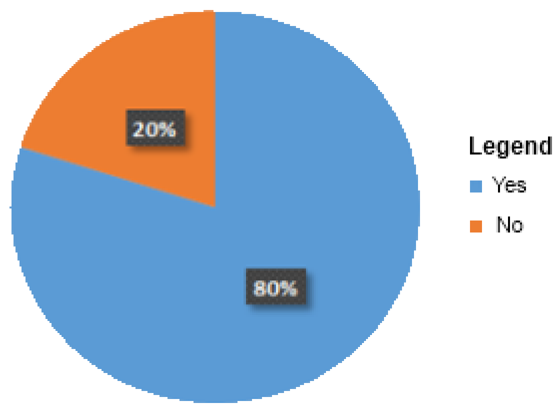


Figure 6.11: Acceptance of Application

6.5.4 Test Conclusion

The above results confirms that the system passed all the requirements set by the expert and performs as expected hence fit for market use.

6.6 System Deployment

The mobile solution would be deployed on the cell phones as an Android application package (APK) file. The mobile application should be hosted on a public server or an application store where it can be downloaded. Further, the web platform and web services would be hosted on a web server that has an IP which is exposed to the public while the core database engine would be hosted on a server whose access is limited to the application server.

6.7 Summary

The chapter has presented some screenshots of a fully functional and complete system. Waterfall model guided the development of the mobile solution from the initial stage of requirement gathering to implementation of the mobile solution. The post-test analysis as indicated in section 6.5.4 gives a firm backing that the proposed mobile solution has met its objectives.

CHAPTER SEVEN: DISCUSSION AND KEY FINDS

The chapter looks at each research question that was covered in this dissertation.

The type of data required in public transport was identified. Some of these data include: ticket data, bus stops, route, fare chart, buses, and crew. These data was useful and helped to guide the design and development of database entities that handles all aspect related to transport and also gave direction to the development of the ticketing function and other related processes.

Several cashless systems that were rolled out for use in public transport were identified. These systems incorporate varied technologies ranging from mobile money service like M-PESA to card based payment systems such as KCB Pepea card, BebaPay, PesaPrint, My 1963, Co-operative Bank M-Nauli and Abiria card. Furthermore, a big fraction of these cashless systems incorporates NFC technology thus payment is made by tapping the card to a specific POS or an NFC enabled device. The study has shown that NFC technology may prove to be expensive especially for small companies, to buy and maintain related machine and equipment. Likewise, security concern has been raised in regard to NFC technology in that it is possible to steal data from an NFC system from greater distance.

The mobile application was designed incognizant of all the stakeholders in mind that were identified. Design tools such as data flow diagrams, use cases, entity relation diagrams, and sequence diagrams were used to model the mobile solution. These tools helped to deeper understand the major processes, data flow, data stores, interaction between entities, identification of behaviour within the system and relationship between entities for the mobile solution. Thereafter, the solution was implemented through the use of tools such as Android Studio, Edit plus, and MySQL workbench.

Lastly, software testing was conducted and definitely assists in identification of bugs that existed in the system during development. Several software testing techniques were employed in order to best test the mobile solution. The tests subjected to the solution included: functionality test, usability test, software metrics test, and compatibility tests.

CHAPTER EIGHT: CONCLUSION AND RECOMMENDATION

8.1 Conclusion

The research thus concludes that there is need for a mobile application that provides an alternative channel through which the passengers use to pay for fare in a cashless fashion. In addition, the mobile application provides the PSV investors with a tool through which revenue earned is effortlessly tracked hence safeguarding their income against risk associated in carrying cash and theft. Other challenges such as delays in getting change or overcharging will be addressed. Generally, the mobile solution will go a long way in restructuring the operations of PSVs and spin off the benefits to stakeholders involved.

The mobile application has been developed and has passed the requisite tests. Accordingly, the mobile application is ready for the market. Further, the application was designed to work on the most popular mobile operating system which runs on the cell phones that a majority of the commuters in Nairobi owns.

KommutePal can and will aid in transforming the business operations in PSVs.

8.2 Recommendations

The platform which was picked was native, thus, it was fast, had an awesome user interface and its internal storage was excellent.

The researcher come up with the following recommendations:

i. The developed solution is applicable to Internet enabled Android phones. The usage of the mobile application is recommended over Wireless Fidelity (Wi-Fi) network or mobile broadband network.
ii. The implemented mobile solution can be scaled up to other PSVs such as country bus, taxis and commuter trains.

8.4 Functionality Not Implemented

There are several functionalities that have been identified and would make the mobile application more appealing to the stakeholders.

8.4.1 Integration to more Payment Services

The mobile solution needs to be integrated to more payment services such as VISA, MasterCard, bank payment services and other mobile money services to provide an alternative through which passengers can recharge their electronic wallet account on KommutePal mobile application.

8.4.2 Implementation of Notifications Feature

The feature will provide an avenue through which the commuters will be able to have a two way communication with the PSV owners. Through this channel the commuters will be able to raise queries or compliments via the mobile application.

8.4.3 Implementation of a Ticket Sharing Feature

The feature will allow the passengers to transfer tickets to other persons using the KommutePal mobile application.

8.4.4 Implement a Way to Charge for Intervals within a Journey

Provide a mechanism to charge the passengers for interval stop-overs within a segment rather than a flat charge applicable to the whole journey.

8.4.5 Implement a Way to Charge for Passenger's Luggage

Provide a means to charge for passenger's luggage. The revenue generated from the luggage should be trackable and accounted for on the mobile application.

8.5 Future Research

The future research studies and improvement worth considering include the following:

i. Develop a mobile solution that will be work across several mobile operating system such as iOS and Window Mobile.
ii. Consideration of implementing tamper proof and secure electronic tickets using the QR code technology. A multi facet approach can be used to harden the QR Code to avoid compromise by unknown applications.

