PASSENGER AND LUGGAGE TRACKING SYSTEM USING SENSOR NETWORKS FOR PUBLIC TRANSPORT

By

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DECLARATION

I, the undersigned, declare that this has not previously been submitted in candidature for any degree. The dissertation is the result of my work and investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. A complete list of references is appended.

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CERTIFICATE OF APPROVAL

This document prepared by GEORGE KASANGA is approved as fulfilling the requirements for the award of the degree of Masters of Engineering in Information and Communication Technology Security by University of Zambia

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DEDICATION

I dedicate this research to my parents, Edmond and Catherine Kasanga for their untiring support, for always challenging my perceptive of reality and believing in my dreams, my sisters Clara, Chishimba and Chola have always been my pillars and cheerleaders we celebrated every little victory along this journey. Last but not the least the woman am spending the rest of my earthling days with Cecilia Banda thank you for been understanding, supportive and strong for us when all strength in me wanted to give up.

GLOSSARY

Abbreviation	Description
ERD	Entity Relationship Diagram
OO	Object-Oriented
OOP	Object-Oriented Programming
OOSD	Object-Oriented Software Development
OOSDM	Object-Oriented System Development Methodology
RF	Radio Frequency
RFID	Radio Frequency Identification
SDLC	System Development Life Cycle
GSM	Global System for Mobile Communications
UML	Unified Modelling Language
WSN	Wireless Sensor Network
SMS	Short Message Service
GPRS	General Packet Radio Service
WSN	Wireless Sensor Network
IOT	Internet of Things
WWW	World Wide Web
TAM	Technology Adoption Model

ABSTRACT

Technology has revolutionized communication and how services can be delivered to the intended end-users, luggage tracking systems are becoming more important for travellers as an extra security measure to ensure they retrieve their belongings, they make use of many different technologies to help track and identify bags from GPS location to close range radio frequencies. The study reports results from members of the public, bus operators, and local authorities from the council. The study aimed at developing a prototype system to be used for luggage tracking using wireless sensor network at the intercity bus terminus, the results showed 28 Percent of the sample population acknowledged to have misplaced or lost luggage during a journey, the study further shows the current IT infrastructure capacity of bus operators to adopt technology in their operations. With the help of local authorities, the current business process was understood and design considerations were based on already deployed luggage tracking and unique user requirements. OOSDM was adopted for the development process which led to the creation of use cases, class diagrams, sequence diagrams and entity Relationship Diagrams. A prototype was implemented and tested using RFID, Arduino UNO R3, SIM808, sensors and a web-based interface.

Keywords: Luggage Tracking, Public transport, RFID, TAM, OOSDM, WSN, Intercity bus terminus.

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CHAPTER ONE:

INTRODUCTION TO THE RESEARCH

1.1 Introduction

In this chapter, the research study is introduced. The motivation and significance of the research are covered. The scope, problem statement and aim are given. This is then followed by the objectives, research questions and the research contributions. Finally, the organization of the dissertation and a summary of the chapter are presented.

1.2 Introduction to the Research Study

We live in a World of Sensors. You can find different types of Sensors in our homes, offices, cars etc. working to make our lives easier by turning on the lights by detecting our presence, adjusting the room temperature, detect smoke or fire, open garage doors as soon as a car is near the door and many other tasks.

A sensor is a device that measures physical input from its environment and converts it into data that can be interpreted by either a human or a machine [1]. Most sensors are electronic (the data is converted into electronic data), the most frequently used different types of sensors are classified based on the quantities such as Electric current or Potential or Magnetic or Radio sensors, Humidity sensor, Fluid velocity or Flow sensors, Pressure sensors, Thermal or Heat or Temperature sensors, Proximity sensors, Optical sensors, Position sensors, Chemical sensor, Environment sensor, Magnetic switch sensor.

Speed Sensors used for detecting the speed of an object or vehicle is called a Speed sensor. There are different types of sensors to detect the speed such as Wheel speed sensors, speedometers [2].

Passive Infrared (PIR) Sensor used for measuring the infrared light radiation emitted from objects in its field of view is called as a PIR sensor Every object that has a temperature above absolute zero emit heat energy in the form of radiation radiating at infrared wavelengths which is invisible to the human eye but can be detected by special purpose electronic devices such as PIR motion detectors. Automatic Door Opening System is a typical application of PIR sensors which is intended for automatic door closing and opening operations based on body movement near the door. PIR-sensor-based-automatic-door- opening system circuit mainly consists of a PIR sensor, an 8051 microcontroller, a driver IC, a door motor [3].

Weight Sensors used to measure weight are referred to as load cells or force sensors. There are many different types of load cells, they measure weight based on the amount of compression which is detected by the sensors within the cells. Very often strain gauges are used for this process. Different types of load cells are suitable for different capacities. Some common applications for load cells are; On-board weighing - the process of weighing the capacity of what is on-board a truck, lorry or vehicle. Platform scales - used within warehouses to measure the weight of pallets or boxes [4].

Magnetometer Sensor a device that measures the magnetism direction, strength, or relative change of a magnetic field at a particular location. The measurement of the magnetization of a magnetic material Smartphones uses built-in magnetometers to measure magnetic fields and determine which way is north through the current from the phone itself[5].

Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation, and wireless communications capabilities. These sensors can communicate either among each other or directly to an external base station [6].WSNs have been widely adopted in many areas such as;

i) Distribution supply chain and logistics

ii) Industrial tracking and visibility

iii) Location awareness and safety

iv) Data centre resource management

Luggage Tracking has been widely adopted in the aviation industry, this is due to high volumes of domestic, commercial and cargo flights carrying goods and luggage destined to various parts of the world, to minimise incidences of delayed, lost luggage and been placed on a wrong flight.

The study focuses on public transportation in Zambia, the most common mode of transportation been by road, buses are readily available for short and long-distance travel, the study further focuses on intercity bus terminus in Lusaka, to understand the current business process, management of luggage and the supporting ICT infrastructure concerning luggage tracking from the source to the destination.

1.3 Statement of the Problem

The 2019 Global innovation index ranks Zambia 124 out of 129 countries [7], despite the recognition of ICT's as enablers for social and economic development. Public transportation has not made much use of technology to improve the provision of services, there is little research that has been conducted in developing a luggage tracking system for the public transportation sector in Zambia. Therefore, this study investigates sensor network technologies and applications to develop a luggage tracking system for the public transport sector.

1.4 Aim

The study aims to design and develop a passenger luggage system, system models and a prototype to aid bus operators in managing passenger luggage to improve accountability and reduce lost customer luggage incidences.

1.5 Objectives

The specific objectives that will enable the achievement this objective are as follows:

i) Assess the level of usage and adoption of technology among operators and passengers.

ii) Analyse technologies, topologies and applications of sensor networks for tracking systems.

iii) Develop a sensor network luggage tracking system for the public transport sector.

1.6 Research Questions

This research was guided by the following research questions:

i) What are the challenges faced by bus operators and passengers in adopting new technology?

ii) How can the business processes for tracking Passenger luggage be designed?

iii) How can the firmware for the passenger luggage tracking system, in (ii) be implemented?

1.7 Motivation and Significance of the Study

Zambia like many other developing countries is making strides in the usage of technology, to improve service delivery to the members of the public by improving workflows, reducing ques, decentralising operations and promoting the use of online services as opposed to paper-based operations, this is evident from the smart Zambia initiative fostering E-government and our seventh national development plan promoting innovation as well as improving ICT infrastructure. The study will explore how technology can be incorporated in the operations of intercity bus terminus, in the bid to improve luggage management at our bus stations and customer experience, by providing a prototype system to help operators and passengers in tracking and monitoring valuable luggage throughout the journey, this opens an avenue for further research and adding to the body of existing knowledge.

1.8 Scope

The research was conducted in Lusaka, the capital city of Zambia. A baseline study was done at the intercity bus terminus, which is our biggest bus station for buses that make trips to other cities and towns within Zambia as well as neighbouring countries. A detailed literature review of RFID technology, sensors sensor networks their applications in luggage tracking and management was conducted to determine the most cost-effective and efficient method to implement the system.

1.9 Research Contributions

The business processes that will enable automation of the public transportation passenger luggage management system from the current manual-based processes were mapped. Implementation of the RFID firmware using C++ language for the intercity bus terminus passenger luggage management was done. Some of this work has been published in the Proceedings of the international conference in ICT (ICICT2019) See the list of publications in the appendix for the research articles published from this work.

1.10 Organization of Dissertation

The work done in this dissertation is organised into five chapters. Chapter 1 is the Introduction to the Research. In this chapter, a brief overview of the work in this dissertation is given. Then the problem statement, aims and motivation are presented. This chapter concludes by giving an outline of the dissertation.

Chapter 2 looks at the background theory and related works. In this chapter, a comprehensive review and the background theory of Radio Frequency Identification, Wireless Sensor Networks, GSM, GPRS and IoT are given. Related works regarding object tracking, event notification and management are presented. The research methodology is given in Chapter 3. In this chapter, the methods used to conduct the baseline study and implement the system are presented. In Chapter 4, the research findings of the baseline study and the system implementation are presented.

Finally, in Chapter 5 the discussion and conclusion are given.

1.11 Summary

In this chapter, the basic introduction of the work in this dissertation was given. The luggage management highlighting challenges globally, regionally and narrowed it down to Zambia, was discussed. The motivation, significance and scope of the work in this study were then outlined. Finally, the problem statement outlined the aims, the research contributions were given and the chapter was closed with the outline of the dissertation.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature and the works related to this research study are reviewed. Firstly, an extensive review of Radio Frequency Identification and how it can be used to improve operational efficiency through computerised luggage management is carried out. This is followed by a brief review of Wireless Sensor Networks, GSM, GPRS and IoT. Also, a review of the software development approaches is presented in the following section. Lastly, this chapter closes by looking at related works to Passenger luggage tracking, and management.

2.2 Review of Literature

2.2.1 Radio Frequency Identification (RFID)

RFID is a non-contact, programmed automatic identification technology that utilizations radio signal to distinguish, track, sort and identify an assortment of articles including individuals, vehicles, merchandise and resources without the requirement for direct contact (as found in magnetic stripe technology) or line of sight contact (as found in bar code technology). RFID innovation can follow the developments of items through a system of radio-empowered examining gadgets over the separation of a few meters. A gadget called an RFID tag is a key segment of the innovation. An RFID tag normally has at any time two components, an integrated circuit and antenna for getting signals [6]. Figure 2.1 shows the components that constitute an RFID system.

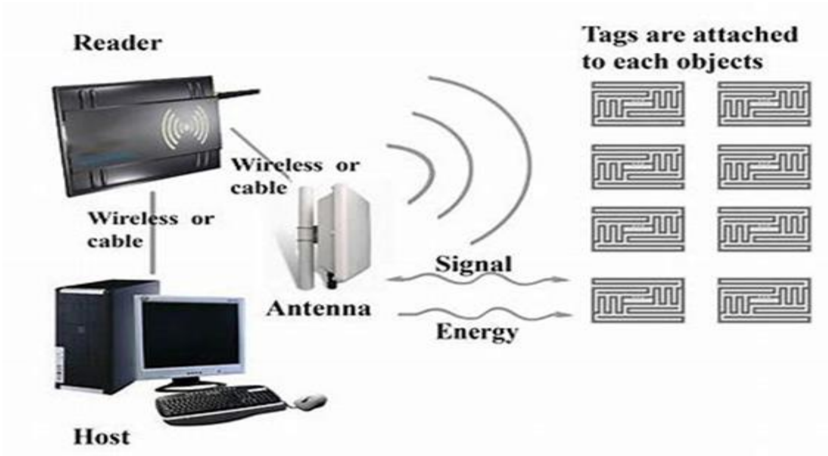


Figure 2.1: Shows the components that constitute an RFID system [11].

RFID ta can be inserted in an article or can be put inside a package [8]. A regular RFID framework establishes four essential segments including RFID Tags, readers, antenna and a central node. A computer system that may house the database server and management software (middleware) [6] as shown in Figure 2.1.RFID operates at different frequency bands which are categorized as low, high and ultra-high [9].

i) Low frequency: provides a frequency band 30 kHz to 300 kHz (read range between 0 cm and 100 cm), reading is too slow but the data rate of piracy is moderate compared to other frequencies during playback.
ii) High frequency: frequency band 3 MHz to 30 MHz (read range between 10 cm and 1m), read speed is fast but the piracy rate is higher compared to the low frequency.
iii) Ultra-high frequency: frequency band 300 MHz to 3 GHz (the reading distance can exceed 15 meters), the playback speed is faster, but the piracy rate is still higher compared with the high frequency, this frequency is used nowadays in different logistics firms, particularly in the area of storage, inventory and stock management.

A powerful RFID tag can prevent RFID readers without special permission (access control or right frequency) to read the content. [10] There are 2 main categories of RFID tags, they can be either passive or active [12]: Passive tag: uses waves to transmit information through the energy transmitted by the reader, which supplies the on-board electronic circuits. Active Tag: usually embeds a source of internal energy (battery with up to 10 years autonomy), it sends the various information stored on the electronic circuit to the RFID server. A hybrid tag can be considered a comparison of features among active, semi-passive and passive tags is made.

Table 2.1: Active vs. Passive vs. Semi-Passive Tags [13]

Feature	Passive	Active	Semi-Passive
Read Range	Short(Up to10cm)	Long(Up to100m)	Long(Up to100m)
Battery	No	Yes	Yes
Life Validity	Up to 20 years	Between 5- 10years	Up to 10 years
Storage	128 bytes read/write	128 bytes read/write	128 bytes read/write
Cost	Cheap	Very Expensive	Expensive
Application	Attendance Management System	Monitor the condition of fresh produce	Measurement of temperature periodically

2.2.2 RFID Tag

The RFID tag or transponder is the data carrier that transmits information to the RFID reader (transceiver) within a given range through a microchip and antenna embedded in it [16] [24] [25] [26]. A microchip in the tag stores a unique serial number or other information based on the tag's memory type, which can be read-only, read-write or write-once-read-many [26]. The microchip-an Integrated Circuit (IC) has unique hexadecimal or Electronic Product Code (EPC) contained in it. The antenna which is attached to the microchip in the tag transmits information from the chip to the reader. A larger antenna indicates a longer read range [24] [25] [26].

The tag is attached to or embedded in an object to be identified such as a product, box, or pallet [26]. The tags can be scanned by mobile or stationary readers using radio waves [26]. The RFID tag forwards the information to a host computer which houses the database through the RFID reader [24] [25] [26]. Tags may vary by the amount of information they can hold, life expectancy, recycle ability, attachment method, usability, and cost.

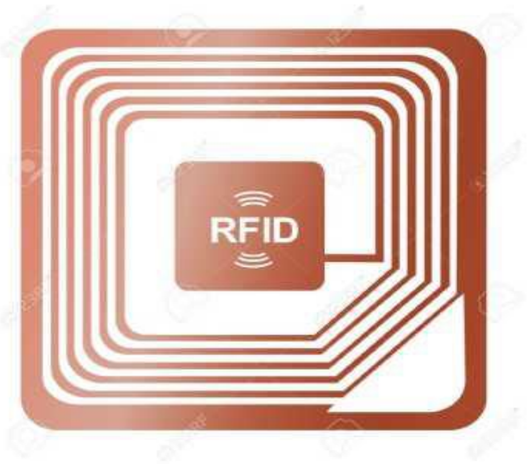


Figure 2.2: RFID Tag [27]

Electronic Product Code (EPC) is a 64 bit or 98-bit code electronically recorded on an RFID tag and intended to design improvement in the EPC barcode system. EPC code can store information about the type of EPC, unique serial number of product, its specifications, manufacturer information etc. EPC was developed by Auto-ID centre in MIT in 1999.

The Electronic Product Code (EPC) is the code that is used for automatic and unique identification of objects such as parts, products, pallets, locations and so on. It is a standard product coding structure for item management applications [30]. EPC is the standard designed to allocate a unique identifier to each object. EPC comprises four sequences of binary digits, these include [41]:

i) an eight-bit header,

ii) the EPC manager (28 bits),

iii) the product type (24 bits) and,

iv) A serial number of the product (36 bits).

EPC global Inc. oversees the development of the EPC Standard [41]. Figure 2.3 shows an example of an EPC. The development of the Electronic Product Codes (EPC) was initiated by the auto-ID centre in 1999 [42].

Figure 2.3: EPC example [41]

2.2.3 RFID Reader

The second component of an RFID system is the reader. It consists of an antenna, a decoder and a transceiver. The reader is also known as a transceiver. This means that it’s a combination of a transmitter and a receiver. The readers’ role is to query a tag and receive data from it [42]. A reader uses its built-in antenna to communicate with the tag. When a reader broadcasts its radio waves, all the tags were chosen to respond to that frequency and within the range of the reader will respond. A reader can communicate with tags without a direct line of sight depending on the radio frequency and type of tag used. Readers can process several items at once, this allows for increased read and processing times [44]. Readers convert radio waves from tags into a form that can be passed to middleware. Readers accomplish two tasks, these include, receiving commands from the application software and communicating with tags [42]. Readers fall into two categories. These are active and passive readers. Active readers can detect an active tag at a few meters to the line of sight. The passive reader, on the other hand, can only detect passive tags at a few centimetres away from itself [43]. Readers contain built-in anti-collision schemes. A single reader can operate on multiple frequencies. Readers can be used as standalone electronic devices or can be integrated with other devices. A Reader consists of components such as power for running the reader, a communication interface, a Microprocessor, channels, a controller, a receiver, a transmitter, and memory built into it [45].

A reader can be fixed in a suitable place or hand-held. A hand-held reader is a small, mobile, lightweight device that is used to receive information from the tag as one moves along

2.2.4 Central Node (Middleware)

Middleware and the database server are at the heart of a comprehensive RFID system [46] [47] [48]. The data transmitted between the tag and reader is not useful for a commercial application unless the immense amounts of information are integrated within a larger system [49]. Middleware, at the central node, manages this incorporation of data. Middleware manages the information exchange between the readers and the backend database server [42]. Middleware between readers and applications comprises two interfaces, namely the application interface and the reader interface, to communicate with the environment [40]. Readers are typically connected through middleware to a backend database. Middleware cleans the data received from communications by eliminating false reads, it also performs aggregation and filtering of data. Furthermore, by monitoring multiple readers, middleware can detect the movement of tags as they pass from the read range of one reader to another [50]. In addition to middleware, servers housing the databases are critical components of a complete RFID system. Computer database servers provide the data storage, management and read-write control of the radio frequency tags. They provide the data obtained from the reader to the software application [51].

2.2.5 RFID Applications

i) Asset Tracking:

Static or in-motion assets tracking or locating, like a healthcare facility, wheelchairs or IV pumps in, laptops in a corporation and servers in a data centre, was not so easy task.

User can instantly determine the general location of tagged assets anywhere within the facility with the help of active RFID technology. Control point detection zones at strategic locations throughout the facility allow the user to define logical zones and monitor high traffic areas. Tagged assets moving through these control points provide instant location data. Asset tracking applications will see an almost vertical growth curve in the coming years and the growth rate in this area will be much higher than the growth rate of the general RFID market.

ii) People Tracking:

People tracking system are used just as an asset tracking system. Hospitals and jails are the most general tracking required places. Hospital uses RFID tags for tracking their special patients. In emergency patient and other essential equipment can easily track. It will be mainly very useful in mental care hospitals where doctors can track every activity of the patient. Hospitals also use these RFID tags for locating and tracking all the activities of newly born babies.

The best use of the people tracking system will be in jails. It becomes an easy tracking system to track its inmates. Many jails of different US states like Michigan, California, and Arizona are already using RFID-tracking systems to keep a close eye on jail inmates.

iii) Document tracking:

This is the most common problem. Availability of a large amount of data and documents brings lots of problem in the document management system. An RFID document-tracking system saves time and money by substantially reducing:

a) Time spent searching for a lost document
b) The financial and legal impact associated with losing documents.

iv) Government library:

Many government libraries use barcode and electromagnetic strips to track various assets. RFID technology uses for reading these barcodes unlike the self-barcode reader RFID powered barcode reader can read multiple items simultaneously. This reduces queues and increases the number of customers using self-check, which in turn will reduce the staff necessary at the circulation desks.

v) Healthcare:

Patient safety is a big challenge of healthcare vertical. Reducing medication errors, meeting new standards, staff shortages, and reducing costs are the plus points of use of RFID solutions. RFID wristbands containing patient records and medication history address several of these concerns.

vi) Manufacturing & Aerospace:

RFID technology provides an easy way to manage a huge and laborious manufacturing process. It offers all the benefits of small production parts to batch, processes and manufacturing. This type of process helps in better analysis, reduce and eliminate bottlenecks, reduced time in locating parts and products and production process based sensors can be installed to alert any anomalies. Aerospace industry and the Department of Defence have a lot to gain from RFID integration into their production and process lines. Boeing and Airbus, according to the direction of US Federal Aviation Administration, make it mandatory to put an appropriate tracking mechanism to track the aircraft parts.

vii) Toll Road Payments

Highway toll payment systems [53], uses RFID technology to electronically collect tolls from passing cars. Instead of stopping at the toll booth, cars pass directly through in the Pass lane and the toll is automatically deducted from a pre-paid card.

2.2.6 Bar Codes

RFID, Barcodes and QR codes are similar in the fact that they are data collection technologies, meaning they automate the process of collecting data. However, they also differ significantly in many areas. Barcodes, QR Codes and RFIDs help to manage and keep track of the inventory.

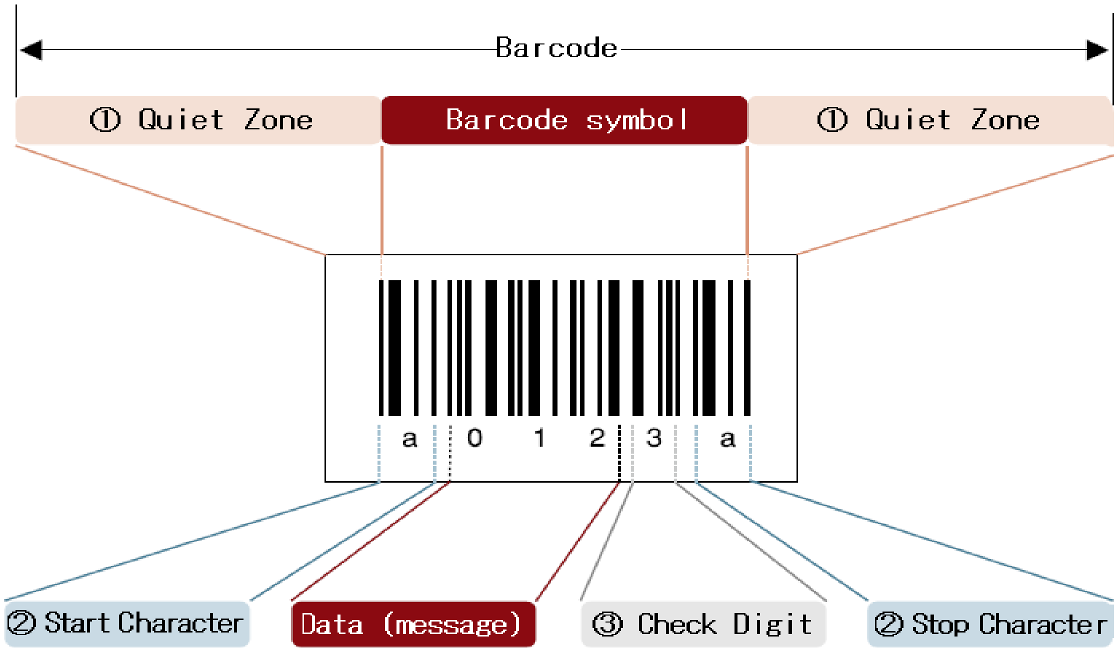


Figure 2.4: Structure of Barcode[41]

i) Structure of Barcode

Quiet Zone: The minimum required space for bar code scan-ability, preceding the Start Character of a bar code symbol. The quiet zone should be free from any printing and be the same colour and reflectance as the background of the barcode symbol. The Quiet Zone should be ten times the width of the narrowest element in the bar code, or 0.25-inch minimum, also known as Clear Area.

Start Code: Indicates the start of the barcode. These are special bar code characters & they signify the start of data to the scanner/reader. Start characters are usually stripped-off and not transmitted to the host.

Check Digit: Check digit (not always present) is a mathematical sum that is used to verify the accuracy of the other elements of the barcode. It is the extra digit added at the end of a bar code to allow the scanner to confirm that it read the bar code correctly. It is typically stripped from the data and not transmitted to the host.

Stop Code: Indicates the stopping point of the barcode. These characters signify the end of data to the scanner/reader. They are also stripped-off and not transmitted to the host.

ii)Operation of Barcode

A laser beam is incident on a mirror/prism which is then directed on the barcode from left to right. The dark bars of barcode absorb the incident light but the light is reflected by light spaces. The photodiode measures the reflected light and gives out an electrical signal. The analogue electrical signal is then converted into a digital one. And the corresponding barcode is read.

2.2.7 QR Code

Bar codes have become widely popular because of their reading speed, accuracy, and superior functionality characteristics. As bar codes became popular and their convenience universally recognized, the market began to call for codes capable of storing more information, more character types, and that could be printed in a smaller space. As a result, various efforts were made to increase the amount of information stored by bar codes, such as increasing the number of bar code digits or layout multiple bar codes. However, these improvements also caused problems such as enlarging the bar code area, complicating reading operations, and increasing printing cost.

2D Code emerged in response to these needs and problems. The creator intended the code to allow its contents to be decoded at high speed. Unlike the older one-dimensional barcode that was designed to be mechanically scanned by a narrow beam of light to extract data, the QR code is detected as a 2-dimensional digital image by a semiconductor image sensor and is then digitally analyzed by a programmed processor. The processor locates the three distinctive squares at the corners of the image and uses a smaller square near the fourth corner to normalize the image for size, orientation, and angle of viewing. The small dots are then converted to binary numbers and their validity checked with an error-correcting code.

The QR (Quick Response) Code is a two-dimensional (2-D) matrix code that belongs to a larger set of machine-readable codes, all of which are often referred to as barcodes, regardless of whether they are made up of bars, squares or other shaped elements. Compared with 1-D codes, 2-D codes can hold a larger amount of data in a smaller space, and compared with other 2-D codes, the QR Code can hold much more data still. Also, an advanced error-correction method and other unique characteristics allow the QR Code to be read more reliably than other codes [41].

Figure 2.5: QR Code [42]

Due to the design of Reed–Solomon codes and the use of 8-bit code words, an individual code block cannot be more than 255 code words in length. Since the larger QR symbols contain much more data than that, it is necessary to break the message up into multiple blocks. The QR specification does not use the largest possible block size, though; instead, it defines the block sizes so that no more than 30 error-correction symbols appear in each block. This means that at most 15 errors per block can be corrected, which limits the complexity of certain steps in the decoding algorithm. The code blocks are then interleaved together, making it less likely that localized damage to a QR symbol will overwhelm the capacity of any single block. Thanks to error correction, it is possible to create artistic QR codes that still scan correctly, but contain intentional errors to make them more readable or attractive to the human eye, as well as to incorporate colors, logos, and other features into the QR code block. A QR Code can also be scanned in any direction. These 3 QR Codes are all the same only they have been rotated 90 Degrees each time [42].

i) Scanning of QR-Code

Step 1: Launch the application on your device.

Step 2: Use the viewfinder on the screen of the device to centre the QR code inside the scanner then hold the device still until the scanner has captured the image. Step 3: Perform the action indicated on your phone screen to discover what information the QR code contained. For example, a link to a website could appear on a screen prompting you to click the link and be directed to the site of the QR code creator.

Table 2.2 Comparison of Barcode, QR code and RFID [54]

Attribute	Barcode	QR code	RFID
Line of Sight	Required	Required	Not required (in most of the cases)
Read Range	Several inches to feet	Several inches to feet	Passive RFID -Up to 30 feet Active RFID -Up to 100s feet
Identification	Most barcode only identify the only type of item (not uniquely)	QR code can identify each item uniquely (Limited up to certain value)	It can uniquely identify each item
Read\Write	Only read	Only read	Read Write
Technology used	Optical (laser)	Optical (laser)	RF(Radio frequency)
Automation	Most barcode Scanners need humans to operate	QR scanners need humans to operate	Fixed scanners don‘t need human labour
Updating	Cannot be Updated	Cannot be Updated	New information can be written on the old tag
Tracking	Manual tracking required	Manual tracking Required	No need for tracking
Information Capacity	Very less	Less	More than QR and Barcode
Ruggedness	No	No	Yes
Reliability	Wrinkled and smeared tags won‘t work	Wrinkled tags may work 30Percent data recoverable	Nearly flawless read rate
Data capacity	<20 characters with linear	up to 7,089 characters[9]	100s to 1000 characters
Orientation Dependent	Yes	No	No
Marginal Cost	0.01$	0.05$	0.05-1$

2.2.8 Wireless Sensor Networks

Sensor systems are utilized in ecological monitoring, for example, forest identification, animal tracking, flood location, estimating and climate expectation, and in business applications like seismic exercises forecast and observing. [25] Field of interest and are remotely controlled by a user. Enemy tracking, security location are likewise performed by utilizing these systems. [25]Health applications, for example, Tracking and checking of patient's response to medication specialists utilize these systems. [25]The most often used wireless sensing element networks applications is within the field of transport systems, for example, checking of traffic, dynamic steering the board and observing of parking garages, and so on., utilize these networks.[25][26]

Characteristics of WSN

These gadgets work under the Transmit, Receive, Idle and Sleep modes having different levels of energy consumption.

A detecting subsystem: Low power segments can help to fundamentally reduce power consumption. Since this subsystem (sensors and actuators) is answerable for the sharing of data between the sensor network and the outside world.

A power supply subsystem: It comprises of a battery which supplies power to the node [26]

Some of the unique characteristics of a WSN include

i) Limited power they can harvest or store.
ii) Ability to withstand harsh environmental conditions
iii) Ability to cope with node failures
iv) Mobility of nodes
v) Dynamic network topology
vi) Communication failures
vii) Heterogeneity of nodes Large scale of deployment
viii) Unattended operation.

In RFID systems, data collected by the RFID reader is normally transmitted to the central node over a wired connection [49]. Depending on the size of the location, installing the necessary wired infrastructure may outweigh the small number of benefits of wired networking, such as reliability and low power consumption [49] [55]. Moreover, the high installation cost in the implementation of a wired network infrastructure may not be justifiable [49] [55]. Sheridan et al [49], recommend that the best option to enable reader and central node communication is by implementing a Wireless Sensor Network (WSN). Sohraby et al. [48] define a sensor network as an infrastructure *comprised of sensing, computing, and communication elements that give an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment*.

WSN Topologies

Star network: all of the nodes on the network must be connected to one central device. All traffic that traverses the network passes through the central hub.

Tree network: a central 'root' node (the top level of the hierarchy) is connected to one or more other nodes that are one level lower in the hierarchy (i.e., the second level) with a point-to-point link between each of the second-level nodes and the top-level central 'root' node, while each of the second-level nodes will also have one or more other nodes that are one level lower in the hierarchy (i.e., the third level) Connected to it.

Mesh network (Partially connected) Some of the nodes of the network are connected to more than one other node in the network with a point-to-point link – this makes it possible to take advantage of some of the redundancy that is provided by a physical fully connected mesh topology without the expense and complexity required for a connection between every node in the network [39].

WSN Routing Techniques

Almost all of the routing protocols can be classified according to the network structure as flat, hierarchical, or location-based. In flat routing protocols, all nodes are typically assigned equal roles or functionality. In hierarchical protocols, the nodes are clustered so that cluster heads can do some aggregation and reduction of data to save energy location-based protocols utilize the position information to relay the data to the desired regions rather than the whole network [39].

WSN Security Challenges

Table 2.3 Attacks on various layers of a WSN and their countermeasures [103]

Layer	Attacks	Defence
Physical	Jamming	Spread-spectrum, priority messages, lower duty cycle, region mapping, mode change
Link	Collision Exhaustion Unfairness	Error-correcting code Rate limitation Small frames
Network	Spoofed routing information & Selective forwarding Sinkhole Sybil Wormhole HELLO Flood Acknowledgement flooding	Egress filtering, authentication, monitoring Redundancy probing Authentication, monitoring, redundancy Authentication, probing Authentication, packet leashes by using geographic and temporal info Authentication, verify the bi-directional link authentication
Transport	Flooding De-synchronization	Client puzzles Authentication

A WSN is a special type of network. It shares some commonalities with a typical computer network but also exhibits many characteristics which are unique to it. The security services in a WSN should protect the information communicated over the network and the resources from attacks and misbehaviour of nodes.

SMS (Short Message Services) is the most common and economically affordable service and it is used for both receiving and sending a text message. SMS is based on transferring information via GSM network and a single text message can include up to 160 characters.

General Packet Radio Service (GPRS) is a packet-oriented wireless data communication service available on the 2nd and 3rd generation cellular communication systems for mobile communications. GPRS operates at the speed up to 115 kbps and compared to 9.6 kbps speed of GSM [103]. It supports a wide range of bandwidth. It is, therefore, it is not only suitable for sending and receiving small bursts of data such as web browsing and e-mail but also is equally useful for large volumes of data transmission. The core network of GPRS allows WCDMA, 2G, and 3G mobile networks to transmit IP packets to outer networks such as the Internet. The GPRS system is an incorporated part of the GSM network switching subsystem. GPRS extends the GSM Packet circuit-switched data abilities to perform and makes the subsequent services possible like Multimedia Messaging Service (MMS), Wireless Application Protocol (WAP), SMS messaging and broadcasting, Push to talk over the cell phone (PoC) etc. It supports point-to-point protocol (PPP), Internet protocol (IP) and X.25 connections. Transmission speed, approx. 28 to 32 SMS per/min maybe achieve over GPRS. It is faster than using the normal SMS over GSM, whose transmission speed of SMS is about 5 to 10 SMS per/min

Global Positioning System (GPS): GPS is a system composed of a network of 24 satellites of the US. The satellites periodically emit radio signal to GPS receivers. The GPS receiver receives the signal from at least three satellites using the triangular technique to compute two-dimensions, or four satellites to compute three dimensions (latitude, longitude and altitude).

Google Map: Is a version of Google Earth it's a free software to provide a map by satellite image, the programming language of Google Map is KML (keyhole mark-up language). It used to show lines and pins objects.

Arduino: is a freely available prototyping platform based on easy to use hardware and software. It is used to build interactive prototypes and experiments. Arduino boards can read inputs e.g. light on a sensor or serials embedded in RFID tags. The Arduino then turns the input into an output e.g. publishing something online or giving out serials embedded in RFID tags. The Arduino board can be told what to do by sending a set of instructions to the microcontroller on the board. To do this, the Arduino programming language (based on wiring) is used and the Arduino software Integrated Development Environments (IDE) based on processing. Arduino runs on all major operating system platforms including Windows, Linux and MacOS. Arduino is a key tool to learn new things [40].

Figure 2.6: Arduino Microcontroller

WAMP: is the combination of words Windows, Apache, MySQL, and PHP. It's a software stack, which means that when installing WAMP, Apache, MySQL, and PHP services together on a computer are installed [106] windows referring to the most commonly used operating system on computers developed by Microsoft, Apache is most commonly used web server software to make web pages available on the internet, MySQL is a relational database for holding all the information, PHP (Personal Home Page) a scripting language used for producing dynamic web pages.

SIM808: This board based on the latest SIMCOM SIM808 GSM/GPS module, it offers cellular GSM and GPRS data along with GPS technology for satellite navigation, and it features ultra-low power consumption in sleep mode, giving the project incredibly long standby times. Furthermore, there's an on-board battery charging circuit that can be used with LiPo batteries. The GPS receiver is incredibly sensitive with 22 tracking and 66 acquisition channels, and also supports assisted-GPS (A-GPS) for indoor localisation. The board is controlled by AT command via UART and supports 3.3V and 5V logical level. It comes with a mini GPS and GSM antenna, however, a battery is optional, and the board uses the 2G (not 3G or LTE) GSM networks [113].

Buzzer: is an audio signalling device, which may be mechanical, electromechanical, or piezoelectric (piezo for short). Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke [116].

Breadboard: is a rectangular plastic board with a bunch of tiny holes in it. These holes let you easily insert electronic components to prototype, The connections are not permanent, so it is easy to remove a component if you make a mistake, or just start over and do a new project, these breadboards are called solderless breadboards because they do not require soldering to make connections. Soldering is a method where electronic components are joined together by melting a special type of metal called solder, many electronic components have long metal legs called leads sometimes, and shorter metal legs are referred to as pins instead. Almost all components with leads will work with a breadboard, Breadboards are designed so you can push these leads into the holes.

Strips are typically marked by red and blue (or red and black) lines, with plus (+) and minus (-) signs, respectively. They are called the buses, also referred to as rails, and are typically used to supply electrical power to your circuit when you connect them to a battery pack or other external power supply [115].

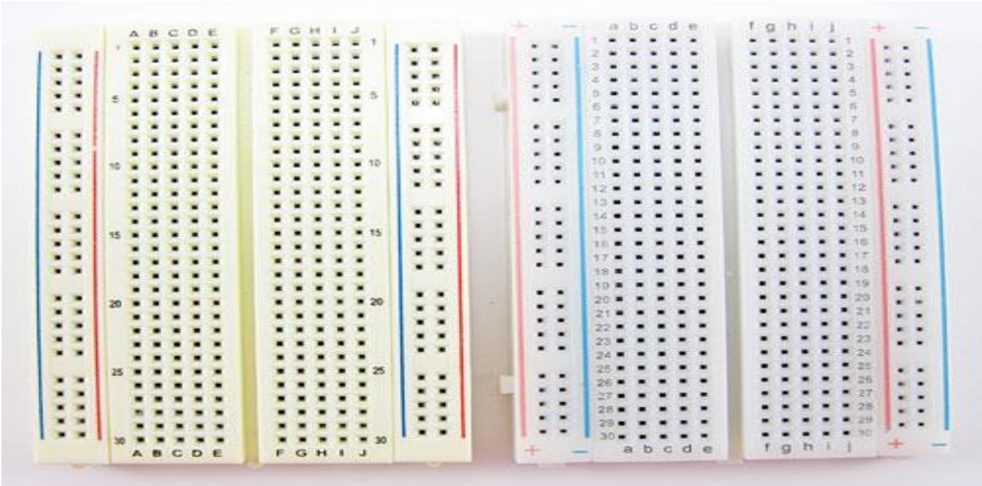


Figure 2.7: Breadboard [115]

2.2.9 Software Development Methodology

A Software Development Methodology (SDM) is a sequence of processes that leads to the development of an application [55] it constitutes a set of modelling conventions, comprising of a modelling language and a process [56]. The modelling language assists in modelling the different aspects of the system and the process determines what activities should be carried out to develop the system [56]. Software processes are sets of related activities that lead to the production of software products [58]. In a software process, user needs are translated into software requirements. The requirements are then translated into designs, the designs are implemented and the implementation is then tested. The software processes might overlap or be performed iteratively [55]. An SDM can be categorized into two classes, that is, a Traditional SDM and an Object-Oriented SDM (OOSDM).

2.2.10 Traditional Methodology vs. Object-Oriented Methodology

Traditional approaches to system development view software as a collection of programs or functions and isolated data. Algorithms and data structures make up a program. An example of a traditional approach to system development is a structured methodology that is based on the Waterfall Model [58] [65] [60]. The Waterfall Model adopts a very formal approach to the System Development Life Cycle (SDLC) phases and activities. Activities of one phase must be completed before moving on another phase and no iterations are permitted [58] [65] [60]. The OO approach to the SDLC, on the other hand, follows an iterative and incremental approach to systems development. In OO, the SDLC is viewed as a series of increments or phases. Each of the SDLC phases is visited iteratively until the developer is satisfied [59] [65] [60].

The main distinction between traditional system development methodologies and OOSDMs depends on their main focus. The traditional approach focuses on the functions of the system. The OOSD approach, on the other hand, focuses on the Object, which combines data and functionality [59] [65] [60]. The phases of developing a system, that is, planning-analysis-design-implementation, do not change. However, the only change that takes place in how they are performed. The structured approach focuses on understanding a problem using a model called the Data-Flow Diagram (DFD). Hence, all system components are evolved from the DFD [59] [65] [60]. Contrariwise, the OO approach uses Use Cases. There are many models to deal with in the OO approach and there are no clear-cut steps such that the design of the system components evolves logically from a single model [58] [59] [60].

2.2.11 Object-Oriented System Development Methodology

An Object-Oriented System Development Methodology (OOSDM) can be defined as a system of principles and procedures applied to Object-Oriented Software Development (OOSD) [61]. OOSD provides a way to develop software by building self-contained modules or objects that can be easily replaced, modified and reused. Object Orientation (OO) is a way of viewing and modelling the world or system as a set of interacting and interrelated objects [62]. An Object may be a tangible physical entity or intangible.

a) Advantages of Object-Oriented System Development

Advantages of using an OOSD approach to system development as opposed to using a traditional approach are [58] [59]:

i) Object Orientation (OO) provides a higher level of abstraction at the Object level. Objects encapsulate both data and functions, hence they work at a higher level of abstraction. Development can proceed at the Object level, ignoring the rest of the system for as long as necessary; this makes designing, coding, testing and maintaining the system simpler.

ii) OO provides seamless transition among different phases of software development. OO uses the same language to talk about analysis, design, programming and database design. This seamless approach significantly reduces the level of complexity and redundancy. It makes for clearer, more robust system development. On the other hand, traditional approaches to system development require different styles and methodologies for each step of the development process.

iii) OO promotes reusability. Objects are reusable because they are modelled directly from a real-world problem domain. Each object stands by itself or within a circle of other objects.

iv) b) Unified Modelling Language

The Modelling Language used in an Object-Oriented SDM is the Unified Modelling Language (UML). UML is a set of diagramming techniques [60]. The UML uses graphical notations to express the design of software developments [91]. Examples of design artefacts include requirements, architecture, design, source code, test cases, prototypes, and so on [62] [63]. Modelling provides a representation or simplification of reality. It provides a blueprint of the system. UML supports specifications that are independent of particular programming languages, technologies and development processes [62] [63]. The underlying assumption of the UML is that no one diagram can capture the different elements of a system in its entirety [91]. UML consists of three basic building blocks namely, elements, relationships and diagrams. Elements are the main parts of the model while relationships tie elements together. Lastly, diagrams provide mechanisms to group collections of elements and relationships. Example elements in UML, include [62] [63]:

i) Structural: is the static part of the model that represents a conceptual element. Examples of structural elements include classes, use cases, collaboration and component.

ii) Behavioural: represent behaviour over time and space. Interaction and state depict behavioural elements.

iii) UML is characterized by nine major diagrams. A diagram is a graphical presentation of a set of elements and relationships where nodes are elements and edges are relationships. The nine major diagrams are class, object, use case, sequence, collaboration, statechart, activity, component and deployment [62] [63].

iv) Object-Oriented System Development: A Use Case Driven Approach

A use case is an interaction between a user and a system that captures the user's goals and needs [89] [63]. The main advantage of a use case driven approach to OOSD is that all design decisions can be traced back directly to user requirements [64]. OOSDMs consist of an Object-Oriented System Development Life Cycle (OOSDLC). The OOSDLC consists of three macro processes namely, Object-Oriented Analysis (OOA), Object-Oriented Design (OOD) and Object-Oriented Implementation (OOI). The OOSDLC macro processes can be further broken down into the following phases [62] [63] [65]:

i) Object-Oriented Analysis (OOA) Phase: user requirements are modelled for what the eventual system must do. OOA affords a way to understand the business needs as well as to process requirements. OOA's focus is on developing an object-oriented model of the problem domain. OOA answers the question of what the system must do. The output of this phase is a conceptual model consisting of two deliverables, namely, the Requirements and Object Models.

ii) Object-Oriented Design (OOD) Phase: OOD provides a way of developing object-oriented models of a software/system to implement the requirements identified during OOA. The result of OOD is a plan of how the system will do what the Requirements Analysis model asks for. OOD answers the question of how the system will do it.

iii) Construction Phase: Object-Oriented Programming (OOP) in an OO programming language and database takes place to produce a software application. Deployment and user training are also carried out on completion of this phase.

iv) Object-Oriented Testing (OOT) Phase: thorough and complete unit testing of individual classes and programs is carried out in increments.

v) Maintenance Phase: Bug fixes and enhancements are carried out on the final software product.

vi) d) Object-Oriented Languages

OOP languages include Java, C-sharp (C#), and C-plus-plus (C++). Java is a portable OOP language introduced by Sun Microsystems [66] [67]. C# is an OOP language based on C++ and Java and was developed expressly for Microsoft's .NET platform. Microsoft's .NET platform provides developers with the capabilities they need to create and run computer applications that can execute on computers distributed across the Internet. C++ is an extension of the "C" language. C++ provides capabilities for OOP. C++ was developed by Bjarne Stroustrup at Bell Laboratories [67]. Some benefits of using an OOP language as compared to a non-OOP language are [68]:

i) Improved software-development productivity: OOP is modular, that is, it provides separation of duties in object-based program development. It is extensible, as objects can be extended to include new attributes and behaviours. In OOP Objects can be reused within and across applications. On account of these three factors, that is, modularity, extensibility, and reusability, OOP provides improved software-development productivity over traditional procedure-based programming techniques.

ii) Improved software maintainability: For the reasons stated above, object-oriented software is easier to maintain. Owing to the modularity of the system design, part of the system can be updated in case of problems without the need to make large-scale changes.

iii) Faster development: Reusability enables faster development. OOP languages come with rich libraries of objects. Code developed during projects is also reusable in future projects.

iv) Lower cost of development: The reuse of software lowers the cost of development. Usually, more effort is put into the Object-Oriented Analysis and Design (OOAD), which lowers the overall cost of development.

v) Higher-quality software: Faster development of software and lower cost of development allows for more time and resources to be used in the verification of the software. OOP tends to result in higher-quality software.

2.2.12 Internet of Things (IoT)

The internet of things is a concept of a network for information exchange and communication through extending or stretching its client to goods and goods based on the internet [32], We can also understand this concept as through radio frequency identification (RFID), infrared sensors, global positioning systems, information sensing devices or other laser scanners agreed by the agreement, connected to the Internet to exchange information and communicate to achieve intelligent identification, location, tracking, monitoring, and management.