8.6 Summary

Through this chapter we have seen what the research concluded and the recommendations made for any future events in this topic.

REFERENCES

Abiria Card. (n.d.). Retrieved July 15, 2015, from http://www.kenyabus.net/abiria/ABIRIA_CARD_NEWS_Revised_2014.pdf

Akaki, L. (2014, November 8). My 1963 Card launched for easy payments in PSVs - Hapa Kenya. Retrieved July 14, 2015, from http://www.hapakenya.com/1963-card-launched-easy-payments-psvs/

Asingo, P., & Mitulla, W. (2007). Implementing Road Transport Safety Measures in Kenya Policy Issues and Challenges. Retrieved January 15, 2015, from https://www.uonbi.ac.ke/patrick_asingo/files/road_safety_policies.pdf

Baghudana, A., & Leis, J. (2015). NAVIGATING NAIROBI: Digital Innovation in Urban Transport and Logistics in Kenya. Retrieved January 10, 2016, from http://mastercardcenter.org/wpcontent/uploads/2015/04/Navigating-Nairobi-_WEB-FINAL-VERSION.pdf

Boden, R. (2014, June 30). Edinburgh trams use QR codes to validate mobile tickets before boarding • NFC World+. Retrieved January 10, 2016, from http://www.nfcworld.com/2014/06/30/330032/edinburgh-trams-use-qr-codes-validate-mobile-tickets-boarding/

Boyd, M. (2014, May 22). How Smart Cities are Using APIs: Public Transport APIs | ProgrammableWeb. Retrieved January 10, 2016, from http://www.programmableweb.com/news/how-smart-cities-are-using-apis-public-transport-apis/2014/05/22

Briseno, M. V., Hirata, F. I., Lopez, J. S., Hipólito, J. N., Garcia, E. J., & Cota, C. N. (2012, March 7). Using RFID/NFC and QR-Code in Mobile Phones to Link the Physical and the Digital World. Retrieved July 20, 2015, from http://www.intechopen.com/books/interactive-multimedia/using-rfid-nfc-and-qr-code-in-mobile-phones-to-link-the-physical-and-the-digital-world

Carmody, P. (2012). The Informationalization of Poverty in Africa? Mobile Phones and Economic Structure. Retrieved January 10, 2016, from http://itidjournal.org/itid/article/viewFile/911/382

Co-operative Bank Launches M-Nauli - It's Cashless System. (n.d.). Retrieved March 2, 2015, from https://www.co-opbank.co.ke/files/download/ee22d9bcd07576b

Eby, C. (2015, May 12). Retrieved February 11, 2016, from www.thonky.com/qr-code-tutorial/introduction

EMVCo. (2011, May). Retrieved January 15, 2016, from https://paysmart.com.br/wp-content/uploads/2013/03/EMVCo-A-Guide-to-EMV.pdf

Equity Bank partners with Google to introduce a cashless solution. (n.d.). Retrieved March 12, 2015, from http://www.equitybank.co.ke/blog/view/equity-bank-partners-with-google-to-introduce-a-cashless-solution

Eric, G. J., Chavis, C., Li, Y., & Daganzo, C. F. (2009). Multimodal Transport Modelling for Nairobi, Kenya: Insights and Recommendations with an Evidence-Based model. Retrieved January 10, 2016, from http://www.its.berkeley.edu/sites/default/files/publications/UCB/2009/VWP/UCB-ITS-VWP-2009-5.pdf

FAQ. (n.d.). Retrieved March 12, 2015, from http://www.my1963.co.ke/index.php/faq

Fripp, C. (2014, April 16). 67% of mobile phones sold in Kenya are smartphones. Retrieved January 7, 2016, from http://www.itnewsafrica.com/2014/04/67-of-mobile-phones-sold-in-kenya-are-smartphones/

Gielen, S. (2012, August 22). SIM Toolkit In Practice. Retrieved from http://www.cs.ru.nl/bachelorscripties/2012/Sjors_Gielen___3003698___SIM_Toolkit_In_Practice.pdf

Graeff, J. (2009). The Organization and Future of the Matatu Industry in Nairobi, Kenya. Retrieved January 15, 2015, from http://www.vref.se/download/18.53e8780912f2dbbe3a580002295/Organization+and+Future+of+the+Matatu+Industry.pdf

Gura, D., O'Shea, K., Reddy, A., & Sabatté, M. (2011). Retrieved April 7, 2015, from http://www.kellogg.northwestern.edu/faculty/greenstein/ftp/Teaching/papers/QRCodes.pdf

Herbling, D. (2014, October 1). Commuters win as cashless fare system embraces integration. Retrieved January 15, 2015, from http://www.businessdailyafrica.com/Commuters-win-as-cashless-fare-system-embraces-integration/-/1248928/2471830/-/11x2txvz/-/index.html

Herbling, D. (2014, December 22). Co-op Bank card to tap county fee payments - Money Markets. Retrieved January 15, 2015, from http://www.businessdailyafrica.com/Co-op-Bank-card-to-tap-county-fee-payments/-/539552/2566010/-/alnp7h/-/index.htm

Israel, G. D. (n.d.). Determining Sample Size. Retrieved February 20, 2016, from http://www.sut.ac.th/im/data/read6.pdf

Kawabata, R., Kasahara, T., & Itoh, K. (2007). *Systems Analysis for Collaborative System by Use Case Diagram, Journal of Integrated Design & Process Science*.