Some of the IoT architectures are European FP7 Research Project: Interoperable IoT systems like retail, healthcare etc. are connected through the internet with interoperable technologies like RFID, ZigBee, Bluetooth, etc. ITU Architecture: As recommended by the International Telecommunication Union (ITU), the architecture of Internet of Things is similar to the Open Systems Interconnection (OSI) reference model used in computer networks that consist of Sensing Layer, Access Layer, Network Layer, Data Layer and Application Layers. IoT Forum Architecture: According to the IoT Forum the Internet of Things Architecture is categorized into three types namely the applications, processors and transmission.

Qian Xiaocong, Zhang Jidong Architecture: According to this architecture three layers namely the perception layer, transportation layer and application layer needed for IoT. IoT Technologies Radio Frequency Identification (RFID) [13]: It was the RFID application that gave rise to the concept of the Internet of Things. Radio Frequency Identification (RFID) is a system that transmits the identity of an object wirelessly using radio waves. RFID comprises of a tag, an antenna, a reader, software and a server. It is low-priced, effective and secured thus making it reliable [14]. Internet Protocol (IP) Internet Protocol (IP) is the prime network protocol across the network. The two versions of Internet Protocol (IP) in use are IPv4 and IPv6 as stated in Bicknell, IPv6 Internet Broken, and Verizon Route Prefix Length Policy 2009. The protocol provides for 4.3 billion IPv4 addresses while the IPv6 will significantly augment the availability to 85,000 trillion addresses. This supports around for 2128 addresses.

IoT Architecture

[33]Notes that there is no single and general agreement about the architecture of IoT that is agreed on by the whole world and researchers. Many and different architectures have been proposed by researchers. According to some researchers, IoT architecture has three layers, but some researchers support the four-layer architecture. They think that, due to enhancement in IoT, the architecture of three layers cannot fulfil the requirements of applications. Due to a challenge in IoT regarding security and privacy, the architecture of five layers has also been proposed. It is considered that a recently proposed architecture can fulfil the requirements of IoT regarding security and privacy.

The progressive system of all proposed layered design of the Internet of Things (IoT) is shown in Figure 2.8, which shows the layer models of IoT comprising three layers, four layers, and five layers individually.

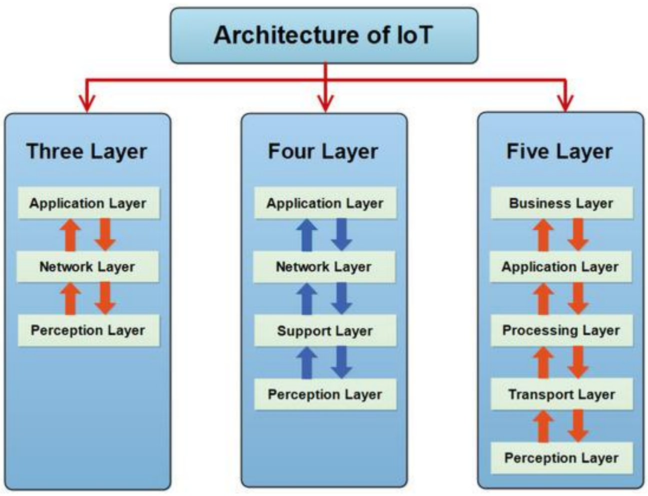


Figure 2.8: The layered architectures of IoT (three, four and five layers) [33].

The use of IoT has become so pervasive Individuals utilize the innovation named Internet of Things (IoT) not only because of popularity but as well as the advantages and services offered by it. With IoT, assignments can be performed without utilizing human intervention, figure 2.9 projects the usage of IoT devices.

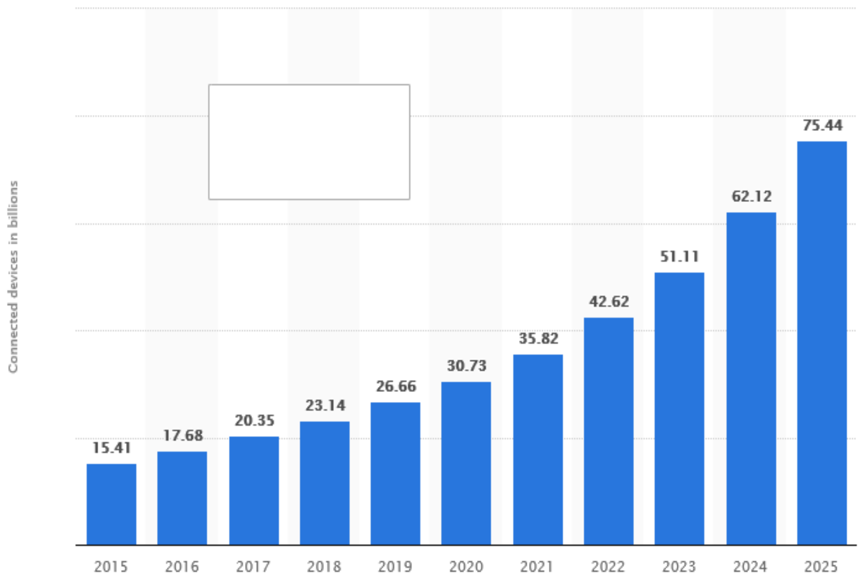


Figure 2.9: Number of connected IoT devices from 2015 to 2025 [32].

IoT Applications

i) Home automation: Home automation is building automation system for homes. It involves the control and automation of lighting, heating, ventilation, air conditioning, and security as well as home appliances. Smart Home ranks one in IoT applications as on all measured channels.

ii) Smart gadgets: Wearables remain are smart electronic devices (electronic device with microcontrollers) that can be worn on the body as implant or accessories. Apple watch2 and Fitbit are creating waves in the wearable technology and are called tech game-changers of 2017 [19].

iii) Smart City: Smart City solutions promise to alleviate the real problems of people living in cities these days. IoT solutions in the area of Smart City solve traffic congestion problems, reduce noise and pollution and help make cities cleaner and safer.

iv) Smart Grid: Smart grids refer to the electric grid which is a network of transmission lines, substations, transformers that deliver electricity from the power plant to your home or business. This automates the distribution system and reduces power pilferage. It uses information about the behaviours of electricity suppliers and consumers in an automated fashion to improve the efficiency, reliability, and economics of electricity.

v) Industrial Internet of Things (IIoT): IIoT is the use of Internet of Things technologies in manufacturing. It incorporates machine learning, big data, using sensor data, machine-to-machine (M2M) communication and automation technologies that have existed in industrial settings for years. IoT holds great potential for quality control, sustainable and green practices, supply chain traceability and overall supply chain efficiency.

vi) Smart Car: Connected cars consists of Navigation systems, which will enable drivers to determine not just the fastest route but also the most fuel-efficient and Vehicle management systems, which will provide detailed information about the car’s performance. Price Water Coopers predicts a bright future for connected cars by 2020.

vii) Connected Healthcare: Connected healthcare management and delivery by using technology to provide healthcare services remotely.

viii) Smart retail: Retail industry is slowly transforming from an unorganized sector to an organized one by incorporating technology. Smart retailing is evolving and proving to be a promising

ix) Smart supply chain: Radio frequency identification (RFID) is the technology that uses an RFID tag on objects or people, so that they can be identified, tracked and managed automatically using IoT technology. Supply chains have already been reaping benefits from IoT.

x) Smart farming: Growing concerns about farming like climate change, limited arable land, and costs/availability of fossil fuels is reducing productivity. The remoteness of farming operations and the large number of livestock that could be monitored the Internet of Things could revolutionize the way farmers work.

Challenges for IoT

i) Standards: Standardization in the areas of architecture, technology and internet protocols is needed. IEEE is working to ensure that the IPv6 packets can be routed across different network types. [39]

ii) Powerful sensors: For Internet of Things to reach its full potential self-sustaining sensors must be developed where, the sensors generate electricity from environmental elements like heat, friction, movement etc.

iii) Security: Privacy and security issues are inevitable, arising from the facts that objects on the IoT transmit information via public data networks, information gathered is often transmitted to third parties. Privacy and security considerations have been of minimal concern in the design of IoT devices and the absence of compliance/ Regulatory body further adds to it.

2.2.13 Internet accessibility survey

Based on the 2018 survey conducted by ZICTA [93] it was established that the proportion of individuals who indicated that they had used the internet before was 14.3Percent in 2018. This finding in figure 2.10 represents an increase in the proportion of individuals that had used the internet from 8.8Percent reported in 2015. However, the proportion of users of the internet in Zambia who reported using the internet at least once in the 3 months preceding the survey was 11.6 Percent.

The population of active users of the internet was concentrated in urban areas constituting 77.8 Percent compared to 22.2 Percent based in rural areas. However, the proportion of individuals within the urban areas that had used the internet was 28.1 Percent while only 5.2 Percent of individuals within the rural areas had used the internet before. The usage of internet services thus increased from the findings established in 2015 when the proportion of individuals that had used the internet that was based in urban areas was 16.8 Percent and 3.2 Percent among individuals that were based in rural areas.

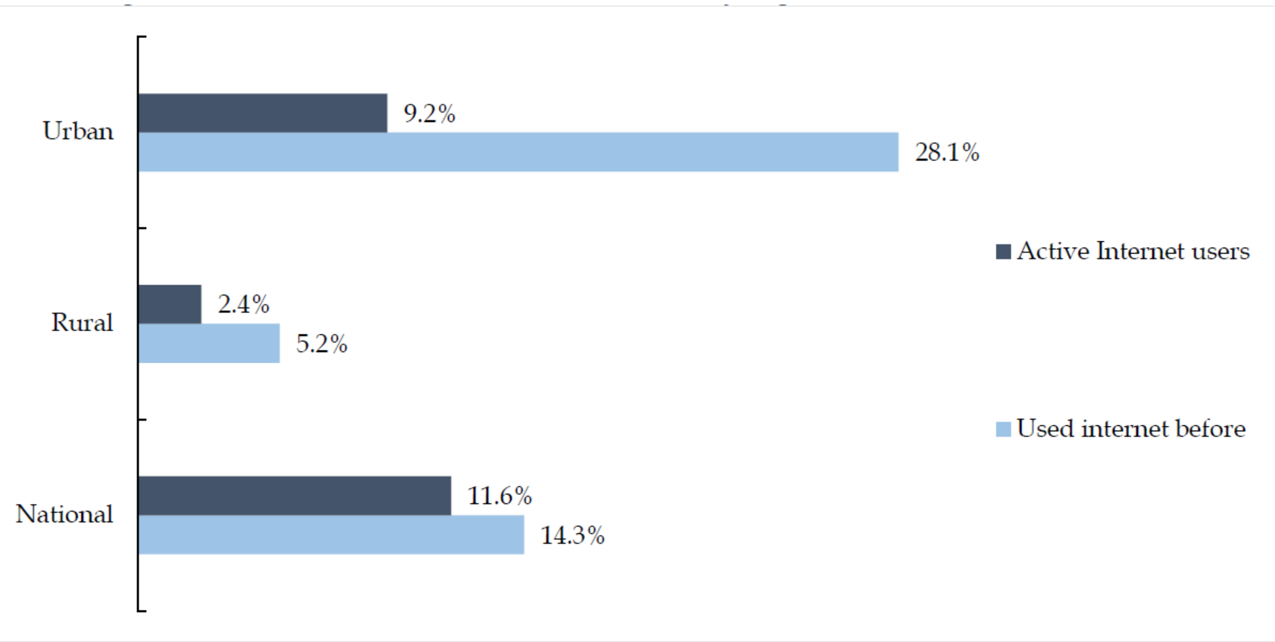


Figure 2.10: Internet user's national survey [93]

The majority of individuals that had used the internet before or were active users of the internet were mainly based in Lusaka province, Southern province and Copperbelt provinces as depicted in figure 2.11. On the other hand, the smallest proportion of individuals that had used the internet or were active users of the internet were based in Northern Province, North-Western province and Western province.

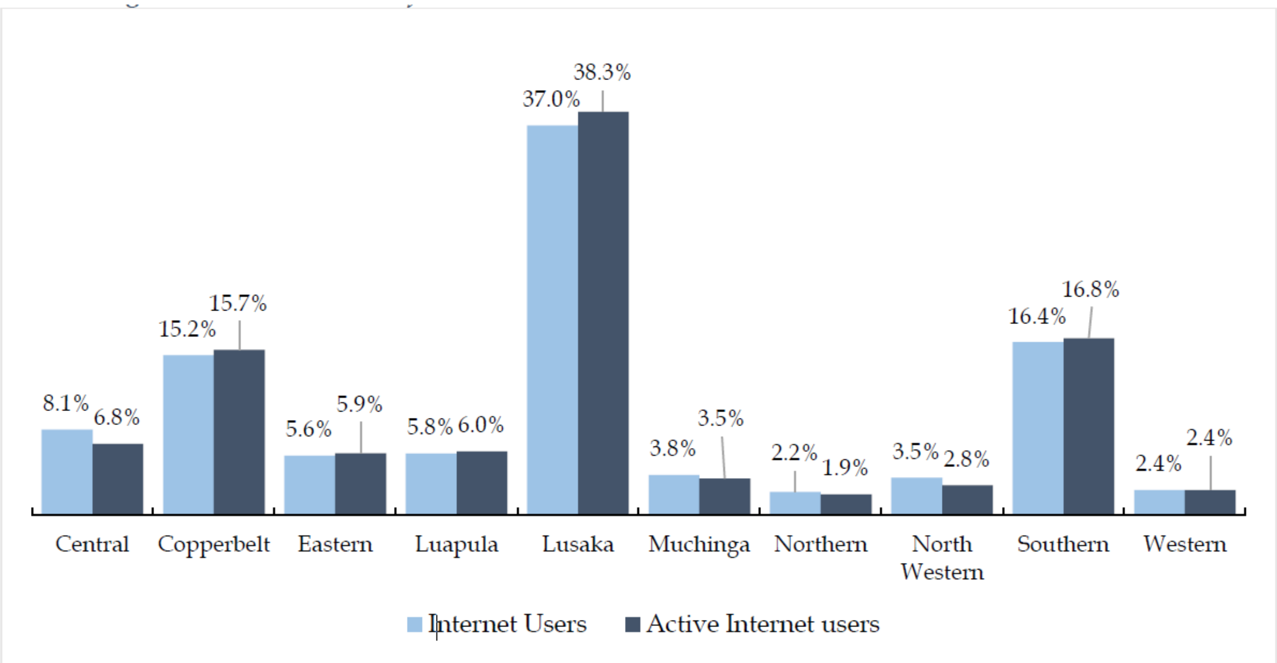


Figure 2.11: Internet users' provincial survey[93]

The majority of internet users were males constituting 52.1Percent of all the users of the internet compared to females who constituted 47.9 Percent. However, 17.3 Percent of all the males had used the internet before while only 12.0 Percent of all the females had used the internet before.

The assessment also revealed that 1.2 Percent of all the internet users had some disabilities. The proportion of individuals with disabilities that had used internet services before was 5.7 Percent.

The majority of individuals that had used the internet before or were active users of the internet were young. Specifically, 72.3 Percent of all the individuals that had used the internet before were aged below 35 years while 72 Percent of the active internet users were aged below 35 years. Less than 5 Percent of the individuals that had used the internet before were aged above 55 years.

2.2.11 Data Encryption

Data can be in the format of documents, pictures, videos, and software or any other electronic format that resides, traverses or is in use on computer systems. With the increase in cybercrime, data must be encrypted, encryption been the conversion of data into an unintelligible format that can only be decoded an authorized user. Symmetric and asymmetric encryption are the two types of encryption from which implementations have been derived. [39]

Data has three states, data in motion, at rest and data in use understanding the different states of digital data can be in can help you select the kinds of security measures and encryption that are appropriate for protecting it. [39]

Data at rest is a term that refers to data stored on a device or backup medium in any form. It can be data stored on hard drives, backup tapes, in offsite cloud backup, or even on mobile devices. What makes its data at rest is that it is inactive data that is not currently being transmitted across a network or actively being read or processed. Data at rest is typically in a stable state. It is not travelling within the system or network, and it is not being acted upon by any application or the CPU. Data at rest is data that has reached a destination (even if only temporarily). At this destination, there can be additional layers of security added to it, such as encryption, multi-factor authentication, and both digital and physical access controls. Data at rest should almost always be encrypted.

Data in motion is data that is currently travelling across a network or sitting in a computer's RAM ready to be read, updated, or processed. Data crossing over networks from local to cloud storage or from a central mainframe to a remote terminal should be encrypted so that it cannot be read or manipulated by any machine or hacker between the data's source and destination. This data in motion includes data moving across cables and wireless transmission. It can be emails or files transferred over FTP or SSH.

Cryptography was originally invented to protect data in motion–such as sensitive communications between a military general and his army. Protect enterprise data from prying eyes by encrypting it before it is transmitted beyond the system where it is stored or generated.

Data in use is data that is not just being stored passively on a hard drive or external storage media. This is data that is being processed by one or more applications. [39]This is data currently in the process of being generated, updated, appended, or erased. It also includes data being viewed by users accessing it through various endpoints. Data in use is susceptible to different kinds of threats depending on where it is in the system and who can use it. The most vulnerable point for data in use is at the endpoints where users can access and interact with it.

Protecting data in use is a challenging task since there is such a variety in the ways the data can be accessed and manipulated. One set of data can potentially have multiple users working with it from multiple endpoints. A large number of in-house systems, devices, and employees are accessing system data from personal devices, the implication of this is that the data should be protected through strong user authentication, identity management, and profile permissions. [39]This will help ensure that only individuals with the proper permission and knowledge can access and manipulate data. Also, since technology makes it nearly impossible to prevent data leakage from endpoints, most employers have their employees sign legal agreements that they will not share private data with anyone that does not have permission to view it.

All true cryptography is composed of three parts: a cipher, an original message, and the resultant encryption. The cipher is the method of encryption used, Original messages are referred to as plain text. A hash function is a function that takes in input value, and from that input creates an output value deterministic of the input value. For any x input value, you will always receive the same y output value whenever the hash function is run. In this way, every input has a determined output.

- Easy to calculate h(x) from x

- Collision Resistance it should be hard to find two different inputs of any length that result in the same hash or as clear text, a message that is transmitted with encryption is called ciphertext.

MD5 [94], an upgrade of the prior variant called MD4, is one of the most widely used hash functions, but it is proved to be broken in practice. MD5 produces a 128-bit hash value and its only use is as a checksum to verify data integrity because it suffers from extensive vulnerabilities [95]. The United States National Security Agency designed SHA-1 [96] (Secure Hash Algorithm 1), a cryptographic

hash function that produces a 160-bit (equivalent to 20-byte) hash value for a given input. SHA-1 established as a U.S. Federal Information Processing Standard many widely used security applications and protocols, such as TLS and SSL, PGP, SSH, S/MIME, and IPsec rely on that. However, since 2005 it has not been considered completely secure and Microsoft [97], Google [98], Apple [99] and Mozilla [100] have all announced that their respective browsers will stop accepting SHA-1 SSL certificates by 2017. Because SHA-1 collision attacks have finally become practical by Stevens et al. [102] which forge two PDF documents with the same SHA-1 hash in roughly $2^{63.1}$ SHA-1 evaluations, two upgrades to SHA-1 have been proposed over the past decade namely SHA-2 and SHA-3 [101] respectively.

2.2.12 Reviewed Luggage tracking Designs

Real-Time Tracking Management System Using GPS, GPRS and Google Earth

The real-time tracking management system is an open system that uses free and open-source software. The system is composed of three components, a GPS Tracking Device, a server and a database. The GPS tracking device is an embedded system that transmits location information to the server through GPRS networks. The server is a personal computer that receives the information and put it in the database. The database formats the information that can search and display using Google Earth software or Google Map[117].

Figure 2.12 Real-Time Tracking Management System design [117]

The study makes use of a Linux operating system, that is robust but few people are familiar with its administration, passenger name, contacts and motor vehicle registration details are not considered.

An RFID wireless sensor network based grain inventory management system for Zambia's Food Reserve Agency

This work proposed the design and development of a Wireless Sensor Network (WSN) based Radio Frequency Identification Grain Inventory Management System (RFID GIMS) for the Food Reserve Agency (FRA.) RFID is an automated system that utilizes wireless technology to uniquely identify and track tagged objects in the form of a unique serial number. WSN is a network comprised of sensing, computing, and communication elements. WSN and RFID are integrated to extend the read range of RFID system applications. [6].

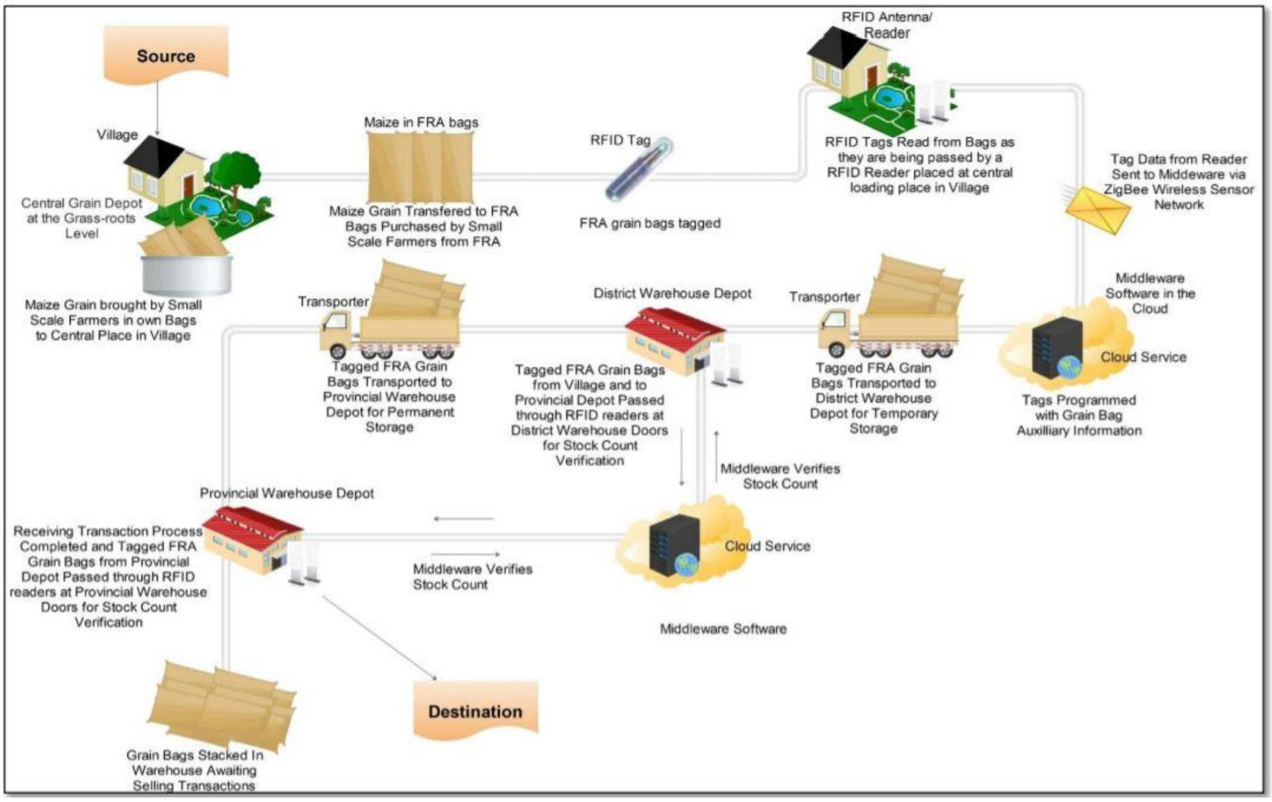


Figure 2.13 FRA Tracking System design [118]

In the study has well-designed architecture ZigBee is used for communication, however, no mention on how the nodes parse the information from node to node and finally the cloud server, the tags used in this research are not reusable hence a lot of tags are required.