Kenya Gazette Supplement. (2015, June 26). Special Issue. Retrieved January 10, 2016, from http://www.labour.go.ke/downloads/Minimum%20Wages.pdf

Khayesi, M. (1999). The Struggle for Regulatory and Economic Sphere of Influence in the Matatu. Retrieved January 10, 2016, from http://www.ku.ac.ke/schools/graduate/images/stories/docs/presentation/Thredbo6-theme3-Khayesi.pdf

Kiarie, J. (2015, August 22). Details of the Sh100 billion Nairobi bus and rail project. Retrieved January 12, 2016, from http://www.standardmedia.co.ke/article/2000173727/details-of-the-sh100-billion-nairobi-bus-and-rail-project

Kieseberg, P., Leithner, M., Mulazzani, M., Munroe, L., Schrittwieser, S., Sinha, M., & Weippl, E. (n.d.). QR Code Security. Retrieved June 12, 2015, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.372.6981&rep=rep1&type=pdf

Kihagi, S. (2014, November 6). What Kenyans Need To Know About My1963 Cashless Card. Retrieved January 10, 2015, from http://www.juuchini.com/2014/11/what-kenyans-need-to-know-about-my1963-cashless-card/

Kuria, W. (2014, May 2). PesaPrint set to roll out cashless fare system for PSVs. Retrieved February 10, 2015, from http://www.kachwanya.com/2014/05/02/pesaprint-set-roll-cashless-fare-system-psvs/

Kuria, W. (2014, November 5). PSV Cashless Payment System ‘my1963’ officially launched. Retrieved February 12, 2015, from http://www.kachwanya.com/my1963/

Larbie, L. (2014, December 16). KCB Launches Pepea Commuter Card To Ease Consumer Journey. Retrieved January 15, 2016, from http://africabusinesscommunities.com/news/kcb-launches-pepea-commuter-card-to-ease-consumer-journey.html

Lipa na M-PESA. (n.d.). Retrieved November 28, 2014, from http://www.safaricom.co.ke/personal/m-pesa/m-pesa-services/buy-goods-and-services

Manica, L., & Vescovi. (n.d.). Mobile Telephony in Kenya... is it “Making the life better”? Retrieved January 7, 2016, from http://m.it46.se/projects/UNITN_ict4sd/assignments/ICT4SD_manica_vescovi.pdf

Mark, O. (2014, April 30). PesaPrint rolls out cashless fare system for PSVs. Retrieved January 16, 2016, from http://www.businessdailyafrica.com/PesaPrint-rolls-out-cashless-fare-system-for-PSVs/-/1248928/2299172/-/oyo3ekz/-/index.html

McCormick, D., Mitullah, W., Chitere, P., Orero, P & Ommeh, M. (2011, July 14). Paratransit Business Strategies a Bird’s Eye View of Matatus in Nairobi. Retrieved January 11, 2016, from http://repository.up.ac.za/bitstream/handle/2263/17310/McCormick_Paratransit%20%282011%29.pdf?sequence=1&isAllowed=y

McGregor, S., & Malingha, D. (2015, March 26). Traffic Costs Nairobi $570,000 a Day as No. 2 Africa Hub. Retrieved January 15, 2016, from http://www.bloomberg.com/news/articles/2014-03-25/nairobi-traffic-loses-570-000-a-day-as-no-2-africa-hub

The Migration to EMV Chip Technology. (2011). Retrieved January 9, 2016, from http://www.pymnts.com/assets/Shared/Gemalto-EMV-Whitepaper.pdf

The Mobile Boarding Pass - check in on the move and save time. (n.d.). Retrieved January 18, 2016, from http://www.lufthansa.com/de/en/Mobile-Boarding-Pass-available-on-many-routes-worldwide

Mobile services of the airline company Lufthansa. (2013, September 20). Retrieved January 5, 2016, from http://qr.biz/articles/mobile_services_of_the_airline_company_lufthansa/

Murdoch, S., & Anderson, R. (2014). Security Protocols and Evidence: Where Many Payment Systems Fail. Retrieved January 5, 2016, from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiQ59bE_6PLAhWBHxoKHV1JAcoQFggiMAA&url=http%3A%2F%2Fwww.springer.com%2Fcda%2Fcontent%2Fdocument%2Fcda_downloaddocument%2F9783662454718-c2.pdf%3FSGWID%3D0-0-45-1486988-p177071689&usg=AFQjCNGRe_I2A16hJf2H5WDuTQ9ES2gbqw

Mwaniki, C. (2014, January 2). Matatus sign to M-Pesa ahead of cash fare ban. Retrieved November 28, 2014, from http://www.businessdailyafrica.com/Matatus-sign-to-M-Pesa-ahead-of-cash-fare-ban/-/539552/2132510/-/12ollnf/-/index.html

Mwenesi, S. (2014, June 5). KCB, KBS partner for Abiria card fare payment platform. Retrieved January 4, 2015, from www.humanipo.com/news/44820/kcb-kbs-partner-for-abiria-card-fare-payment-platform/

National Spatial Data Infrastructure Framework Data. (2011). Framework Data Content Standard – Transportation: Transit. Retrieved January 10, 2016, from https://www.fgdc.gov/training/nsdi-training-program/materials/framwork-training-transportation-transit.pdf

The National Transport and Safety Authority Act. (2012). Retrieved August 12, 2015, from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwj27K7UnOvLAhXBORQKHdRQD5EQFggjMAE&url=http%3A%2F%2Fkenyalaw.org%3A8181%2Fexist%2Frest%2F%2Fdb%2Fkenyalex%2FKenya%2FLegislation%2FEnglish%2FActs%2520and%2520Regulations%2FN%2FNational%2520Transport%2520and%2520Safety%2520Authority%2520Act%2520No.%252033%2520of%25202012%2Fdocs%2FNationalTransportandSafetyAuthorityAct33of2012.pdf&usg=AFQjCNFsDF86any00b0giU9YrYksZHJRYA

Near Field Communication: Advantages and Disadvantages. (2012). Retrieved June 12, 2015, from http://near-field.blogspot.co.ke/p/pros-cons.html

Newcombe, T. (2015, March 25). 3 Advances in Transit Technology. Retrieved January 16, 2016, from http://www.govtech.com/dc/articles/3-Advances-in-Transit-Technology.html

Nyasetia, O.B. (2013). The Influence of Entrepreneurial Personality, Human Capital and Entry Barriers on Performance of Entrepreneurs in the Informal Transport Business in Nairobi, Kenya. Retrieved January 7, 2016, from http://chss.uonbi.ac.ke/sites/default/files/chss/Otachi%20Thesis%2020.11.13%20%28Final%20%20document%20to%20BPS%29a.pdf

Ommeh, M., McCormick, D., Mitullah, W., Orero, R., & Chitere, P. (2013). The Politics Behind the Phasing Out of the 14-seater Matatu in Kenya. Retrieved September 15, 2015, from http://www.wctrs-society.com/wp/wp-content/uploads/abstracts/rio/selected/2864.pdf

Omwenga, M. (2011). Integrated Transport System for Liveable City Environment: A Case Study of Nairobi Kenya. Retrieved January 30, 2016, from http://www.isocarp.net/data/case_studies/2022.pdf

Otieno, M. (2015, October 29). MercatorNet: Nairobi's matatus: in the midst of chaos, a transport system that works. Retrieved January 13, 2016, from http://www.mercatornet.com/harambee/view/nairobis-matatus-in-the-midst-of-chaos-a-transport-system-that-works/17093

Puhe, M., Edelmann, M., & Reichenbach, M. (2014). Integrated urban e-ticketing for public transport and touristic sites. Retrieved January 16, 2016, from http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/513551/IPOL-JOIN_ET%282014%29513551_EN.pdf

QR Code® Essentials. (2011). Retrieved June 12, 2015, from http://www.nacs.org/LinkClick.aspx?fileticket=D1FpVAvvJuo=&tabid=1426&mid=482

Rajasekar, S., Philominathan, P., & Chinnathambi, V. (2013, October 14). Research Methodology. Retrieved January 26, 2016, from http://arxiv.org/pdf/physics/0601009.pdf

Safaricom Introduces Lipa Na M-Pesa Service. (2013, June 28). Retrieved December 20, 2014, from http://paymentsafrika.com/payment-news/mobile/safaricom-introduces-lipa-na-m-pesa-service/

Sato, N. (2013, September 27). Kenyans to pay "matatu" fare with Lipa Na M-Pesa. Retrieved November 28, 2014, from www.humanipo.com/news/33067/kenyans-to-pay-matatu-fare-with-lipa-na-m-pesa/

Sengupta, S. (2015, February 11). Open Transit Data for India. Retrieved January 10, 2016, from datameet.org/2015/02/11/open-transit-data-for-india/

SIM Toolkit (STK). (n.d.). Retrieved January 17, 2016, from https://www.techopedia.com/definition/30501/sim-toolkit-stk

Simard, Y. (2012, September 4). The Risks and Advantages of NFC Technology. Retrieved January 17, 2016, from http://tech.co/risks-advantages-nfc-technology-2012-09

Smiley, S. (2014, November 12). Understanding Near-Field and Far-Field Antennas. Retrieved June 12, 2015, from blog.atlasrfidstore.com/near-field-vs-far-field-rfid-antennas

Soon, T.J. (2008). QR Code. Retrieved January 10, 2016, from https://foxdesignsstudio.com/uploads/pdf/Three_QR_Code.pdf

Sunday, F. (2015, June 3). Smartphones dominate Kenya's mobile phone sales. Retrieved January 17, 2016, from http://www.standardmedia.co.ke/business/article/2000164434/smartphones-dominate-kenya-s-mobile-phone-sales

Tarantola, A. (2012, December 18). How QR Codes Work and Why They Suck So Hard. Retrieved June 29, 2015, from http://gizmodo.com/5969312/how-qr-codes-work-and-why-they-suck-so-hard

Thrasher, J. (2013, October 11). RFID vs. NFC: What's the Difference? Retrieved January 18, 2016, from blog.atlasrfidstore.com/rfid-vs-nfc

TransGironde - Online reservation and QR Code tickets. (n.d.). Retrieved January 9, 2016, from http://www.cityway.company/references/transgironde/

Transport for Edinburgh Mobile Ticketing Terms & Conditions. (n.d.). Retrieved January 18, 2016, from http://lothianbuses.com/tickets/m-tickets/m-tickets-terms-and-conditions

Tsiluma, V. (n.d.). How Lipa Na MPESA Service By Safaricom Company Works In Kenya. Retrieved November 28, 2014, from www.zakenya.com/business/how-lipa-na-mpesa-service-by-safaricom-company-works-in-kenya.html

Van, D., & Jorstad, I. (2005). The mobile phone: Its evolution from a communication device to a universal companion. Retrieved January 10, 2016, from https://www.telenor.com/wp-content/uploads/2012/05/T05_3-4.pdf

Vanishree, & Sunitha. (2014). Encryption and decryption of data using Quick response code. Retrieved October 10, 2015, from http://www.irdindia.in/journal_ijraet/pdf/vol2_iss3/8.pdf

Viswanathan, P. (2014, February 6). Near Field Communication: Pros and Cons. Retrieved January 16, 2016, from http://mobiledevices.about.com/od/additionalresources/fl/Near-Field-Communication-Pros-and-Cons.htm

Want, R. (2006). An Introduction to RFID Technology. Retrieved June 15, 2015, from https://www.cs.cmu.edu/~15-821/CDROM/PAPERS/want2006.pdf

Wanzala, J. (2014, December 20). Cooperative Bank bets on close links with Saccos to unveil cashless system. Retrieved January 15, 2015, from http://www.standardmedia.co.ke/business/article/2000145383/coop-bank-bets-on-close-links-with-saccos-to-unveil-cashless-system

What is a QR Code? (n.d.). Retrieved January 11, 2016, from http://www.qrcode.com/en/about/

Who we are. (n.d.). Retrieved January 25, 2016, from http://www.ntsa.go.ke/index.php?option=com_content&view=article&id=88&Itemid=486