Design and Optimization of Luggage Tracking System for Airport

It is an ARDUINO Controller based. In which an ARDUINO processor, GSM module, Wi-Fi module, GPS module, and accelerometer for the power factor and the device is chargeable (can run without power supply). The working procedure of this device is that it has been kept in the luggage at the airport through which user can get a message from the android app in his phone regarding their location. As this device is chargeable it is automatically turned off when the plane takes off. This is so because the plane generates acceleration and accelerometer prepares the device to enter in airplane mode. And after that when the plane is landing the device is automatically turned on with the help of accelerometer (plane generates acceleration during landing also) and sends the location via SMS to android application. Thus the user can find their luggage. The system comprises of a luggage tracking device that tracks the luggage using a GPS module and sends the location of the luggage using the GSM module. The GSM module sends a text message to the user's mobile specifying the location of the misplaced luggage [119].

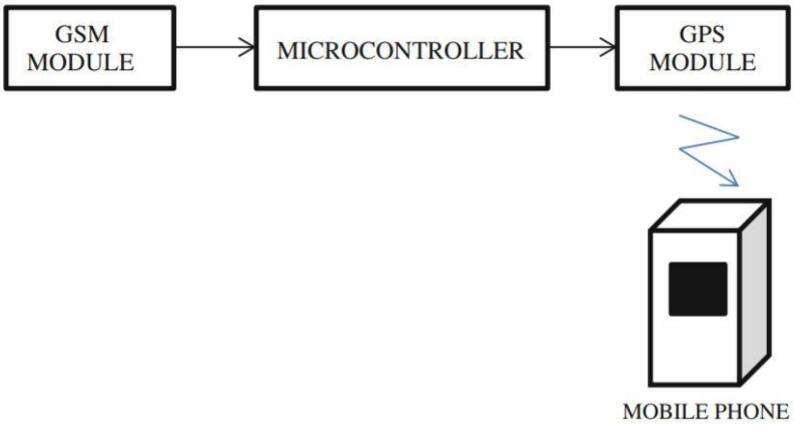


Figure 2.14 Block diagram [119]

In this study the tracking is only localised to a bag, as the tracking module is put inside the bag, however, details of the flight, the passenger are not captured. The system is only linked to one cell number with no administrative view if the linked phone is off there is no way of identifying the owner.

An Efficient RFID-based Tracking System for Airport Luggage (RTSAL)

The emergence of new wireless technologies opened new opportunities to develop more efficient information systems. Radio Frequency Identification (RFID) is among those technologies, which extended the potential of wireless identification and present a potential replacement to old-fashioned identification schemes such as the barcode-based system. The suggested system in this paper considers an enhanced RFID–based approach to identify and track the location of passengers’ luggage. The use of an interactive bracelet that communicates with the RFID system by mean of a database application is investigated. The database application interacts with the bracelet using messages that inform the passenger about his luggage status. The proposed system design and implementation are discussed and the corresponding components are detailed with their interactions. Additionally, a draft cost analysis is presented.

This paper proposes the development of an integrated reusable luggage tag, from the time of the purchase of luggage with RFID tag in the retail store to the airport check-in counter, luggage handling system, aircraft, destination airport, and the hotel. This paper presents the framework and components of the RFID for the reusable tag. A Database Management System (DMS) is suggested for the development. A mobile tracking device is proposed and developed. An integrated IoT system is developed for the tracking of reusable luggage tag [120].

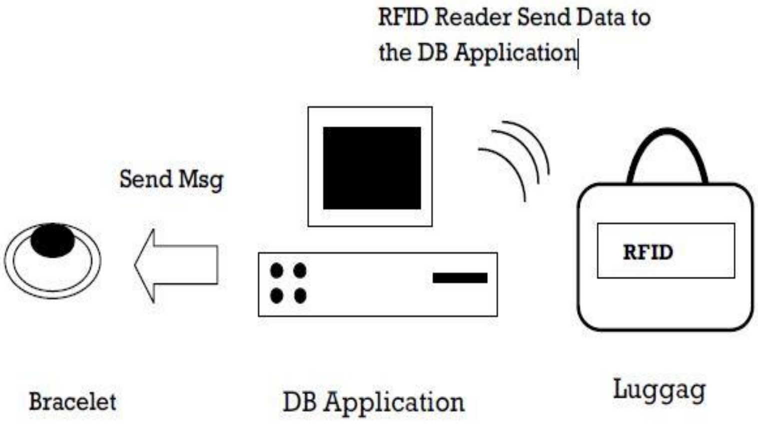


Figure 2.15 Block-diagram of the considered RTSAL [120]

The study is well designed and some module designs adopted, instead of a smart bracelet, a web interface was more practical with a reusable tag to be used on the passenger luggage.

2.3 Related Works

According to [23] whose point was to propose a viable and practical administration platform to realize real-time tracking and tracing for pre-packaged nourishment inventory network dependent on the Internet of Things (IoT) technologies, to guarantee a sheltered nourishment utilization condition. To decrease the production cost while realizing fine-grained tracking and tracing, an integrated solution of utilizing both the QR code and radio-Frequency ID (RFID) tag was proposed. [24]In the proposed work, the authors used an IoT device that retrieves the location Coordinates obtained from the GPS module connected to it and transfers them to Amazon Web Services for further processing and storage. This data is further processed.[37] The proposed IoT model that made use of GPS, RFID, PIR, Wireless radio communication module and GSM technologies. The GPS will be used to monitor and track the location of the vehicle in transit using mobile and web applications. RFID combined with GPRS and Arduino microcontroller was to be responsible for grain bags tallying. [35] Designed a wireless remote sensor network based on android things for monitoring environmental conditions in storage warehouses for the Food Reserve Agency in Zambia. The system used sensor nodes to monitor temperature, humidity, water, and motion. The temperature, humidity, and water were used to monitor the state of the storage environment while the motion sensor was used to detect the presence of intruders. The data from the sensor nodes were sent to an aggregator node via ZigBee and later transmitted to the server in the cloud using a GSM network. The cloud storage service used was the third party which may be inappropriate for storing data for a government agency. However, the prototypes did demonstrate the use of ZigBee in environmental monitoring. In their system, there is also no provision of the usage of the Web application for a more visualized sensor values.

[36]Implemented an animal tracking system for remotely monitoring animal positioning, the system includes an implant device, a global positioning system, a network, one or more remote servers, and at least one wireless computing device. The implant device acts as a GPS receiver, calculating the animal's position and then transmitting the results to the remote server where they are stored in a database. Owners can remotely access the database via a software application installed on a wireless computing device. Users can select an acceptable roaming range for the animal, an acceptable range between the animal and other animals being tracked, a lack of movement.

[30] States that one of the objectives of smart cities is keeping the environment clean and neat. This aim is not fulfilled without the garbage bin management system. Hence the paper “IOT Based Intelligent Bin for Smart Cities” has been developed. Bin management is one of the major applications of IoT. Here sensors are connected to all the bins in different areas. It senses the level of garbage in the bin. When it reaches threshold a message is sent via GSM to the concerned person to clean it as soon as possible. The completed task is done in a lab view environment.

[31]Proposes a Smart Surveillance System using PIR Sensor with Raspberry pi, by using open-source software tools such as Python, Raspbian OS, etc. Smart Surveillance System using PIR Sensor with Raspberry pie merged with the development of the Internet of Things. The basic concept of the application is to allow the client to uses wireless technology to provide essential security using the Surveillance system. The proposed security system captures information and transmits it via a Wi-Fi to static IP, which is viewed using a web browser from any smart devices. Raspberry pi controls a video camera for surveillance. It streams live video and records the motion detected part in the cloud and/or in the window shared folder for future playback. [56]Designed a general-purpose controlling module designed with the capability of controlling and sensing up to five devices simultaneously. The communication between the controlling module and the remote server is done using Bluetooth technology. The server can communicate with many such modules simultaneously. The controller is based on ATMega64 microcontroller and Bluetooth communication TDK Blu2i (Class 1) module which provides a serial interface for data communication. The designed controller was deployed in a home automation application for a selected set of electrical appliances.

[58] Proposed a home appliance control system over Bluetooth with a cellular phone, which enables remote-control, fault-diagnosis and software-update for home appliances through Java applications on a cellular phone. The system consists of home appliances, a cellular phone and Bluetooth communication adapters for the appliances. The communication adapter hardware consists of a 20MHz 16bit CPU, SRAM and a Bluetooth module. The communication adapter board is connected to the home appliance and the cellular phone through serial ports. The appliances can communicate with the cellular phone control terminal via Bluetooth SPP.

[59] Proposed a wireless patient monitoring system which integrates Bluetooth and Wi-Fi wireless technologies. The system consists of the mobile unit, which is set up on the patient’s side to acquire the patient’s physiological signals, and the monitor units, which enable the medical personnel to monitor the patient’s status remotely. The mobile unit is based on the AT89C51 microprocessor. The digitized vital-sign signals are transmitted to the local monitor unit using a Bluetooth dongle. Four kinds of monitor units, namely, local monitor unit, a control centre, mobile devices (personal digital assistant; PDA), and a web page were designed to communicate via the Wi-Fi wireless technology.

[57] Suggested a novel architecture for environmental telemonitoring that relies on GSM for sampling point delocalization, while on-field nodes implement local subnets based on the DECT technology. Local subnets contain two major blocks; Acquisition Station (AS) where sensors and actuators are located and Transmitting Module (TM), i.e., the module that handles several measurement stations and sends data to the control centre (CC). Each AS acts as a data logger, storing in its internal memory device field data; communications between AS and TM are cyclic (round-robin), with a cycle time of about 1–10 min. On the contrary,

Communications between TM and CC occur once a day for data-logging purposes, while alarms or threshold crossings are communicated asynchronously utilizing Short Message Service (SMS). Prototypes have been realized to interface with temperature (T, AD590 from analogue devices), humidity (RH, HumirelHM1500), and carbon monoxide (CO, Figaro TGS2442) sensors. DECT Siemens module MD32 and GSM module MC35 were used. AS was based on Microchip's PIC18F452 microcontroller and TM was designed using 32-bit ARM-based microcontroller from Samsung (S3F441FX).

[86] Described details of the design and instrumentation of variable rate irrigation, a wireless sensor network, and software for real-time in-field sensing and control of a site-specific precision linear-move irrigation system. Field conditions were site-specifically monitored by

six in-field sensor stations distributed across the field based on a soil property map, and periodically sampled and wirelessly transmitted to a base station. An irrigation machine was converted to be electronically controlled by a programming logic controller (Siemens S7-226 with three relay expansion modules activated electric over air solenoids to control 30 banks of sprinklers) that updates the geo-referenced location of sprinklers from a differential Global Positioning System (GPS) (17HVS, Garmin) and wirelessly communicates with a computer at the base station. Communication signals from the sensor network and irrigation controller to the base station were successfully interfaced using low-cost Bluetooth wireless radio communication through Bluetooth RS-232 serial adaptor (SD202, Initium Company).

[104] developed a state of the art WSN based system for monitoring a series of physiological parameters in the vineyard to prevent plant vine diseases. The different soil moistures in the same field are used to decide the correct amount of water for irrigation; sandy soils have very different behaviour to irrigation in respect to clayey ones; water retention capacity is completely different and measuring it exactly where it is needed can help in controlling the irrigation system and saving water. Monitoring air temperature and humidity in different parts of a vine can help in preventing and fighting plants diseases, reducing the number of pesticides only when and where they are necessary. Each node consists of MIDRA mote is equipped with 868 MHz radio transceiver, Chipcon CC1000TM. The master node of the Wireless Sensor Network is connected to a GPRS gateway board, forwarding data to a remote server, using the TCP-IP standard protocol. It included 11 nodes with a total of 35 sensors distributed on 1-hectare area; monitor common parameter using simple, unobtrusive, commercial and cheap sensors,

Forwarding their measurements by the means of a heterogeneous infrastructure, consisting of WSN technology, GPRS communication and ordinary Internet data transfer (TCP-IP protocol). Data coming from sensors are stored in a database that can be queried by users everywhere in the world, only using a laptop or a PDA: the Smart User Interface also allows to read and to analyse data quickly.

[105] describe the emerging wireless sensor networks (WSN) for autonomous Structural Health monitoring SHM systems for bridges. In Smart Brick Network, the base station and sensor nodes collect data from the on-board and external sensors. The sensor nodes communicate their data from quasi-static sensors, e.g., temperature sensors, strain gauges and seismic detectors to the base station over the ZigBee connection. The base station processes these data and communicates them, along with any alerts generated, to several destinations

over the GSM/GPRS link provided by the cellular phone infrastructure. The data are reported by email and FTP to redundant servers, via the Internet, at regular intervals or on an event-triggered basis. The alerts are sent directly by SMS text messaging and by email. Wireless sensor networks are the key enabler of the most reliable and durable systems for long-term SHM and have the potential to dramatically increase public safety by providing early warning of impending structural hazards.

[107] implemented a wireless medical interface based on ZigBee and Bluetooth technology. The purpose is to acquire, process, and transfer raw data from medical devices to Bluetooth network. The Bluetooth network can be connected to PC or PDA for further processing. The interface comprises two types of device: MDIZ and MDIZB. MDIZ acquires data from a medical device, processes them using a microcontroller, and transmit the data through ZigBee network through UART. MDIZB receives data from several MDIZs and transmits them out to PC through Bluetooth network. MDIZB comprises of ZigBee module, two processors, RAM, and Bluetooth module. It receives data from the ZigBee network through its ZigBee module. The data are then sent to processor 1. Processor 1 decides the priority of MDIZs. In processor 1, the data frame is added with Start byte and End byte to mark the beginning and the end of the data frame. After being processed in processor 1, the data are then sent to processor 2 through SPI (Serial Peripheral Interface). Processor 2 transmits data to the PC through Bluetooth network. Processor 2 controls Bluetooth module. Initiate recording when motion is sensed and Raspberry pi devices stores it in a secured folder.

[108] had presented a new strategy for control of baggage handling systems based on Intelligent Transportation Systems. Here three main control issues in baggage handling system, routing and scheduling problem, empty cart management, and line balancing are identified and a combined control approach based on model predictive control is proposed. The control approach can be formulated as a linear programming problem that can be solved efficiently, and hence can be extended to large scale handling system.

[109] had proposed design of baggage tracking and handling system which uses smart RFID and IoT which is based on a cloud server. It has a designed prototype at two locations having both check-in and check-out processes. A more secured algorithm is used for generating tags that are attached to printed baggage label with the details of passenger and airline stored in it and RFID Readers in the check-out areas facilitate step tracking of baggage which prevent baggage loss. The proposed system ensures less consumption of time, security for baggage.

[110] had proposed design for luggage management which uses RFID tags to enhance the ability for baggage tracking, dispatching and conveyance, to improve management efficiency and the user's satisfaction. It uses an intelligent RFID Reader which has the ability of data disposal and provides edge savant service is presented. The prototype readers and its experiment in the airport baggage handling system are also introduced in this proposed model.

[111]Konas bags offers luggage and bag packs that we can track from the smartphone. With the help of the tracking device present in the bag, we can track the device through the application installed in the smartphone. The tags don't provide you with a mobile or computer frontend interface to track and view the location of the bag, instead, the company owning the tag would try to track down the location. A lot of trackable tags are available which can be tied with the bag to track the bags when they are lost. These tags have an inbuilt GPS chip through which the company would track the lost bag. There are a lot of companies in the market who are providing these tags with different features like dyno tag, LugLoc and Robot Check. [112]

Track dot is a luggage tracker device which is placed inside the bag when a person is travelling. It works on ground-based cellular technology and microelectronics. When in an aeroplane during take-off, it shuts down automatically and enters in an aeroplane mode and again activates during landing when the pilot applies brakes. [114]

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter describes the research methods that were employed in the collection and analysis of data for this study. In this component, the researcher explains the general plan of how the research questions were answered. Also, this chapter discusses the credibility of the data collected and the limitations of the study. Thereafter. Details of the data analysis procedures that were employed in the research are also discussed. This is followed by the methodology used to design the models, development and implementation of the prototype.

3.2 Baseline Study

Zambia is situated in Central Southern Africa and shares borders with Zimbabwe, Botswana, Namibia, Angola, DRC, Tanzania, Malawi and Mozambique. It is divided into 10 provinces and has a population of 15million people [129]. Zambia covers an area of 752,612 Km^2 and is highly urbanized with a population density of 100 people per square kilometre in Lusaka. Lusaka has a population of at least 2.8million people [130].

A Mixed Methods Research Methodology comprises a combination of qualitative and quantitative research types [83]. Mixed Methods Research Methodology combines diverse types of data which provides the best understanding of a research problem. A survey was conducted to understand the factors affecting technology adoption based on TAM.

3.2.1 Data Collection

Data was collected from the targeted population who are bus operators and passengers within Lusaka city using interviews and questionnaires. Appendix B contains the questionnaires and other relevant documents that were used in this research. The data collection commenced in August 2019 and ended in September 2019. A descriptive research design was used in describing the current state of affairs, the research employed a mixed-methods approach, which is a combination of both qualitative and quantitative methods. The study used Purposive sampling and convenient sampling.

3.2.2 Inclusion Criteria

The study population included members of staff form the Lusaka City Council, Bus Operators, Passengers and Drivers.

3.2.3 Study Setting

The study was conducted in Lusaka, at our intercity bus terminus.

3.2.4 Sampling

The study employed a mathematical formula to correctly come up with a suitable

Sample for the study. The ideal sample for infinite populations as outlined by (Cochran, 1977) is given as

$$No = (z^2 X p(1-p))/e^2$$

No = $(1.96^2$ X0.5 $(1-0.5))/((0.06)^2)$ = 267

3.2.5 Data Processing and Analysis

Data were coded using excel and analysed using SPSS for correlation.

3.2.5 Ethical Considerations

All the respondents who answered the questionnaires were not required to reveal their identities by writing their names or any information that would give away their identities on the questionnaires. Thus, the respondents were assured of confidentiality and non-persecution arising from their responses.

3.2.6 Limitations of the Baseline Study

The ideal situation would have been to collect data from all the Major Bus Stations for inter-town routes in all provinces and districts. This was hindered by time, logistics and financial limitations. The study was confined to Lusaka city. This could make the generalisations inappropriate as passengers in other areas of the country may be affected by other factors.

3.2.7 Presentation of Findings

The data was summarized and presented in form of tables and figures such as pie charts and bar charts to facilitate understanding.

3.2.8 Technology Adoption Model (TAM)

There are several models existing that have been utilized to explore Technology adoption. A few investigations concentrating on the adoption of mobile services have their foundations in Technology Acceptance Model (TAM) initially proposed by Davies in 1986. The model is initially intended to predict the user's acceptance of Information Technology and usage in an organizational context. TAM focuses on the attitude explanations of intention to use a specific technology or service [21]. Figure 3.1 shows the TAM model proposed by [22].

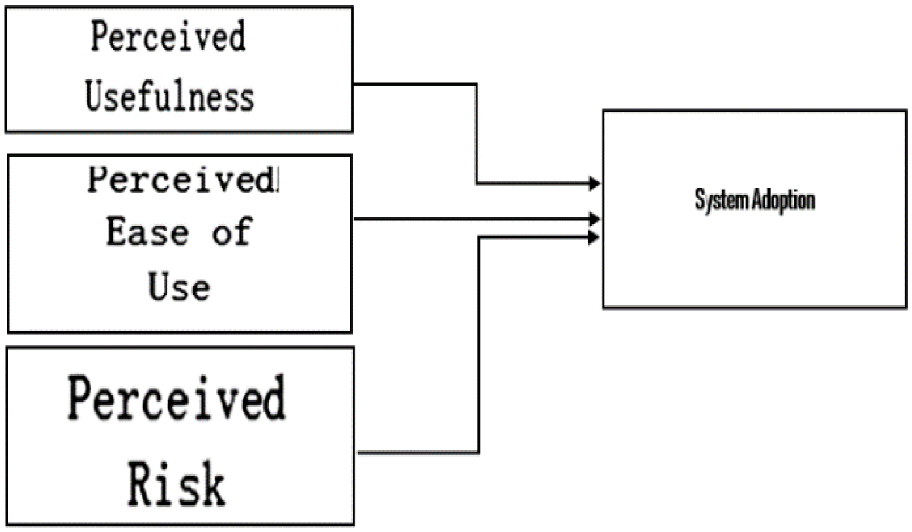


Figure 3.1: TAM Model [22]

Perceived usefulness (PU)

Is defined as "the degree to which a person believes that using a particular system would enhance his or her performance"

Perceived Ease of Use (PEU)

Is defined as "the degree to which a person believes that using a particular system would be free of effort," [20]

Perceived Risk (PR)

Perceived risk is defined as a consumer's perceptions of the uncertainty and the possible undesirable consequences of buying a product or service [21]. Indeed, people may feel a certain degree of risk when using an Internet-based channel because perceived risk has the characteristics to increase vulnerabilities and generate inhibiting aspects to consumers'.

With the usage of the TAM model, we were able to formulate a conceptual framework that we used in developing our prototype.

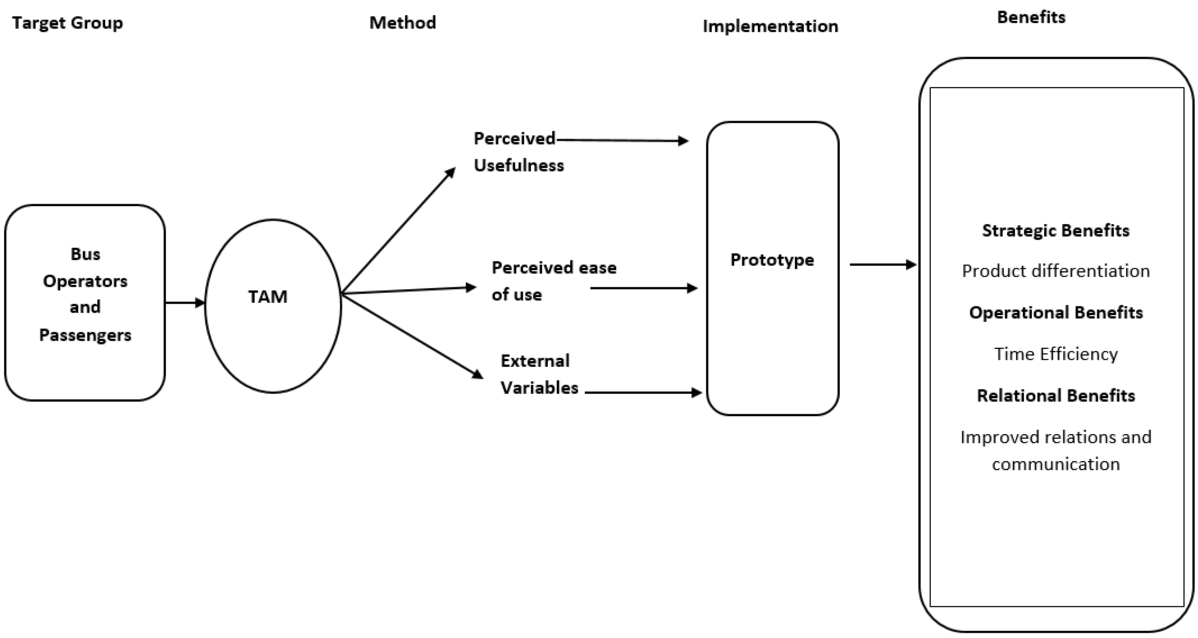


Figure 3.2: Conceptual Framework

The observed business process requires that a passenger makes a payment for their travel and luggage. A ticket is generated that has the passenger information, such as first, name last name, seat number and drop point, the generated ticket is used when the luggage has to be loaded onto the bus, other bus operators label the luggage with stickers that provide a verification mechanism of the information that is on the luggage owners ticket. Once the bus arrives at its destination passengers are required to produce the ticket to claim ownership of the luggage as shown in figure 3.3.

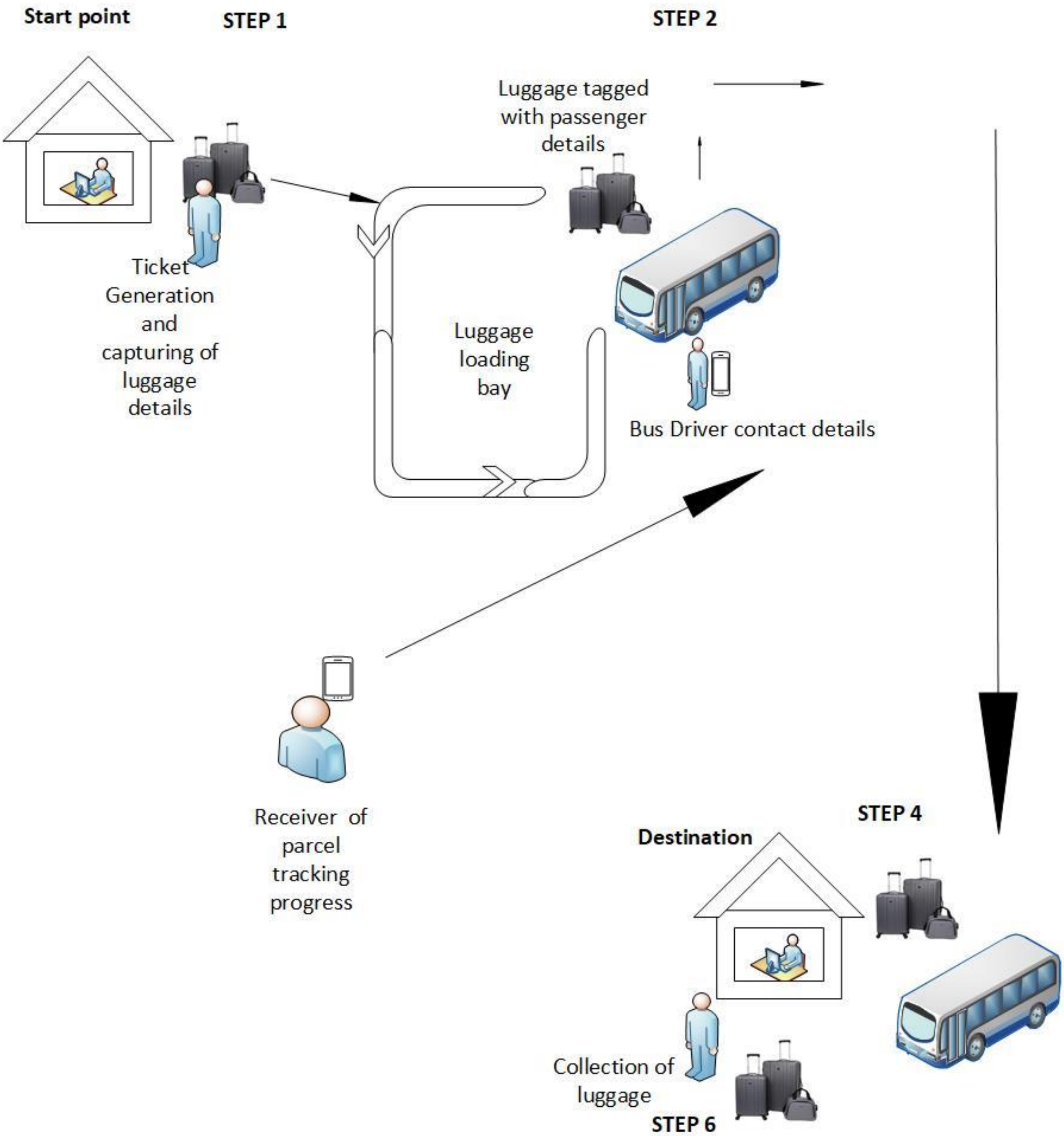


Figure 3.3: Shows the observed luggage handling business process

Materials and Methods

1) Materials

Components for luggage tampering detection

- GSM/GPRS Module (SIM808) to enable the network communication with the Arduino Uno Board R3
- Arduino Uno board R3 (Microcontroller).
- Passive Infrared (PIR) Sensors to enable communication with the Arduino Uno Board R3

Components for luggage tracking

- RFID-RC522 to scan tags and communication with the Arduino Uno Board R3
- RFID tags for unique identification of luggage.
- GSM/GPRS Module (SIM808) to enable the network communication with the Arduino Uno Board R3.
- Arduino Uno Arduino Uno Board R3 (Microcontroller).

Detailed Voltage are operating requirements for Arduino and SIM808 are provided in the appendix

Software requirements

- PHP for the web application
- C++ for the microcontroller programming.
- MySQL database and WAMP remote web server modules to enable communication with the Arduino Uno Board R3.
- Arduino IDE Development environment.
- Google maps module to enable location feed with the Arduino Uno Board R3.

2) Methods

The method adopted for testing and developing our prototype model was experiment-based that enabled splitting implementation into modules namely the luggage tampering detection and the luggage tracking module.

Luggage tampering detection

In our setup, Passive Infrared Sensors (PIR) is associated with a microcontroller (Arduino) at the transmitting end. Once the infrared emission is detected a signal is sent to the microcontroller using the digital connection bus. The embedded program on the microcontroller parses the signal and transmits it to the receiving end as an integer “1” to signify intrusion or “0” to signify a zero. This, in turn, tends to turn on the buzzer alarm. As shown in figure 3.4.

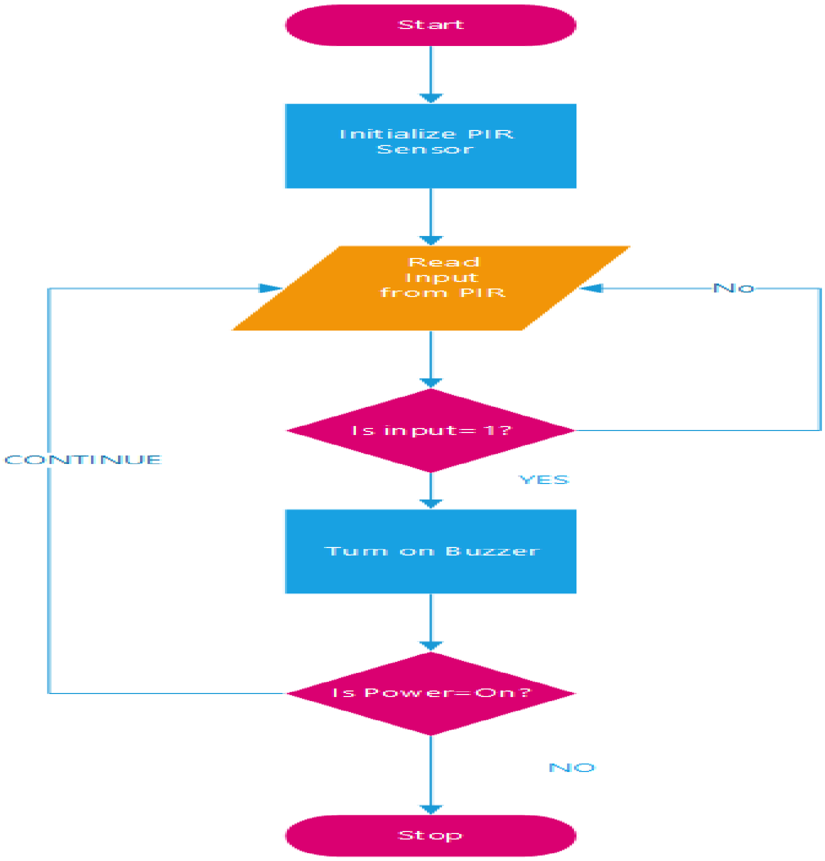


Figure 3.4: Flow chart of luggage tampering

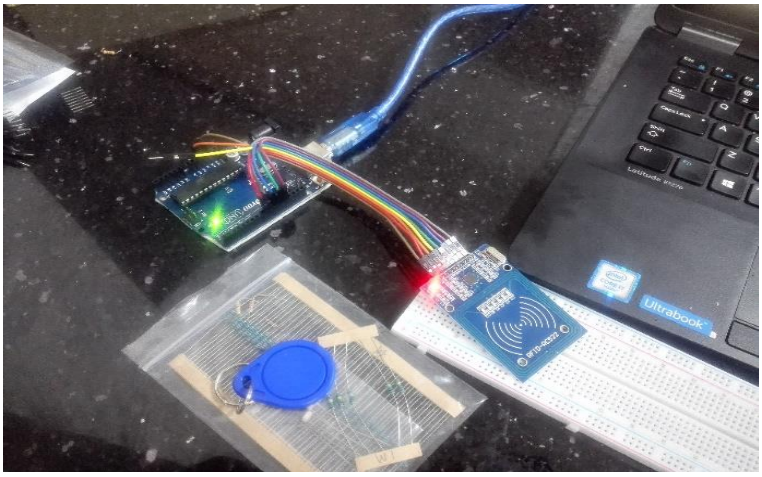


Figure 3.5: RFID Tag being read

Luggage tracking

Our tracking component is based on Radiofrequency identification (RFID), as depicted in figure 3.5 an RFID reader module is connected to a microcontroller (Arduino), and luggage is tagged with RFID tag. At the ticketing office, each bag is scanned to capture information, this information is then transmitted to the remote server using GPRS the opposite is also true at the destination pickup point as shown in figure 3.6.

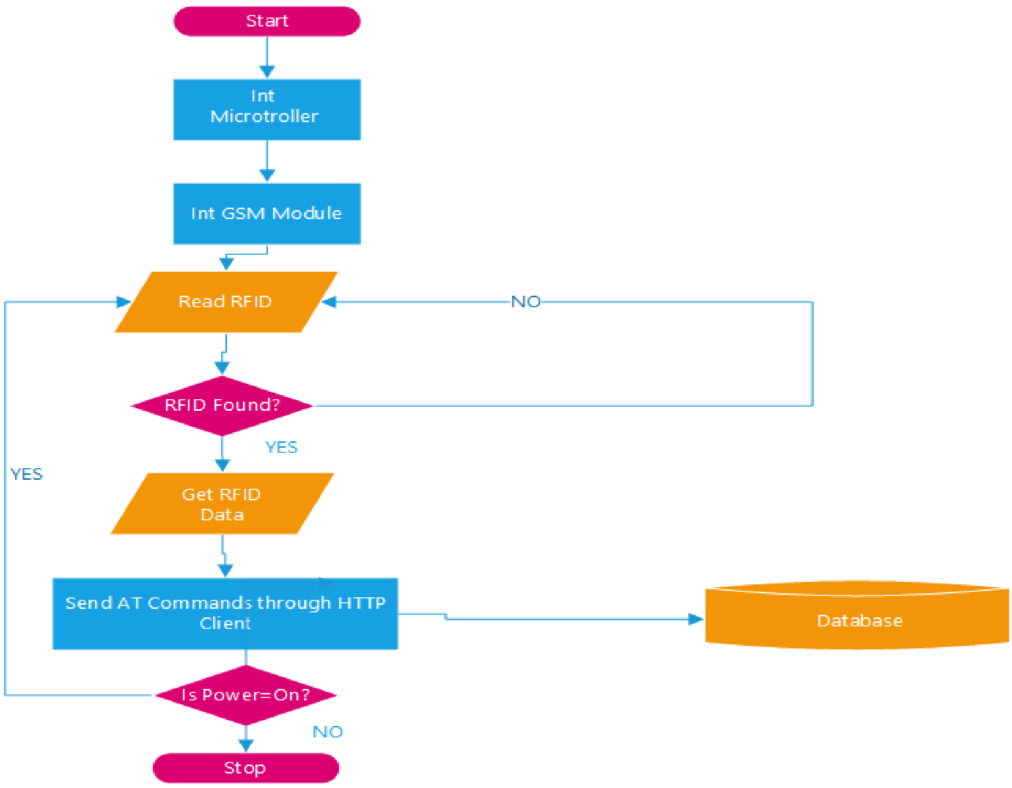


Figure 3.6: Luggage tracking Module

The Arduino board and the RFID reader is connected using serial pins. The Arduino MFRC522 library based on RC522 readers and RFID tags were used as the basis for programming the Arduino board to enable serial communication between the RFID and Arduino, also, between the Arduino board and the application on the computer. The USB cable was used to send the serial data from the Arduino board to the computer. The USB cable is used to power up the Arduino Board through the computer. The software development tools that were used to develop the application were WAMP and Arduino IDE. Arduino IDE was used to program the Arduino board to interact with system components of the system such as PIR sensor, Buzzer, LED light, resistors, RFID reader, tag and SIM808 using C++ programming language. Arduino Uno R3 has a limitation on the number of digital and analogue pins that can be used to connect components, for this reason, a breadboard [115] is introduced to provide pins for various components to be connected.

3.3 System Implementation and Design

3.3.1 System Design

A system analysis was done to determine the requirements of the system. The Passenger Luggage Tracking system requirements document was generated. Functional and non-functional requirements were developed. To develop the requirements, the use case diagram and use case text were developed.

The Passenger luggage management system has three main actors and these are the system administrator, operations manager and the passenger.

Both the Operational manager and passengers have to be enrolled on the system. The role of the administrator is to manage the whole system while the operational managers can only manage their passengers and officers.

Functional Requirements

Functional requirement [92] defines the function of a system and its component. The system supports three users, namely; Administrator, Manager and Passenger.
The following are the functional requirements of the system.

- **Administrator**
    1) **Add Office:** The Administrator must be able to create a Company Profile for a bus operator.
    2) **Delete Office:** The Administrator must be able to delete bus operators that no longer operational.
    3) **View Offices:** The Administrator must be able to view a list of all operators currently using the system.
    4) **Add Manager:** The Administrator must be able to create an operations manager for a bus operator.
    5) **Delete Manager:** The Administrator must be able to delete Operational Managers.
    6) **View Managers:** The Administrator must be able to view a list of all operations manager defined in the system.

7) **Add Consignment:** The Administrator can capture details of the owner of consignment, destination and tagged for the courier.
8) **Update:** The Administrator can update the delivery status report.
9) **Delivered:** The Administrator can view parcels and luggage with the delivery status.
10) **Search:** The Administrator can search for consignment using a unique ID.
11) **View on Map:** The Administrator has access to view real-time location buses carrying luggage and parcels.
12) **Deliveries:** The Administrator can view all the luggage and parcels that are yet to be delivered.

- **Manager**

1) **Add Consignment:** The Operations Manager can capture details of the owner of consignment, destination and tagged for the courier.
2) **Update:** The Operations Manager can update the delivery status report.
3) **Delivered:** The Operations Manager can view parcels and luggage with the delivery status.
4) **Search:** The Operations Manager can search for consignment using a unique ID.
5) **View on Map:** The Operations Manager has access to view real-time location buses carrying luggage and parcels.
6) **Deliveries:** The Operations Manager can view all the luggage and parcels that are yet to be delivered.

- **Passenger**

1) The User or passenger has access to tracking the status of the consignment.

Non-Functional Requirements

In requirement engineering, a non-functional requirement [92] is a necessity that specifies criteria that can be used to judge the operation of a system. Non-Functional requirements can be further defined as global constraints on the software system and they include development costs, operational costs, performance, reliability, maintainability, portability, robustness the non-functional requirements of the application are introduced in Table 3.1.

Table 3.1: Non-Functional Requirements

No.	Requirement	Description
1	**Usability**	- *The application must be easy and simple for all types of people that vary from ages and backgrounds to use.*
2	**Response Time**	- *Notifications should be sent in an appropriate time.* - *When information from the database information should be retrieved in a reasonable time.*
3	**Reliability**	- *Many users can use the application at the same time, and deliver services to all users, as it was intended to.* - *System failure shall not compromise data integrity.*
4	**Security**	- *The application contains the users' confidential data that cannot be seen or accessed into by anyone, except the users themselves, and the admin.* - *The application should be supported by a trusted organization.* - *The drivers' bus will be tracked for security and safety issues.*
5	**Maintainability**	- *New features could be added to the application in the future.*
6	**Performance**	- *All hardware shall run on standard power (220/240v).* - *The system shall be able to sit at idle and resume operations with minimal delay.* - *System failure shall not compromise data integrity.*

3.3.4 System Modelling and Design

To design the system models for the passenger luggage tracking system, Object-Oriented Design (OOD) methodology was used [61], a modular approach was adopted testing the individual functionality, ultimately integrating the entire system functionality.

Interaction Models – Use Cases

Use case modelling is used to model interactions between a system and external factors which may include users and other systems [57]. Actors are a representation of the roles that people, other systems or devices take on when communicating with particular Use Cases in the system [63].

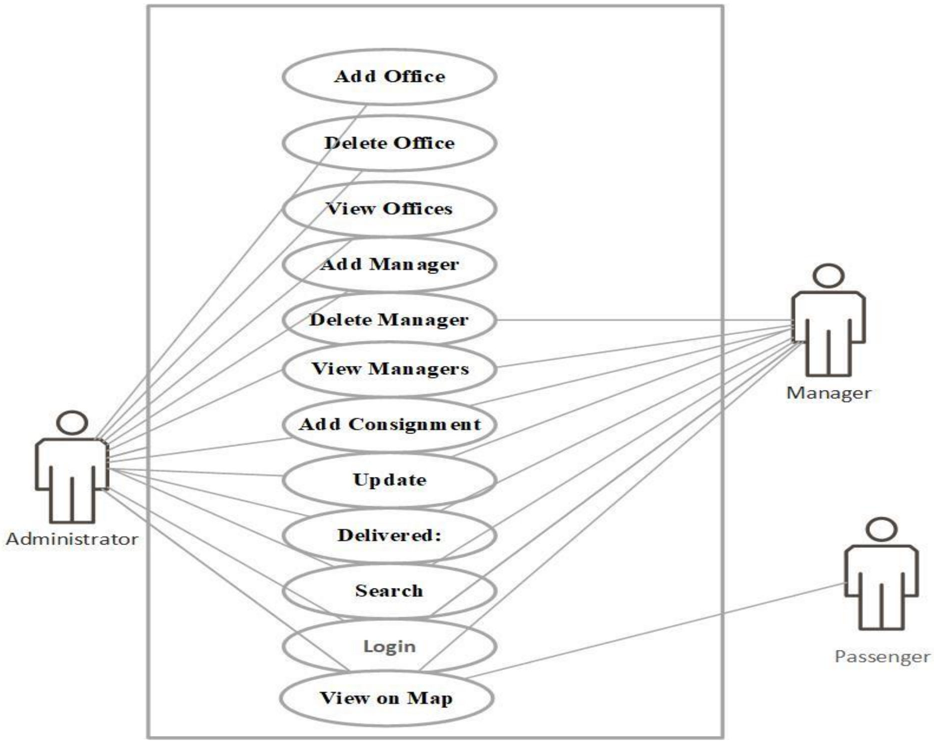


Figure 3.7: Use Case diagram for Users

The use case diagram, shown in Figure 3.7 shows how the users interact with the system.

Use case text

The use case text is a methodology that is used in system analysis to identify, clarify, and organise system requirements.

This section shows the textual story of how the user interacts with the system to perform his/her functional requirements. Only some functional requirements are shown.

The use case text for Login, which is a function that is performed by an administrator, it shows the actor, precondition, post condition, the main scenario and alternative flow. This explanation follows for Tables 3.2 to 3.9, where different use cases and actors are featuring.

Table 3.2: Use case text for Login

Use case Name	Login
Actor	Administrator, Manager
Pre-condition	Know the correct username and password
Post Condition	Login successful
Main Scenario 1. Administrator/Manager: enter login Credentials 2. System: System validates credentials 3. Administrator/Manager: access granted to the system	
Alternative flow 1a Wrong password or username 1. System: Your Credentials are not valid. Please try again. 2. User: user retries login 3a Missing password or username 3. System: Please enter the user name or password 4. User: user retries login	

Table 3.3: Use case text for Add Manager

Use case Name	Add Manager
Actor	Administrator
Pre-condition	Logged in
Post Condition	Manager added
Main Scenario 1. admin: Selects the add Manager 2. System: displays the add Manager form 3. admin: Enter Manager information (name, Address, Phone number, Bus operator and select the add option 4. System: information is saved	

Table 3.4: Use case text for Update

Use case Name	Update
Actor	Administrator and User
Pre-condition	Logged in
Post Condition	Luggage status Edited

Table 3.5: Use case text for Delete Manager

Use case Name	delete Manager
Actor	Administrator
Pre-condition	Logged in
Post Condition	Manager deleted
Main Scenario 1. Admin: select the Manager to be deleted and select the delete option 2. System: delete the Manager	

Table 3.6: Use case text for Search Tag

Use case Name	Search Tag
Actor	Administrator and Manager
Pre-condition	Logged in
Post Condition	Tag searched
Main Scenario 1. admin: Select the search option 2. admin: Enter Tag ID 3. System: displays the search query results for the Tag ID 4. System: the details of Tag are displayed	

Table 3.7: Use case text for Add Office

Use case Name	Add office
Actor	Administrator
Pre-condition	Logged in
Post Condition	Office added
Main Scenario 1. Admin: Select the add office option 2. System: displays a form with fields 3. Admin: Enter name of Bus operator, address, contact person and details 4. System: System saves the record	

Table 3.8: Use case text for View Managers

Use case Name		View Managers
Actor		Administrator
Pre-condition		Logged in
Post Condition		List Displayed
	Main Scenario 1. Admin: Select view Managers option 2. System: displays names of all Managers enrolled.	

Table 3.9: Use case text for View on Map

Use case Name	View on Map
Actor	Administrator, Manager, Passenger
Pre-condition	Logged in
Post Condition	View of real-time google maps location
Main Scenario 1. Admin: click of View map 2. System: displays the location of the bus	

Structural Models – Class Diagram

Class diagrams in an object-oriented system model are used to show the classes in a system and the associations between these classes. An object class can be a general definition of one kind of system object. An association is a link between classes that shows that there is a relationship between these classes. Objects represent something in the real world, such as a person, a transaction, and so on [57]. Figure 3.8 shows a class diagram model of the system.