World Bank. (2002, October 30). Scoping study Urban mobility in three cities. Retrieved January 15, 2015, from https://openknowledge.worldbank.org/bitstream/handle/10986/17691/273240PAPER0SS110Scoping0Study1web1.pdf?sequence=1&isAllowed=y

Wozniaki, T. (n.d.). Benefits of Near Field Communication. Retrieved January 12, 2016, from http://www.nearfieldcommunicationnfc.net/benefits.html

Zab, S. (2015, June 2). Whitepaper: The Growth of the Smartphone Market in Kenya. Retrieved January 11, 2016, from https://www.jumia.co.ke/blog/whitepaper-the-growth-of-the-smartphone-market-in-kenya/

Zuidgeest, H. M. (2005). Sustainable Urban Transport Development:A dynamic Optimisation approach. Retrieved January 15, 2016, from http://doc.utwente.nl/57439/1/thesis_Zuidgeest.pdf

APPENDIX A: Sample Questionnaire

KommutePal Questionnaire

KommutePal is a mobile application that has been designed for PSVs to facilitate cashless means to settle and collect fare, and keep daily track of income earned. Moreover, the mobile application provides a cost-efficient alternative to cashless systems that are already in use in some PSVs. The main aim of this survey is to find out how a mobile application can be used to aid in cashless transactions and modernize operations in PSVs. Your feedback will be highly appreciated.

1. Please tick appropriate category as a respondent.

a) Passenger ( )
b) Conductor ( )
c) PSV owner ( )

2. Have you experienced any challenges settling fare using cash in PSVs?

a) Yes ( )
b) No ( )

If Yes from the table below please tick the problem (s) that you have experienced

Problem	Tick appropriate
Delays in getting back change	☐
Not getting change back	☐
Theft	☐
Others	☐

3. Are you familiar with cashless systems that have been rolled out in PSVs?

a) Familiar ( )
b) Not familiar ( )

4. Do you agree that cashless systems will streamline operation in PSVs?

a) Strongly disagree ( )
b) Disagree ( )
c) Neutral ( )
d) Agree ( )
e) Strongly agree ( )

5. What type of phone do you own?

a) Basic phone ( )
b) Smart phone ( )
c) Do not own one ( )

6. Which Operating System runs on your phone?

a) Apple iOS ( )
b) Android ( )
c) Symbian ( )
d) Blackberry ( )
e) Others ( )

7. If you selected respondent is *passenger* in question 1 above

Would you use a mobile application to settle fare in PSV?

a) Yes ( )
b) No ( )

8. If you selected respondent is *conductor* in question 1 above

Would you use a mobile application in collection of fare in PSV?

a) Yes ( )
b) No ( )

9. If you selected respondent is *PSV owner* in question 1 above

Would you support use of a mobile application in keeping track of collection in PSV?

a) Yes ( )
b) No ( )

Thank you for your time in filling this questionnaire. Be assured that any information you provided will be considered only for the purpose of this research and will be considered private and confidential.

APPENDIX B: Post Test Questionnaire

1) Tick your gender?
   ( ) Male
   ( ) Female
2) Does the application look good?
   ( ) Yes
   ( ) No
   ( ) Neutral
3) How easy is it to use the mobile application?
   ( ) Very easy to use
   ( ) Easy to use
   ( ) Hard to use
   ( ) Very hard to use
4) Can you use the application without instruction?
   ( ) Yes
   ( ) No