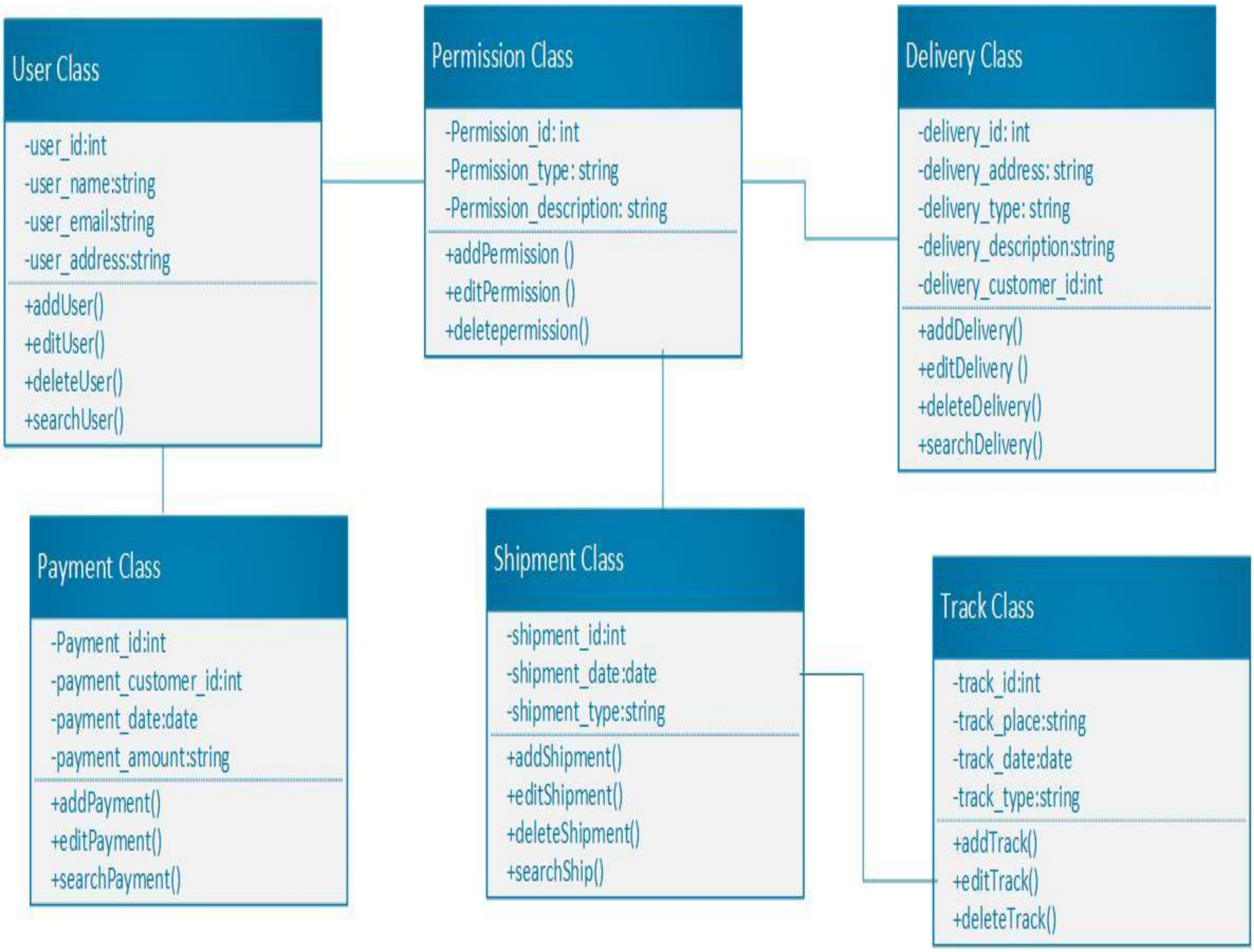


Figure 3.8: System Class Diagram

Data Models

Data Modelling attempts to provide a representation of user reality. It ignores some of the complexity of the real world and simplicity is attained by using a small set of constructs. Data Modelling through Entity Relationship Models (ER) attempts to reduce the organization's world into a description of entities relationships. The ER modelling process is independent of the development platform or software. It enables unambiguous and accurate communication of understanding of the data resource at an abstract level. ER Models consist of entities, attributes and relationships [85].

Entities are a collection of objects or concepts that are identified by an enterprise as having an independent existence and share common characteristics. Entities are usually abstract or concrete recognizable business concepts about which various data are stored. Entity objects or concepts are uniquely identifiable [85]. Attributes, on the other hand, are pieces of information at an atomic level. They are properties of entities that of interest to an enterprise. In ER modelling, only a subset of an entity's attributes which are directly related to the application is of interest. Attributes take on particular values [85]. Finally, relationships are an association among entities.

Relationships are often characterised by degrees, also known as, the degree of the relationship. The degree of the relationship denotes the number of entities involved with the relationship. Entity Relationships usually take on two forms namely, cardinality and participation constraints [85]. Cardinality Constraints determine the number of possible relationships for each participating entity. Cardinality can be simply described as the number of allowed instances of entity "B" that can be associated with each instance of entity "A". The most common degree for relationships is binary cardinality ratios of one-to-one (1:1), one-to-many (1: M) or many-to-many (M: N). On the other hand, Participation constraints determine

Whether the existence of an entity depends on it being related to another entity through the relationship [85].In Figure 3.9 the ER diagram for the passenger tracking system is presented.

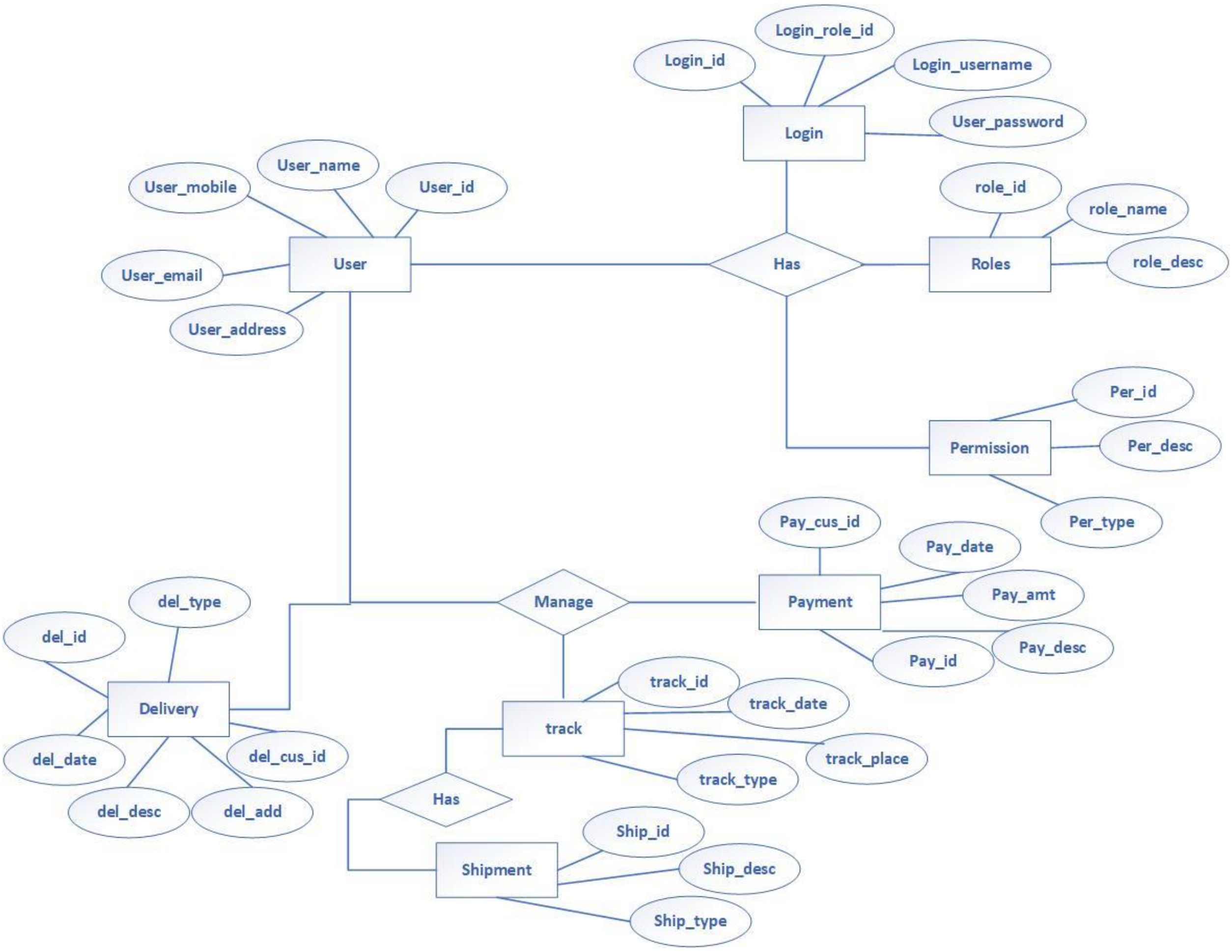


Figure 3.9: System Entity Relationship Diagram

Sequence Diagrams

Sequence Diagrams are interaction diagrams that detail how operations are carried out. They capture the interaction between objects in the context of a collaboration. Sequence Diagrams are time focus and they show the order of the interaction visually by using the vertical axis of the diagram to represent time what messages are sent and when [57].

Sequence Diagrams captures:

The interaction that takes place in a collaboration that either realizes a use case or an operation (instance diagrams or generic diagrams)

High-level interactions between the user of the system and the system, between the system and other systems, or between subsystems (sometimes known as system sequence diagrams)

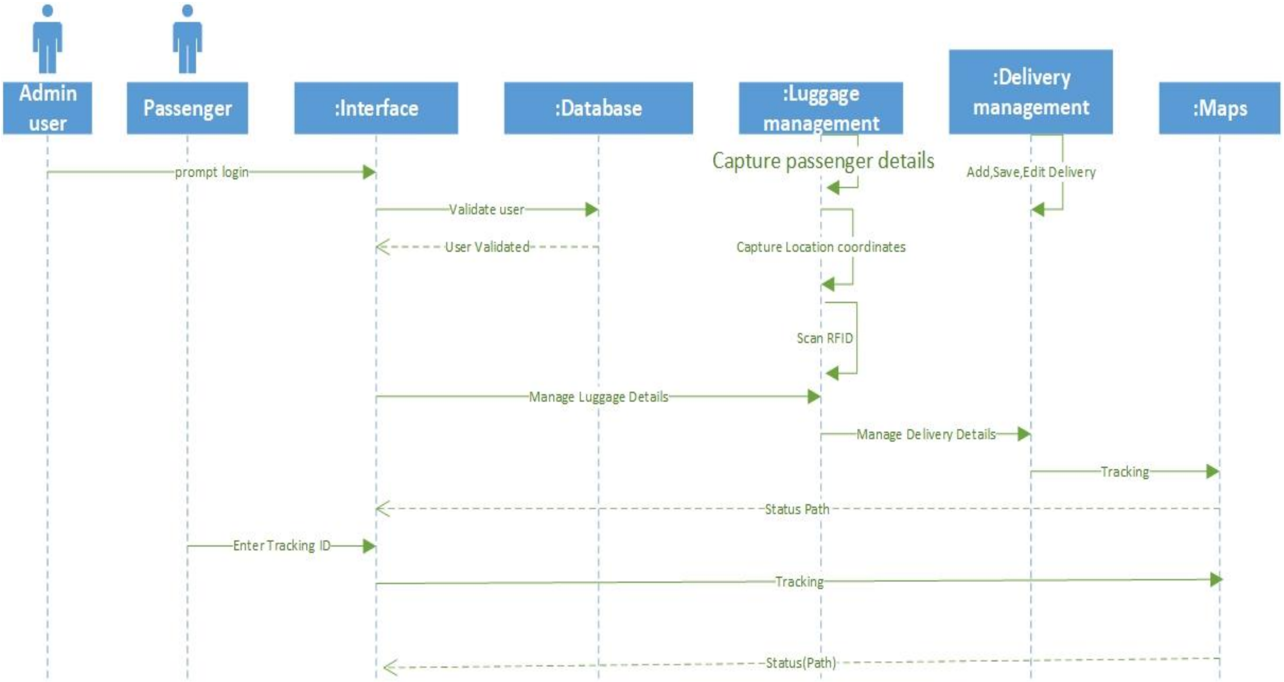


Figure3.10 Sequence Diagram

3.3.2 System Implementation

The hardware components used in this study to implement the prototype were the Arduino Uno Board R3, an RFID-RC522 reader, a USB cable to connect the Arduino board to the computer and two Mifare RFID tags. PIR sensor, Buzzer, LED, GPS/GSM module.

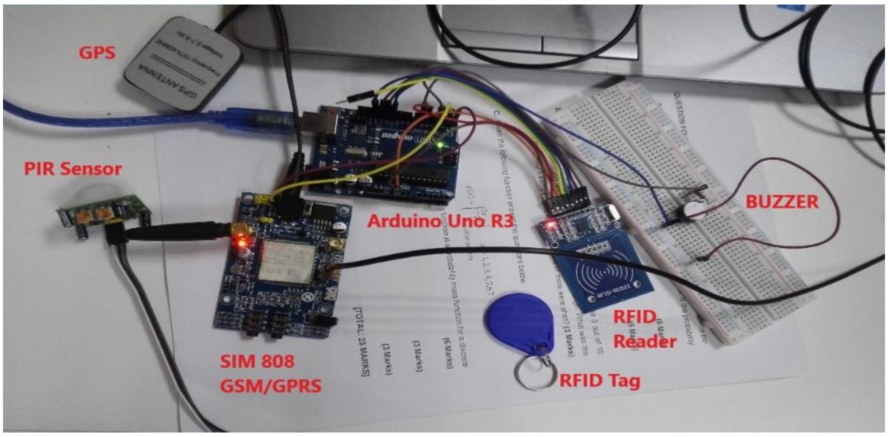


Figure 3.11: Hardware setup

The RFID tags are scanned against the RFID reader as can be seen in Figure 3.11 after a successful scan, the tag data is sent to the Arduino, the Arduino through sim808 GSM/GPRS module sends the scanned data to the server. Once the tag data is received and stored in the database, it is later overlaid on the google map embedded on the PHP, with other luggage information.

3.3.6 System Architecture

The diagrammatic representation of the system architecture of the passenger luggage system is shown

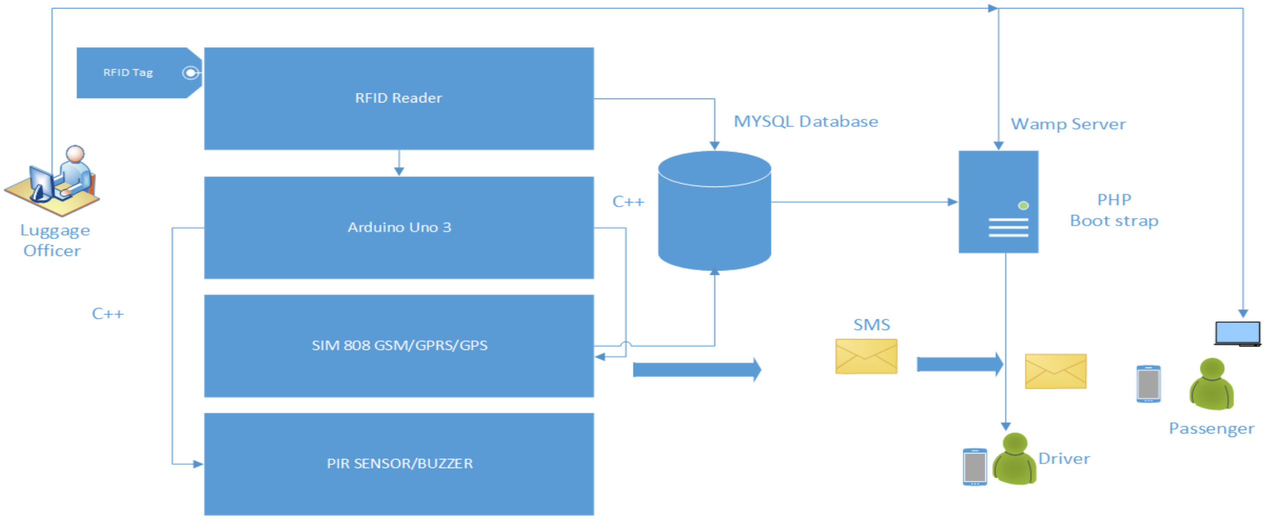


Figure 3.12: System Architecture

The architecture of the system has four distinct components, the first one being the RFID module, it has an RFID tag which has to be scanned using the RFID reader all the processing is controlled by an Arduino microcontroller, which instructs the SIM808 module on events that trigger the sending SMS notifications, the SIM808 module is also responsible for capturing GPS coordinates that are stored in a database, to connect to the internet we make use of GPRS. Our microcontroller is also responsible for controlling signals to the Passive Infrared Sensor and the Buzzer.

The second part of the system is a database that is used for storing all the information, the third part is the server responsible for hosting our webpages, lastly, we have a Graphical user interface GUI which makes it easy for users to query the database for information as shown in figure3.12.A further graphical representation of the interaction of users is given in figure 3.13.

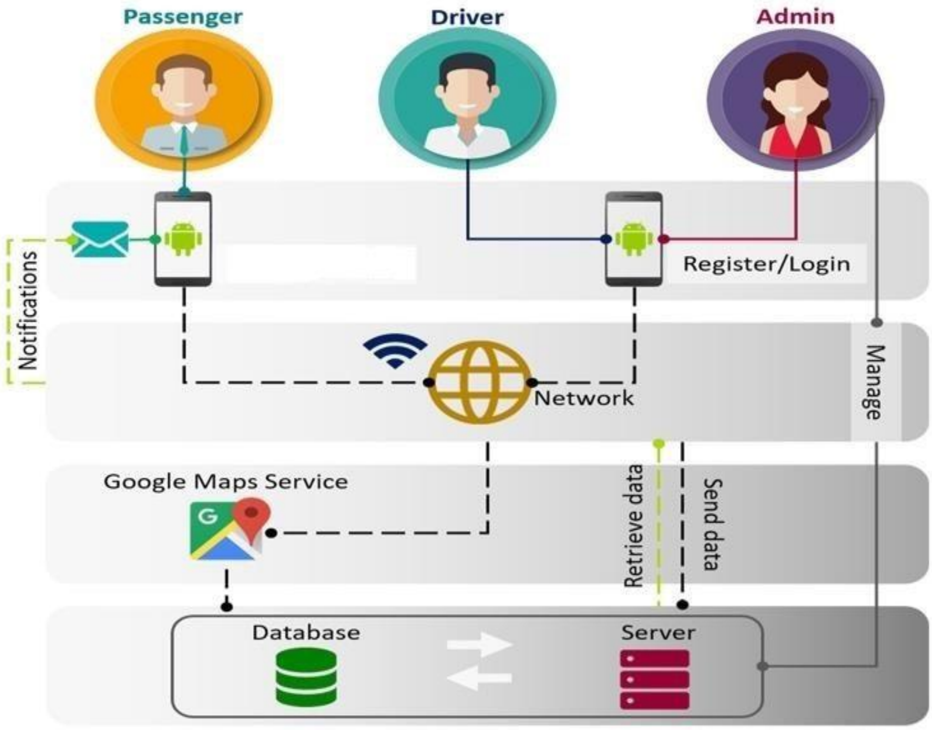


Figure 3.13: System User Interactions

3.4 Summary

In this chapter, the materials and methods that were used in the baseline study and the system automation prototype were outlined. A Mixed Methods Methodology was used in this research study. Random and convenient sampling was used in the baseline study and an Object-Oriented System Development Methodology that is Use Case driven was used in the system design and implementation. System models including data flow diagrams, structural models and data models were presented to provide how the system may be implemented.

CHAPTER FOUR
DATA COLLECTION ANALYSIS

4.1 Introduction

In this chapter, we present the results that were derived from the baseline study. We also present results for the implementation of the system prototype using screenshots of the system application and hardware.

4.2 Baseline Study Results

In this section, the results from the baseline study derived from the analysis of each variable through descriptive statistics are presented. The presentation of the results is in the form of tables, bar charts and pie charts. The implementation and results that were outlined in the previous chapter and how they relate to the objectives of this study.

The first objective sought to establish the level of technology adoption among the bus operators and passengers and understand the operational challenges. The study revealed that 99.5 per cent of the respondents have used public transportation to connect from one end of the country to another. Respondents were asked if they had made online ticket reservation before, 14.5 Percent of the respondents had made online ticket reservation 85.5 Percent had not, this was largely attributed to fear of making paperless payments and lack of knowledge to making electronic payments. Further information to ascertain the respondents' level of computer skills was conducted, over 50 per cent of the respondents stated that they had basic computer skills, which included sending an email, typing a document, switching on a computer and browsing for information on the internet.

The survey also revealed that respondents that had encountered losing or misplacing luggage on a journey were 28 per cent while 78 Percent had never encountered such an occurrence. Once all the information from the questionnaires was collected, it was organized into tables and charts.

4.2.1 Demographic Data

Distribution of Respondents by Gender

Data were collected from 197 respondents, the questionnaire respondents were as follows: 116 (58 Percent) were male participants, 82(42 Percent) were female participants.

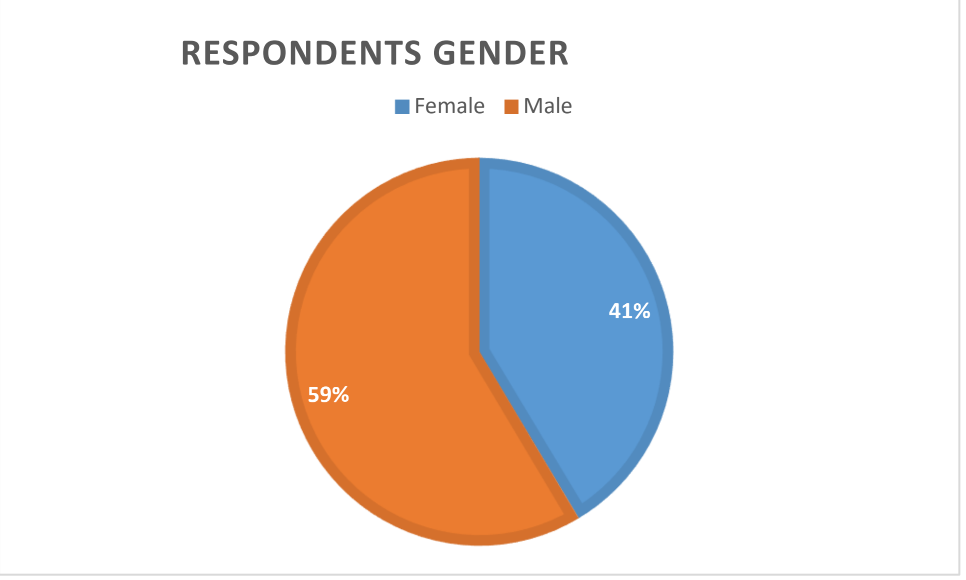


Figure 4.1: Gender of respondents

4.2.2 Distribution of Respondents by Age

On age distribution, it was found that nine (9) respondents were 20 years and below representing 4.55 per cent of the respondents. One hundred and twelve (112) of the respondents came from the 21-30 age group indicating 56.57 per cent and fifty (50) respondents from 31 – 40 age groups corresponding to 25.25 per cent. Furthermore, seventeen (17) respondents representing 8.59 per cent came from 41- 50 age groups. Five (5) respondent representing 2.53 per cent came from 51-60 age groups. The last age group of 61 and above represented five per cent of the respondents. The information on age was crucial because it helped the researcher to know the computer literacy levels and how easily respondents would be able to learn computers to effectively use the luggage tracking system. We got the most feedback from the age group 21-30 as shown in figure 4.2.

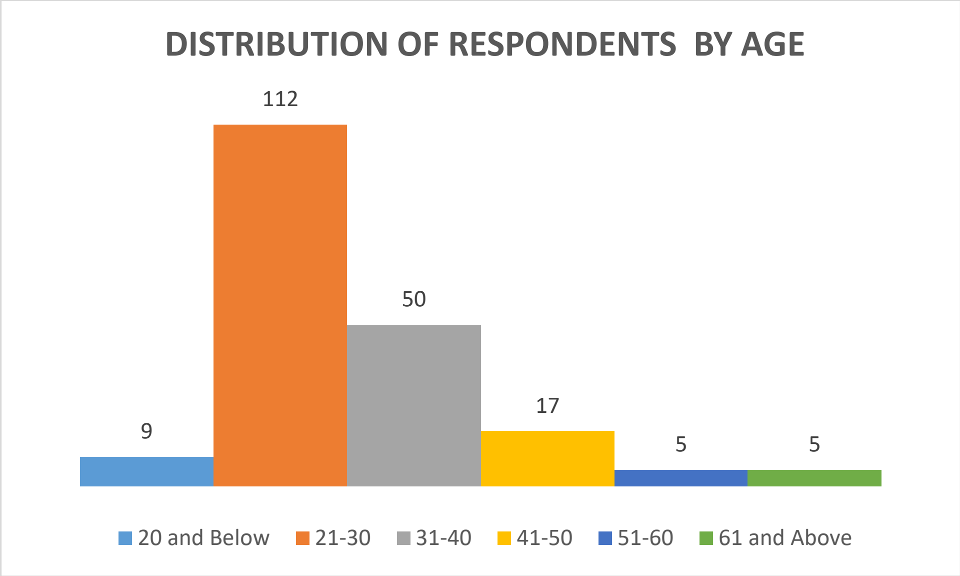


Figure 4.2: Age of respondents

4.2.3 Distribution of Respondents by Occupations

Figure 4.3 shows the findings on the occupations of the respondents. Out of 198 respondents, 40 respondents were unemployed representing 20.20 per cent, while 116 respondents were salaried workers representing 58.59 per cent, 35 of the respondents were self-employed representing 17.68 per cent, finally, 7 of the respondents were senior citizens who are pensioners representing 3.54 per cent The occupations of respondents were crucial in establishing the level of involvement of various people in the development process.

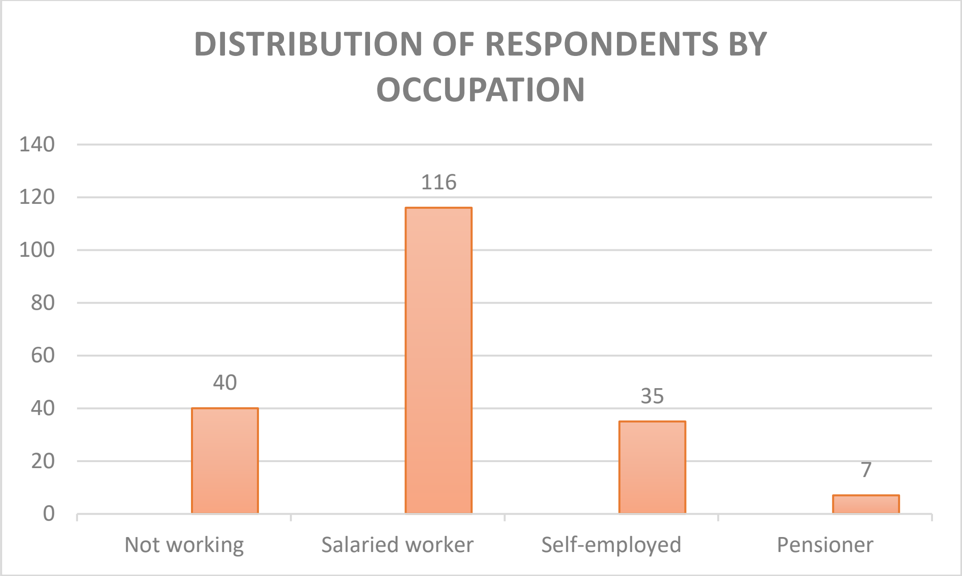


Figure 4.3: Respondents Occupation

4.2.4 Passenger Computer Knowledge

Respondents were asked to evaluate their computer skills, starting with basic operations such as switching on a computer, surfing the internet for information and usage of software packages to complete tasks.

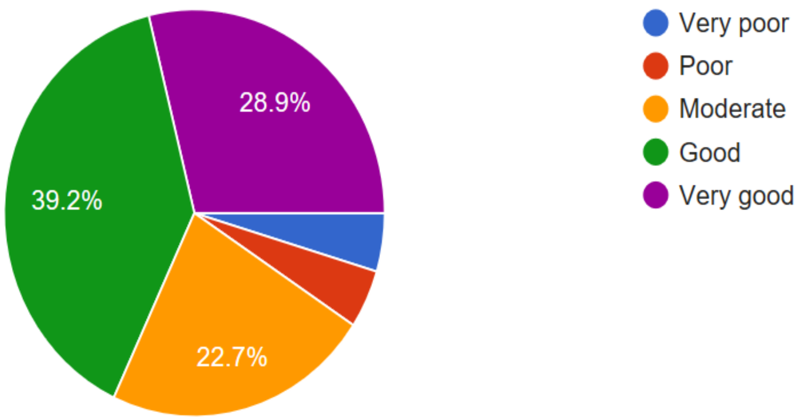


Figure 4.4: Passenger Computer Knowledge.

The study reviewed in figure 4.4 that over 50 per cent of the passenger respondents have the basic knowledge of how the computer-operated. 22.7 per cent had moderate knowledge, 39.2 per cent had good knowledge, 28.9 had very good knowledge and 4.6 per cent had very power poor knowledge.

4.2.5 Passenger Usage of Bus Transportation

When respondents were asked if they had made use of public transportation when travelling from town to another, the study reviewed that 99.3 per cent of the respondents have used public transportation with only 0.7 per cent had not used these services as depicted in figure 4.5.

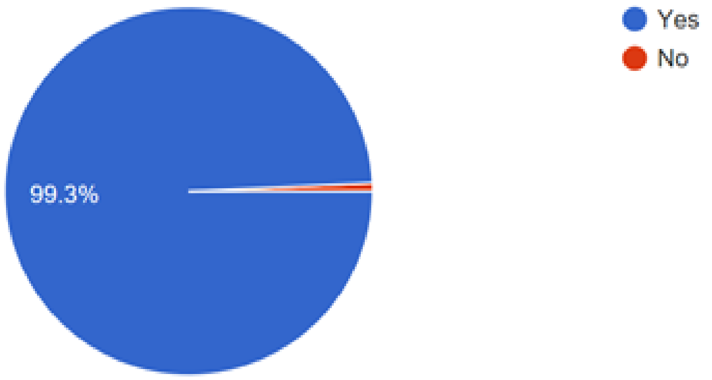


Figure 4.5: Usage of Bus Transportation.

4.2.6 Passenger Luggage Mismanagement

Figure 4.6 reviews the findings of misplaced and lost luggage as passenger make use of public transportation, 55 of the respondents representing 28 per cent confirmed to have experienced an incident of missing or lost luggage while 72 per cent had not lost or misplaced luggage.

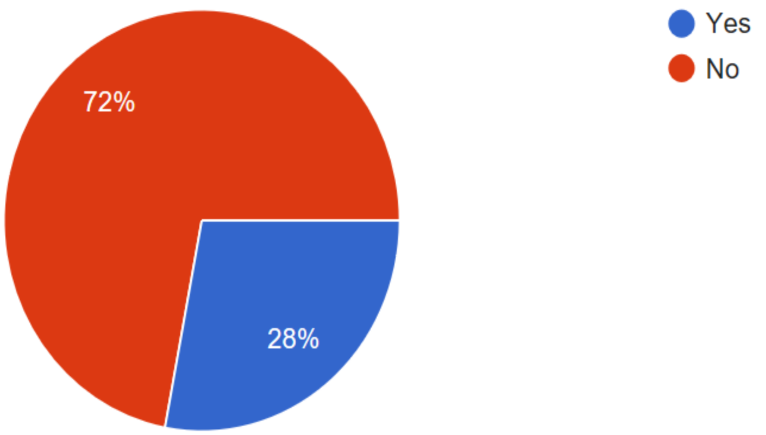


Figure 4.6: Lost or Misplaced Luggage on a journey by passengers.

4.2.7 Bus Owners and Drivers computer knowledge.

In Figure 4.7 findings of bus owners and drivers' computer knowledge is tabulated, they were asked to rank their knowledge of using computers and packages to improve their productivity from poor to excellent. The result shows that bus owners and drivers have at least basic knowledge of computers.

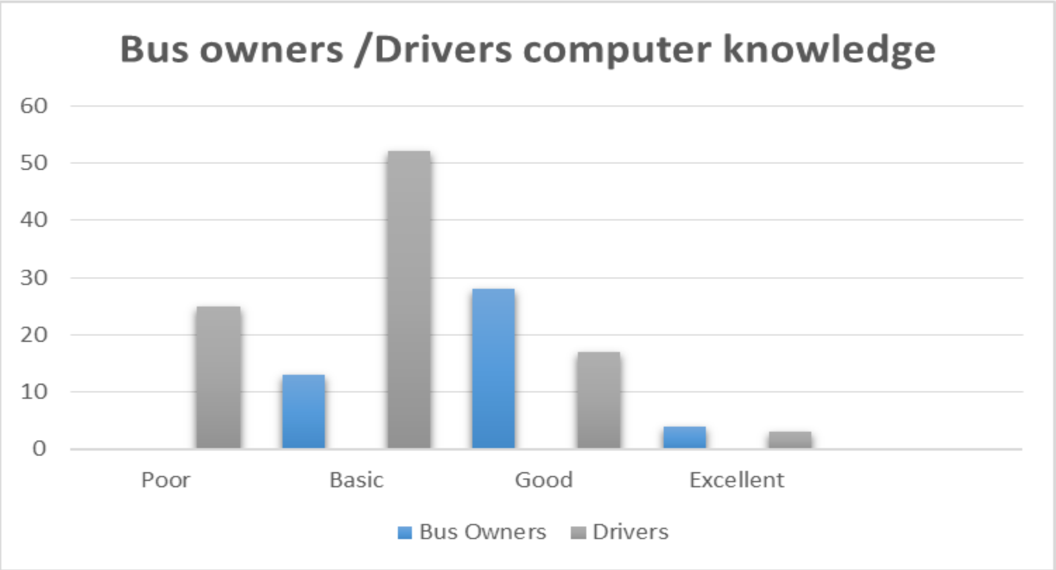


Figure 4.7: Bus Owners and Drivers computer knowledge.

4.2.8 Bus Owners Perceived usefulness of the system

The results in Figure 4.8 show that out of the 46 bus operators that were interviewed 38 perceived the system been useful for daily operation this represented 82.6% respondents. Currently, none of the bus operators is providing luggage tracking mechanism.

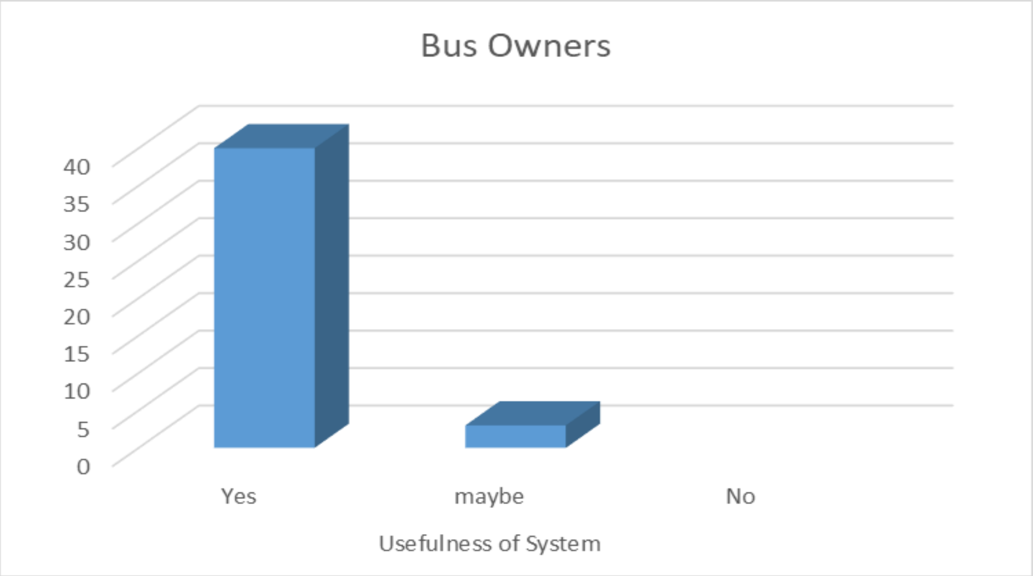


Figure 4.8: Bus Owners Perceived usefulness of the system.

4.2.9 Existing IT infrastructure

The results in figure 4.9 depicts the current infrastructure this was ranging from computers both desktops and laptops, if the offices have a fixed internet link or wireless router that provides connectivity, a printer for coping .scanning and printing, an antivirus to protect their end point devices and firewall to protect their network infrastructure and if they have dedicated IT support staff.

29.2 percent confirmed having computers, printers, firewall and antivirus software at their operating offices, while 20.8 percent confirmed having access to the internet when carrying work activities, 8.3 percent represents operators with a dedicated IT support officer.

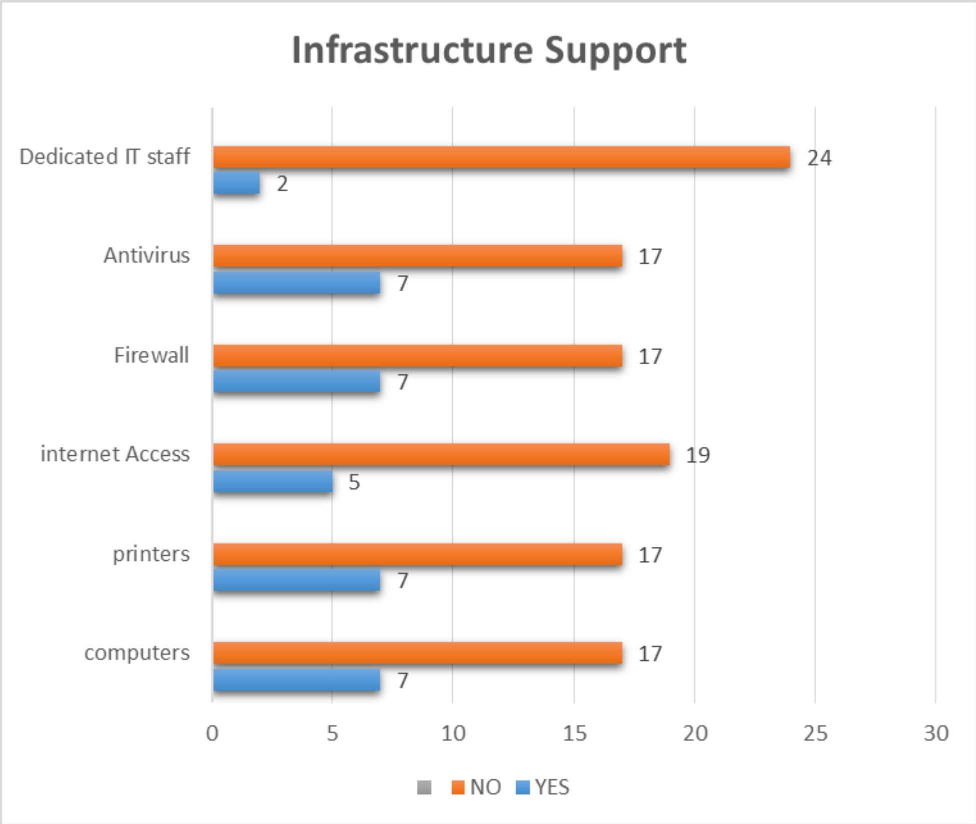


Figure 4.9 infrastructure support

4.2.10 Passenger internet usage experience

The study reviewed that that 90.8 per cent of the respondents had been using the internet for at least 2 years this factor was key in understanding how exposed the respondents are to technology trends as shown in Figure 4.10.

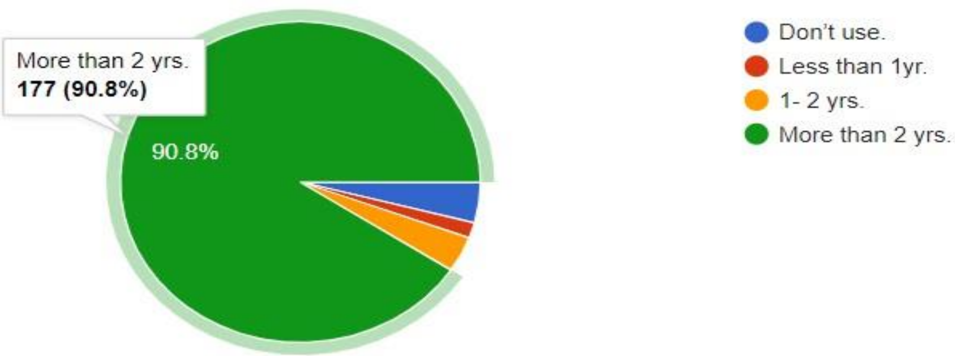


Figure 4.10: Duration of internet usage

4.2.11 Passenger Daily Internet Consumption

Passengers confirmed having spent some time, checking emails, social medial, downloading information or working from the internet, however, 8 of the respondents confirmed they did not use internet services as shown in figure 4.11.

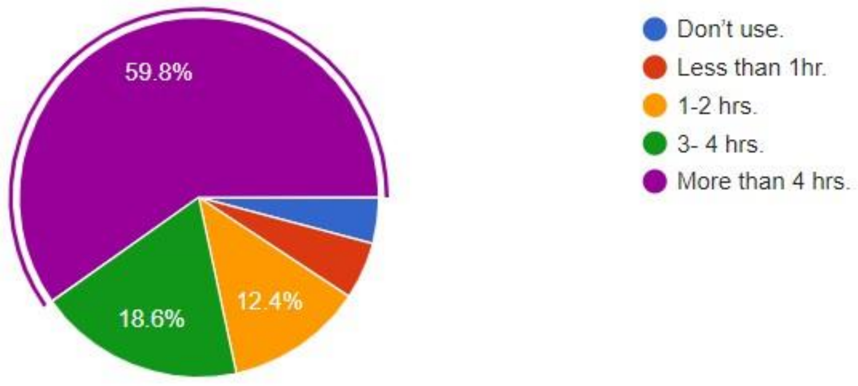


Figure 4.11: Number of hours Passengers spend daily on the internet.

4.2.12 Perceived Usefulness

The study reviewed that 98.4 per cent of the respondents felt that the performance of courier services offered by bus operators can improve with users having the convenience of checking the delivery status online as shown in figure 4.12.

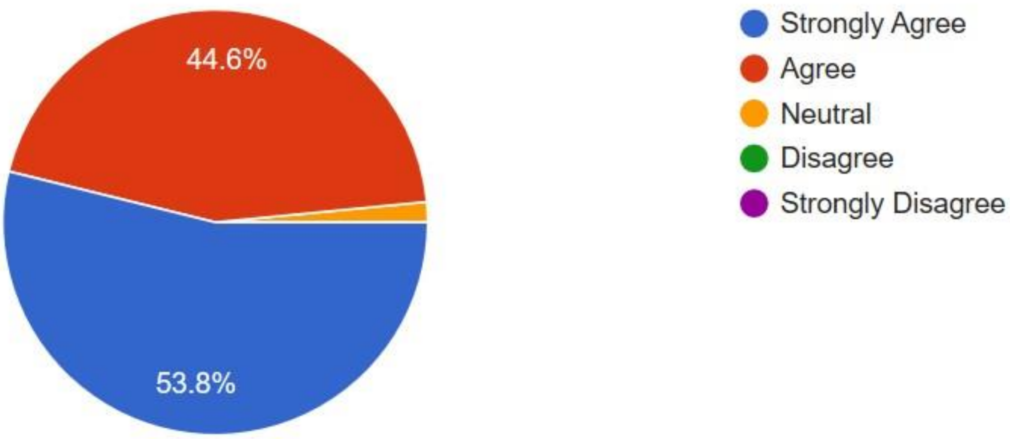


Figure 4.12: Perceived improved performance of courier services by system usage.

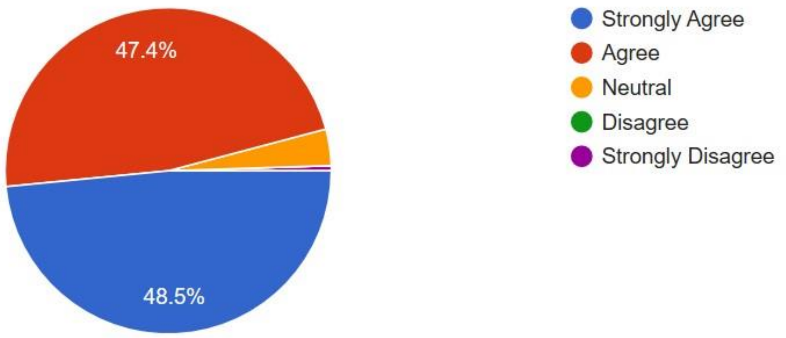


Figure 4.13: Perceived ease of monitoring luggage.

The ability to use a unique tracking ID in the search field to retrieve the live location of the luggage was perceived to be user friendly and not complicated to operate, results show 95.9% of respondents were of this opinion in figure 4.13.

4.2.12 Perceived Ease of Use

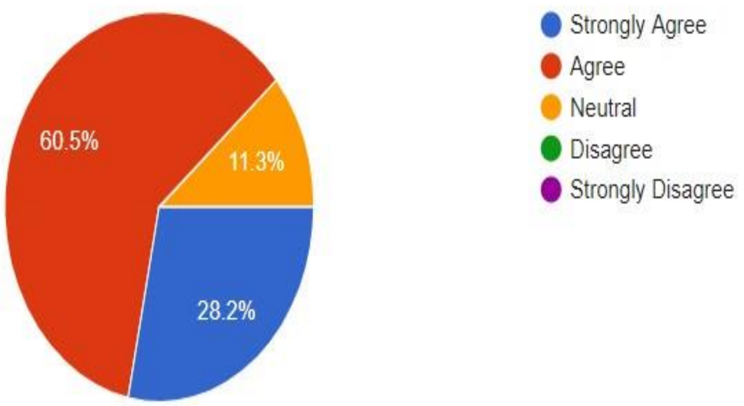


Figure 4.14: Learning to operate a luggage tracking system is easy for me.