Thank you for participating in this survey

APPENDIX C: More Screenshots

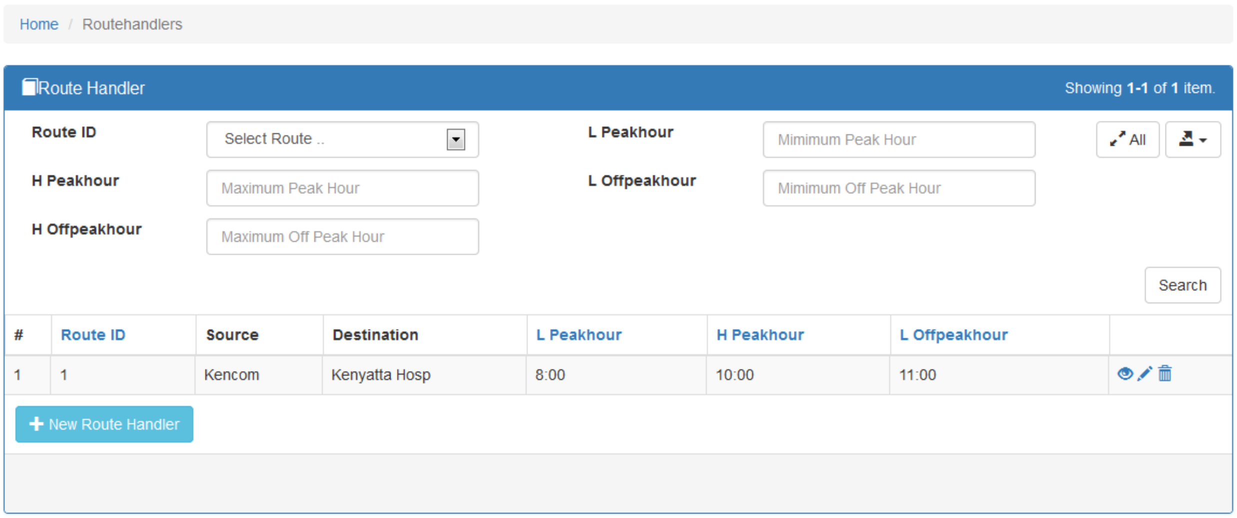


Figure C 1: Add New Route Handler

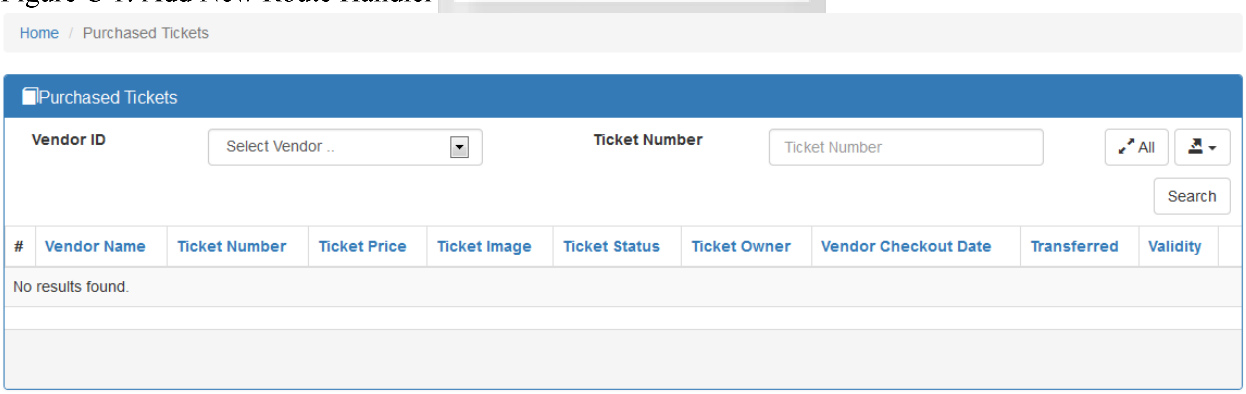


Figure C 2: View Purchased Tickets

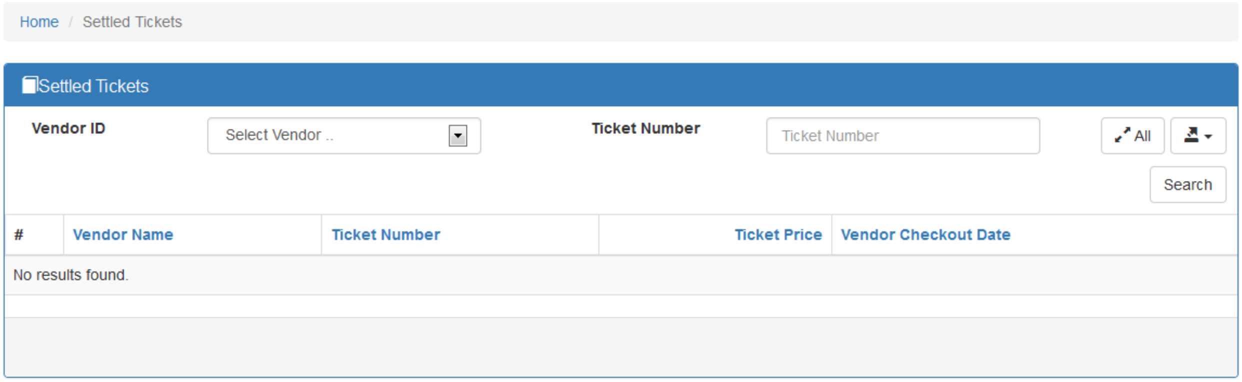


Figure C 3: View Settled Ticket

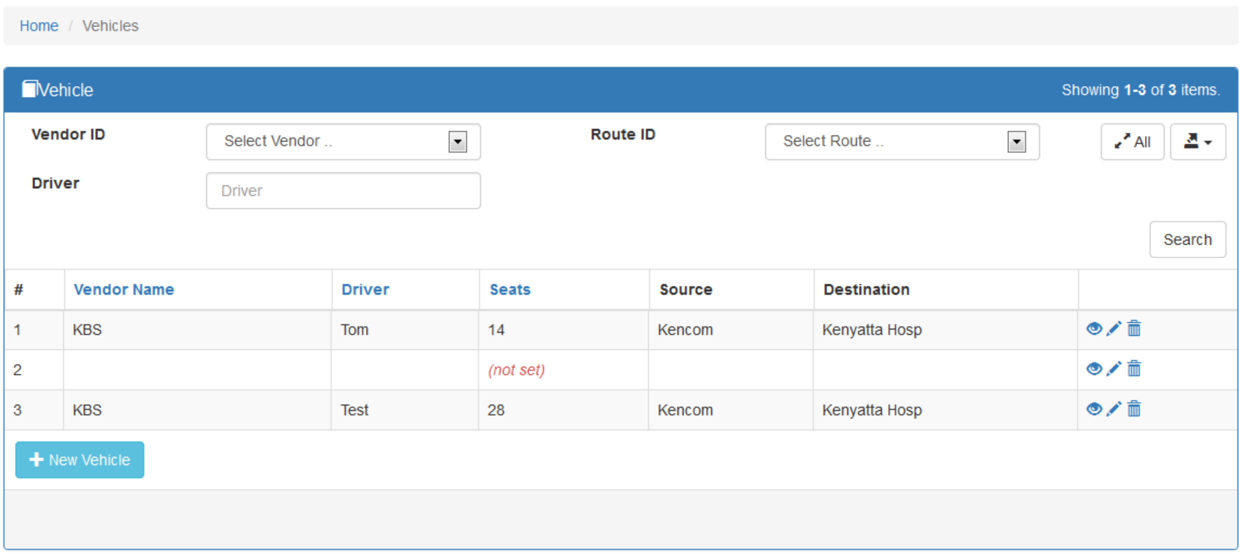


Figure C 4: Add New Vehicle

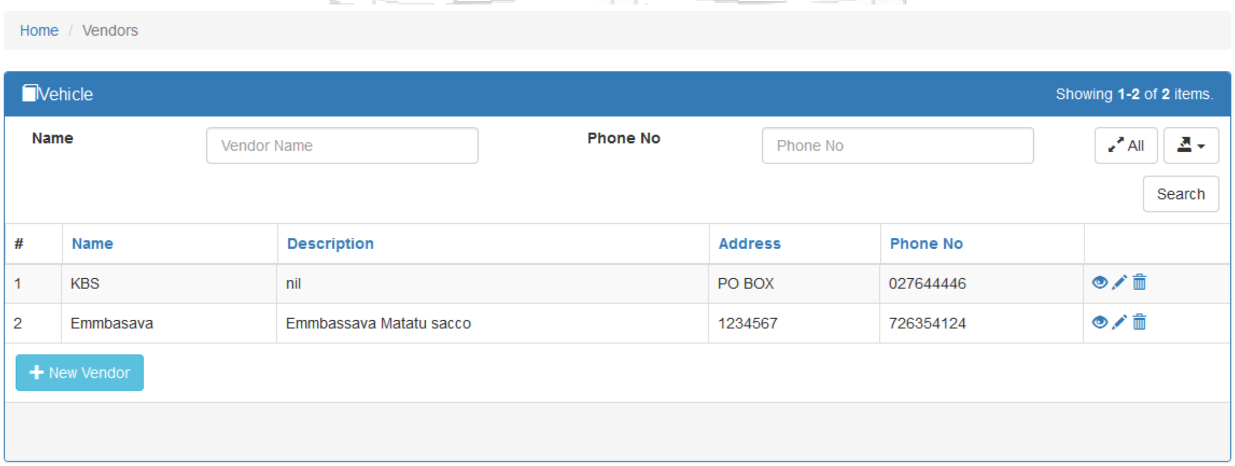


Figure C 5: Add New Vendor

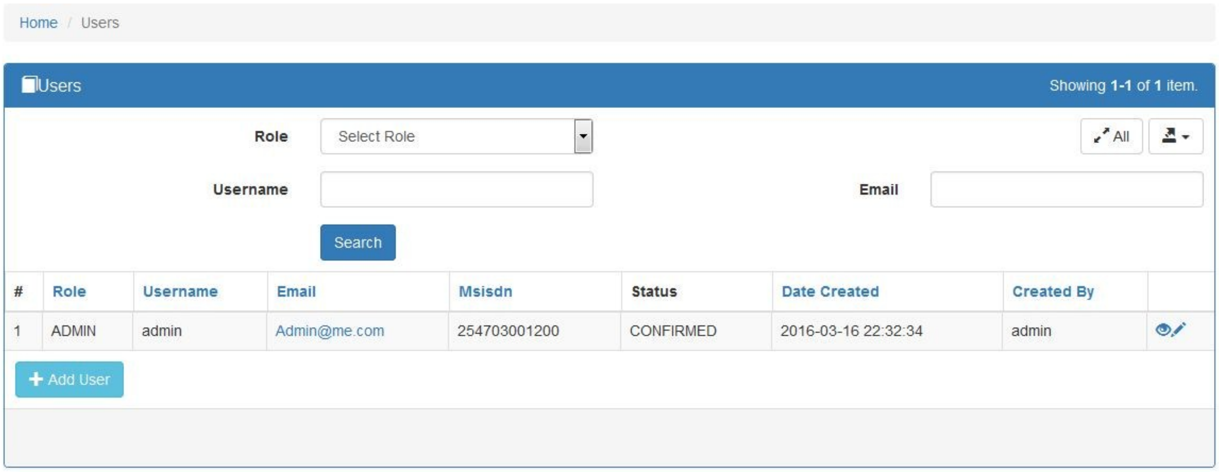
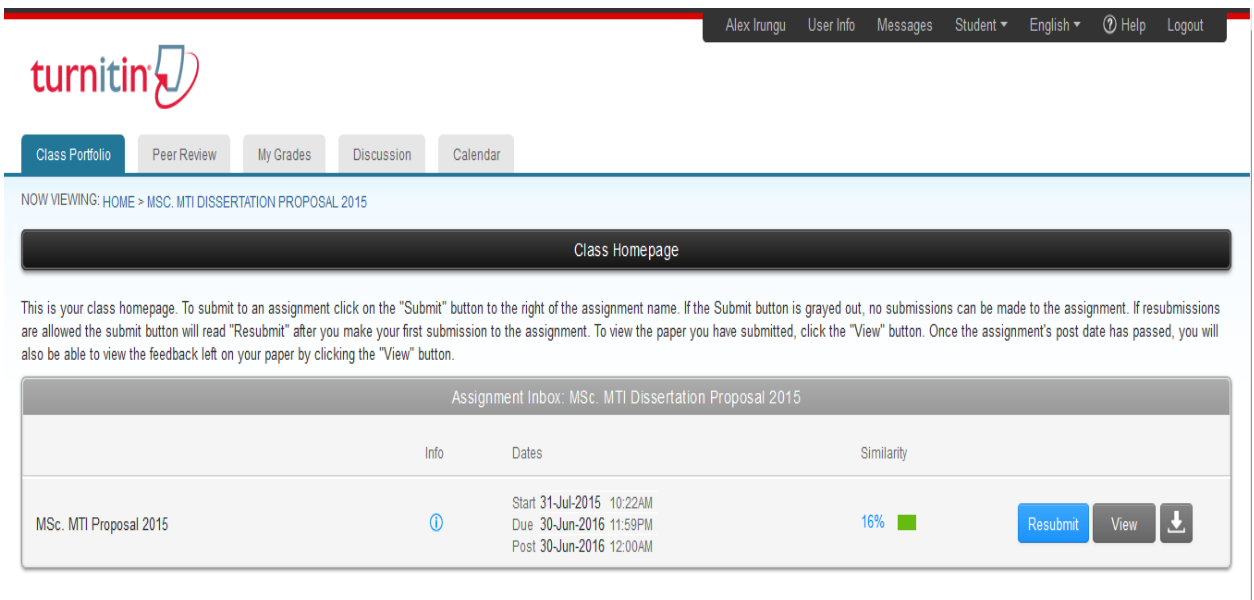


Figure C 6: Add New User

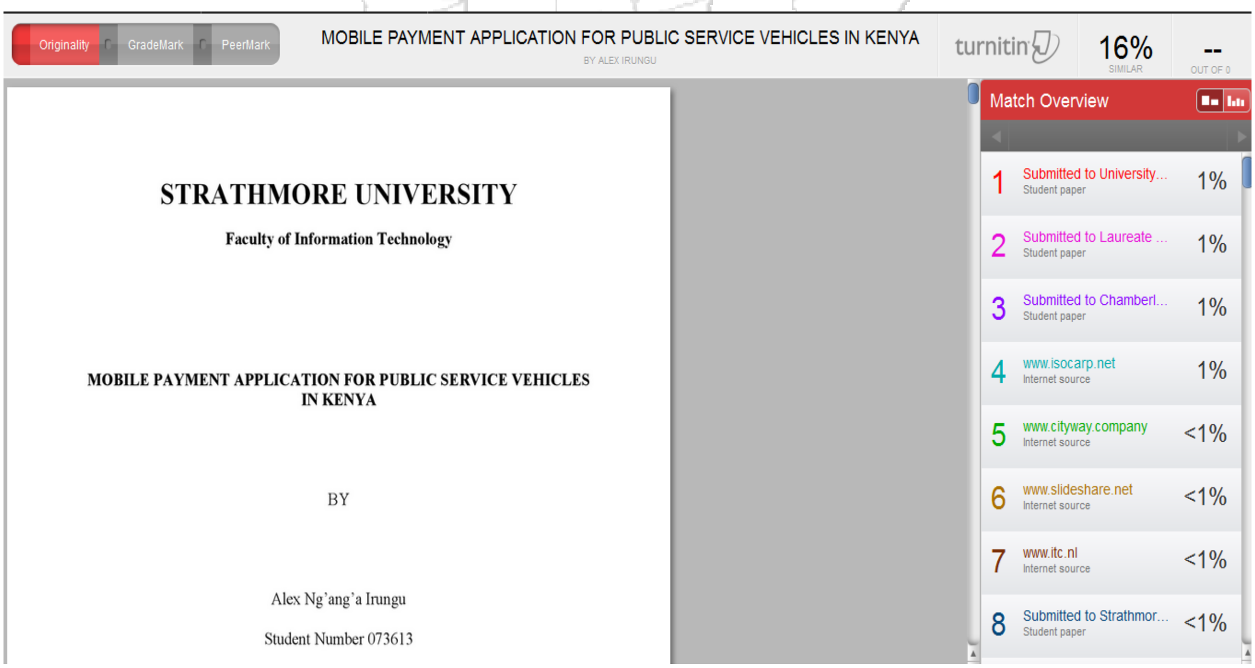
APPENDIX D: Turnitin Report

The TURNITIN report returned a similarity report of 16% which is below the acceptable similarity of maximum of 40% required by the Strathmore University Graduate School for plagiarism check.

Result of Similarity



Screenshot of Matches



turnitin Originality Report

Processed on: 11-Apr-2016 1:30 PM EAT
ID: 656397904
Word Count: 17762
Submitted: 2

Document Viewer

MOBILE PAYMENT APPLICATION FOR PUBLIC SERVICE...
By Alex Irungu

Similarity Index	Similarity by Source	
16%	Internet Sources:	10%
	Publications:	4%
	Student Papers:	12%

exclude quoted   exclude bibliography   exclude small matches

mode: show highest matches together

STRATHMORE UNIVERSITY Faculty of Information Technology MOBILE PAYMENT APPLICATION FOR PUBLIC SERVICE VEHICLES IN KENYA BY Alex Ng'ang'a Irungu Student Number 073613 Supervisor Dr. Humphrey Njogu June, 2016

Submitted in partial fulfillment of the requirements of Masters of Science Degree in Mobile Telecommunication Innovation DECLARATION AND APPROVAL This research proposal is my original work, [54]

except where due acknowledgement is made in the text, and [125]

to the best of my knowledge has not been previously submitted to Strathmore University or

any other institution for the award of a degree or diploma. [119]

Name: Registration number: Alex Ng'ang'a Irungu 073613 Signature: ______________________Date: ________________ TITLE OF DISSERTATION: A mobile payment application for public service vehicles in Kenya PROGRAMME: Masters of Science Degree in Mobile Telecommunication Innovation SUPERVISOR CONFIRMATION: This dissertation has been submitted to Strathmore University by my approval as the supervisor: Name: Dr. Humphrey Njogu Supervisor: _____________________Date: __________________ i ACKNOWLEDGMENTS

I would like to express my gratitude to my supervisor Dr. Humphrey Njogu for his tireless support and guidance throughout the research process. I would also like to [58]

appreciate Mr. Martin Kabachia and Mr. Dominic Kanake for their invaluable assistance during the project work. In addition,

1. 1% match (Internet from 12-May-2013) http://www.isocarp.net
2. < 1% match (Internet from 01-Feb-2016) http://www.cityway.company
3. < 1% match (student papers from 11-Nov-2013) Submitted to University of Greenwich
4. < 1% match (student papers from 24-Nov-2013) Submitted to Chamberlain College of Nursing
5. < 1% match (student papers from 09-Jun-2015) Submitted to University of Greenwich
6. < 1% match (Internet from 10-Dec-2015) http://www.pondiuni.edu.in
7. < 1% match (Internet from 24-Feb-2012) http://www.slideshare.net
8. < 1% match (student papers from 13-Feb-2016) Submitted to Laureate Higher Education Group

Digital Receipt

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Alex Irungu
Assignment title:	MSc. MTI Proposal 2015
Submission title:	MOBILE PAYMENT APPLICATION F...
File name:	Alex_Irungu_073613_KommutePal_..
File size:	2.39M
Page count:	102
Word count:	17,762
Character count:	118,545
Submission date:	11-Apr-2016 01:19PM
Submission ID:	656397904

VT OMNES VNVM SINT