Based on the workflows and demonstrated operations of the proposed system the results show 88.7% of respondents perceived that the system easy to use as shown in Figure 4.14.

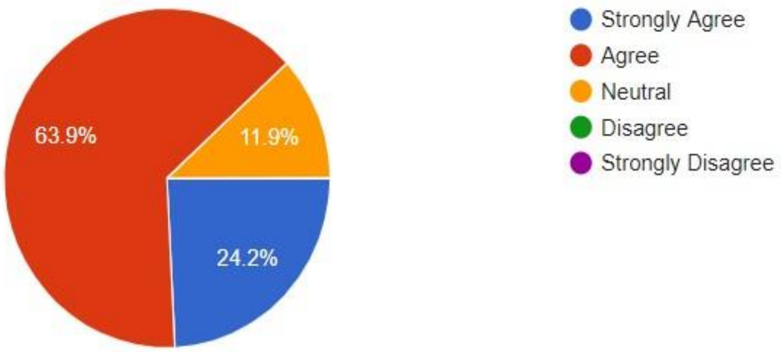


Figure 4.15: It's easy to become skill full at using the system.

88 per cent of the respondents acknowledged that they can easily become skilful with operations of the system once they constantly interact with the system as shown in figure 4.15

4.2.13 Perceived Risk

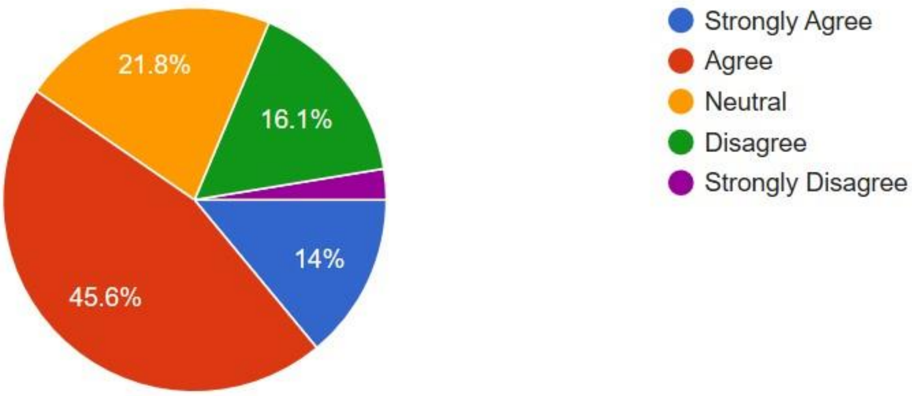


Figure 4.16: Effects of start-up cost and change resistance to non-usage.

Majority of the respondents accounting for 81.4 per cent reviewed that the system may usage can be inhibited by the resistance of bus station management to change of the business operation, start-up cost and investment in Infrastructure as shown in figure 4.16.

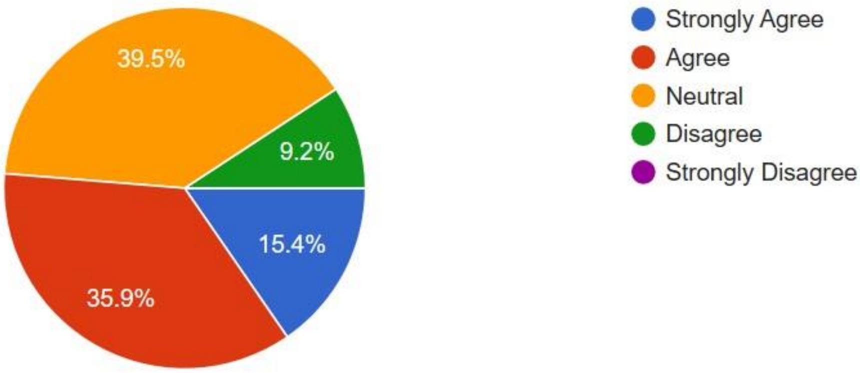


Figure 4.17: Perceived Security Risks.

51.3 Percent of the respondents had concerns about the system been connected to the internet because of the many vast threat models that it poses as reviewed in figure 4.17.

Table 4.1: Correlation between perceived usefulness and ease of use.

			PUF1	PUF2	PUF3	PUF4	PEUF1	PEUF2	PEUF3	PEUF4
Spearman's rho	PUF1	Correlation Coefficient	1.000	.306**	.425**	.479**	.386**	.277**	.252**	.300**
		Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000	.000
		N	197	197	197	197	197	197	197	197
	PUF2	Correlation Coefficient	.306**	1.000	.284**	.297**	.231**	.130	.317**	.223**
		Sig. (2-tailed)	.000	.	.000	.000	.001	.068	.000	.002
		N	197	197	197	197	197	197	197	197
	PUF3	Correlation Coefficient	.425**	.284**	1.000	.419**	.348**	.249**	.266**	.311**
		Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.000	.000
		N	197	197	197	197	197	197	197	197
	PUF4	Correlation Coefficient	.479**	.297**	.419**	1.000	.429**	.368**	.280**	.334**
		Sig. (2-tailed)	.000	.000	.000	.	.000	.000	.000	.000
		N	197	197	197	197	197	197	197	197
	PEUF1	Correlation Coefficient	.386**	.231**	.348**	.429**	1.000	.509**	.480**	.547**
		Sig. (2-tailed)	.000	.001	.000	.000	.	.000	.000	.000
		N	197	197	197	197	197	197	197	197
	PEUF2	Correlation Coefficient	.277**	.130	.249**	.368**	.509**	1.000	.449**	.455**
		Sig. (2-tailed)	.000	.068	.000	.000	.000	.	.000	.000
		N	197	197	197	197	197	197	197	197
	PEUF3	Correlation Coefficient	.252**	.317**	.266**	.280**	.480**	.449**	1.000	.511**
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.	.000
		N	197	197	197	197	197	197	197	197
	PEUF4	Correlation Coefficient	.300**	.223**	.311**	.334**	.547**	.455**	.511**	1.000
		Sig. (2-tailed)	.000	.002	.000	.000	.000	.000	.000	.
		N	197	197	197	197	197	197	197	197

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation coefficient between perceived ease of use factors of the tracking system and perceived usefulness of the tracking system factors range from 0.133- 0.547 at ($p<0.01$). This suggests that there is a substantial positive relationship as depicted in Table 4.1.

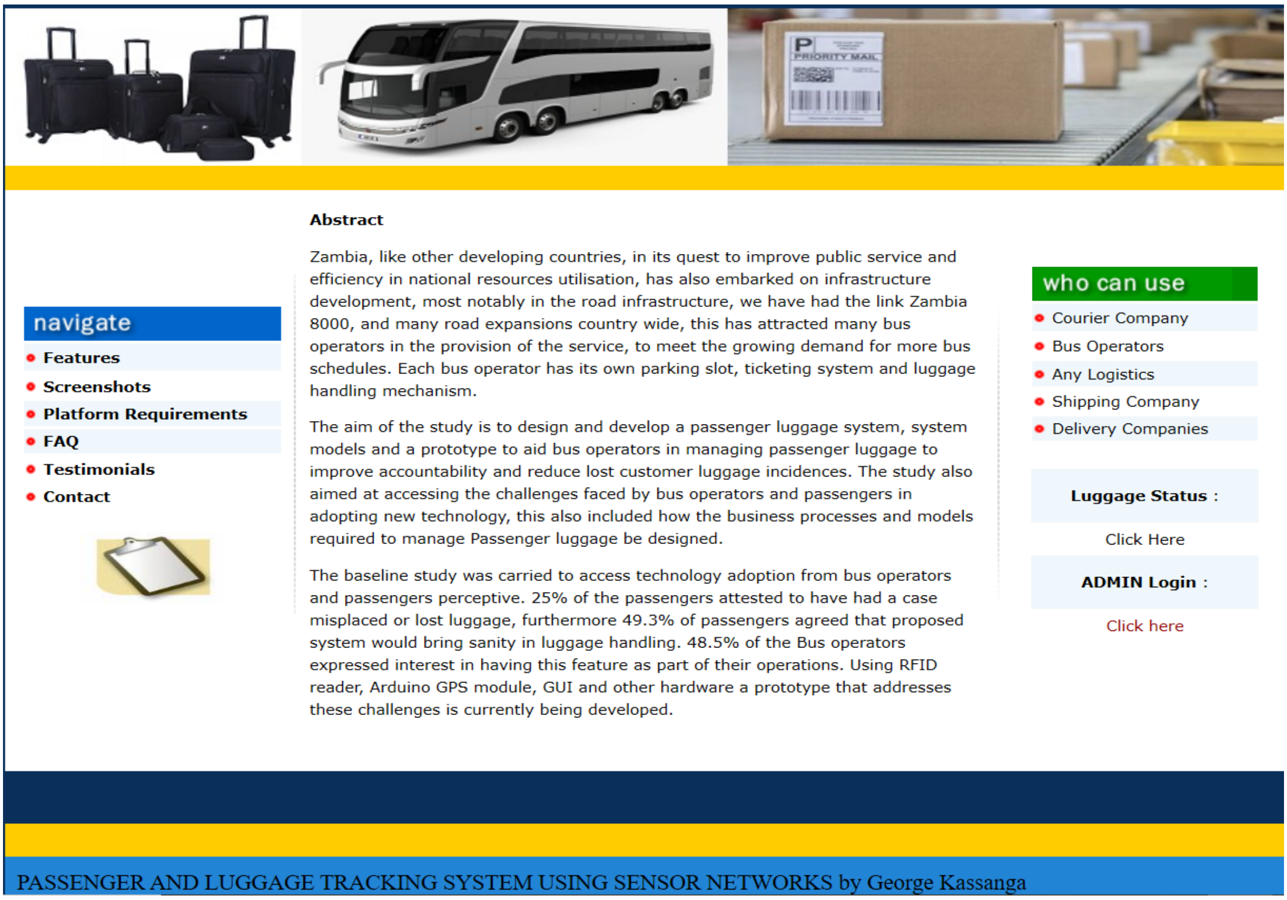


Figure 4.18: Passenger Luggage Tracking System home screen

As can be seen in Figure 4.18, this is the first page that will be accessed by the users of the system it gives an overview of the operations and functionality of the system.

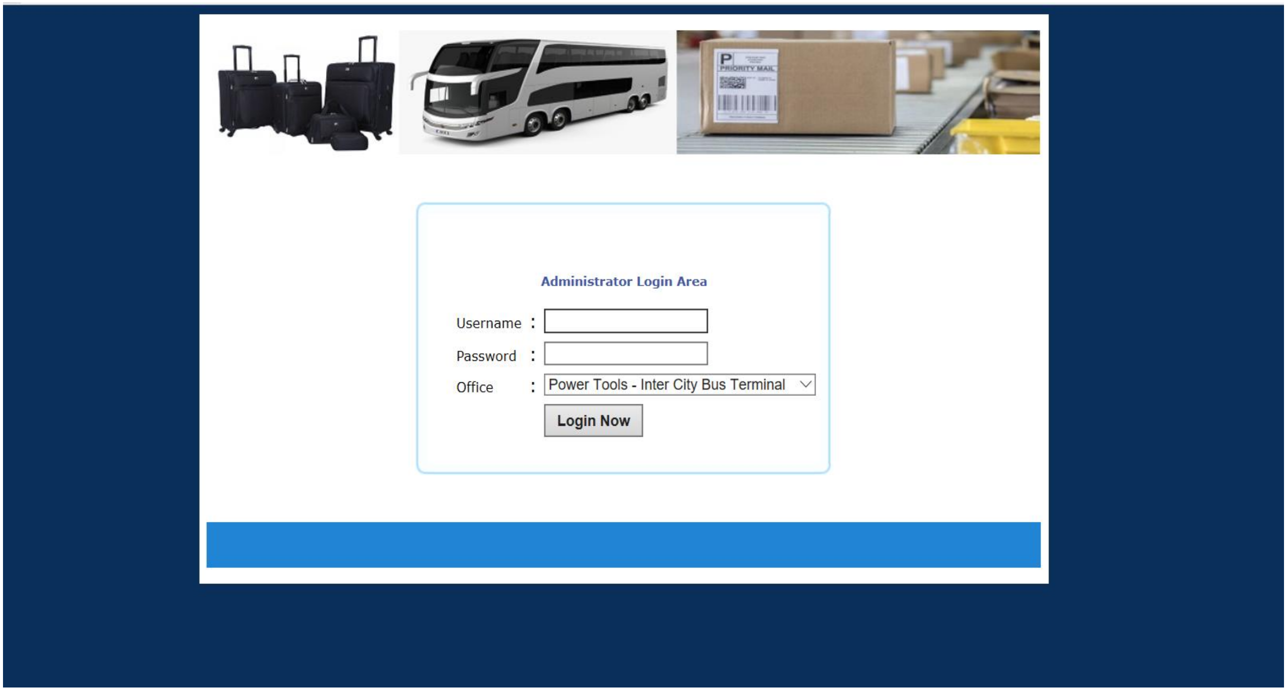


Figure 4.19: Administrator login page

The screen allows for users that have administrative access rights to log in, a username and password have to be provided for authentication, each bus operator has a defined office or compartment of operation which has to be selected before a user is logged in as shown in figure 4.19.

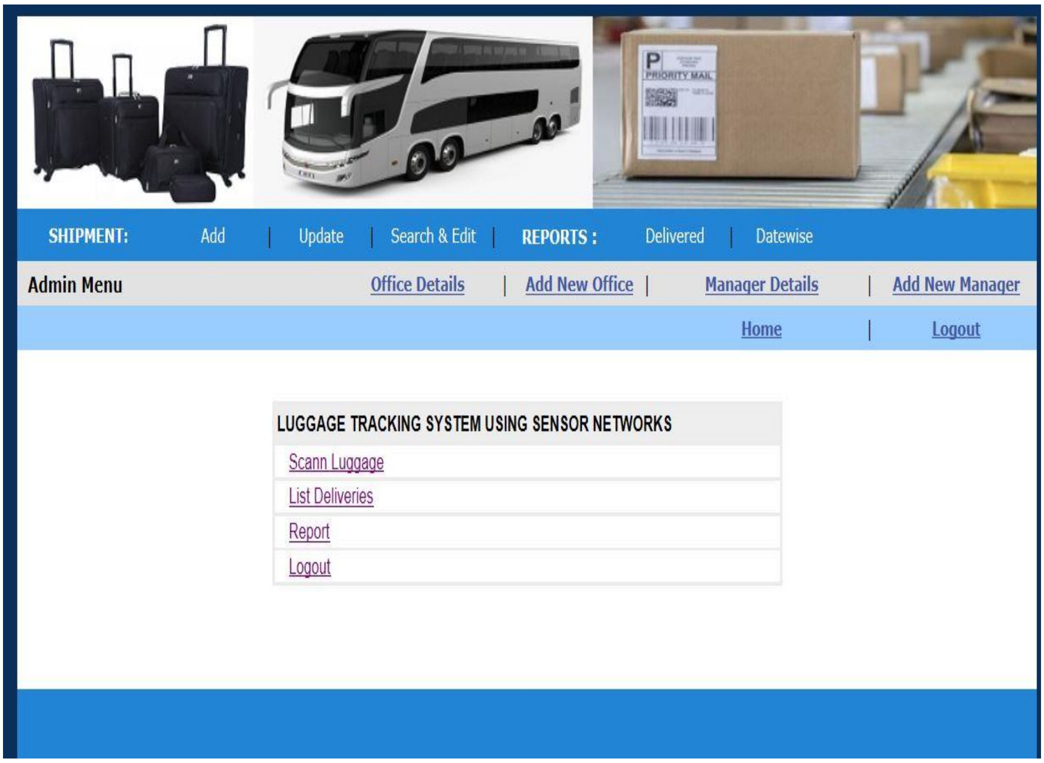


Figure 4.20: The Manage services screen

Once a user with administrative rights logs in they have access to adding new luggage information, edit and update passenger information captured including reports of all the luggage and delivery status can be viewed searches can be performed using tag information or passenger names on the system using the window, shown on Figure 4.20.

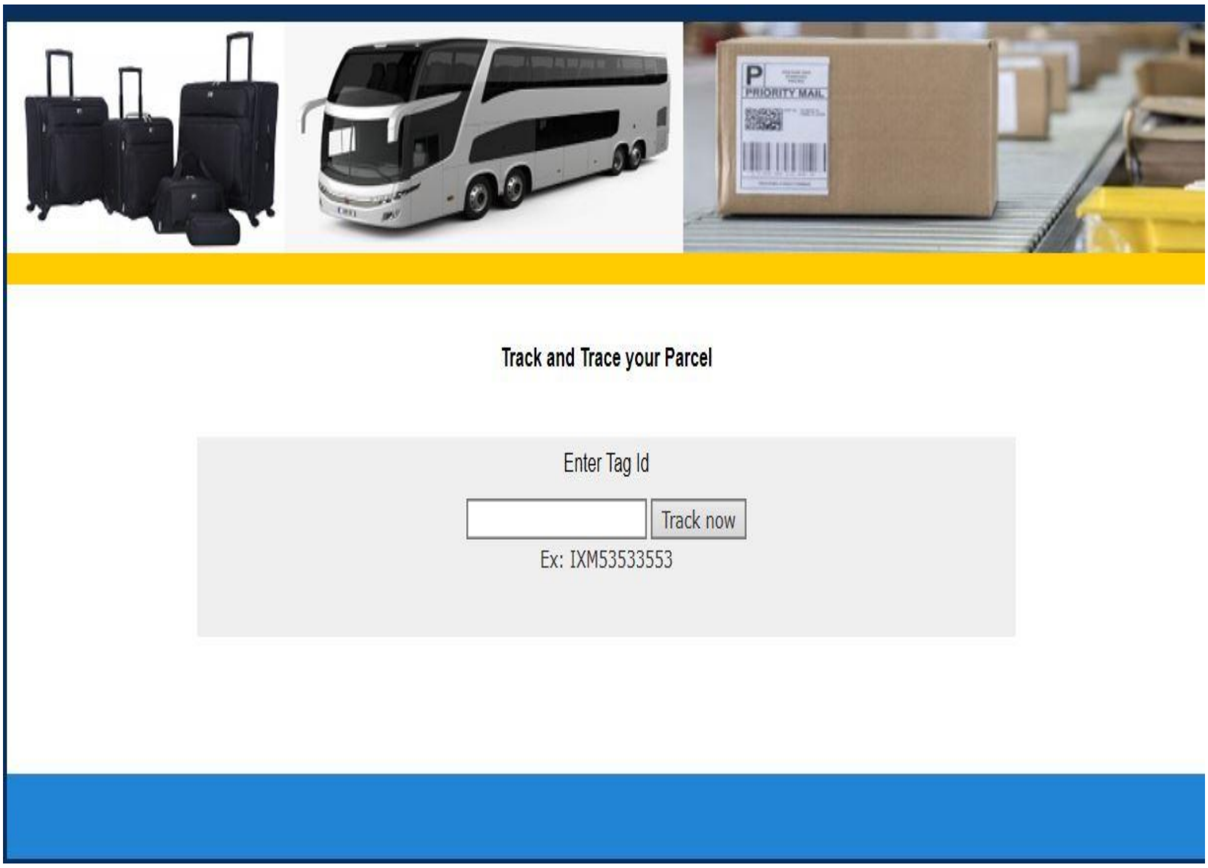


Figure 4.21: Track luggage screen

Once the user information is captured and stored in a tag which has a unique ID, this ID can be used by the passenger to fetch and retrieve the luggage location details as shown in figure 4.21.

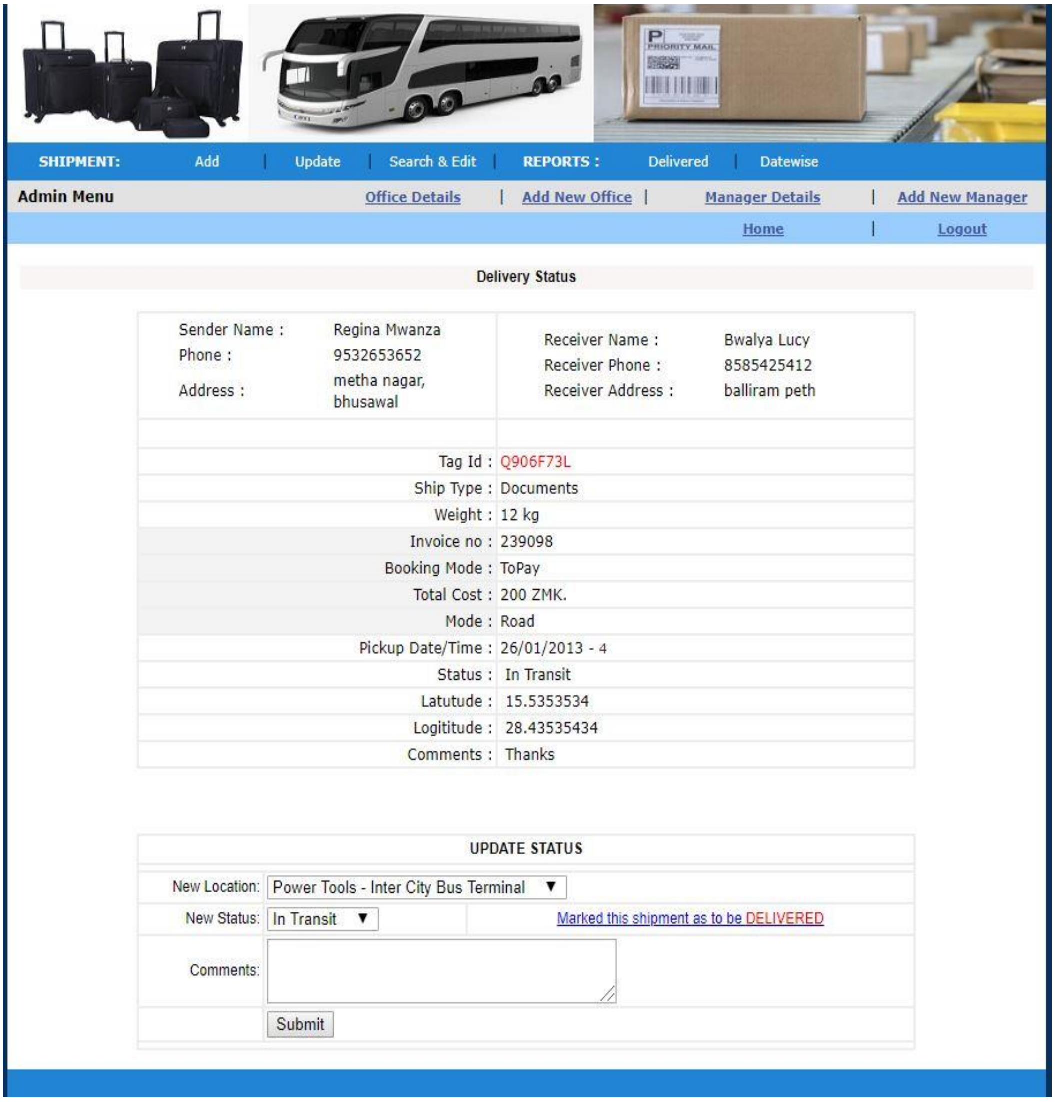
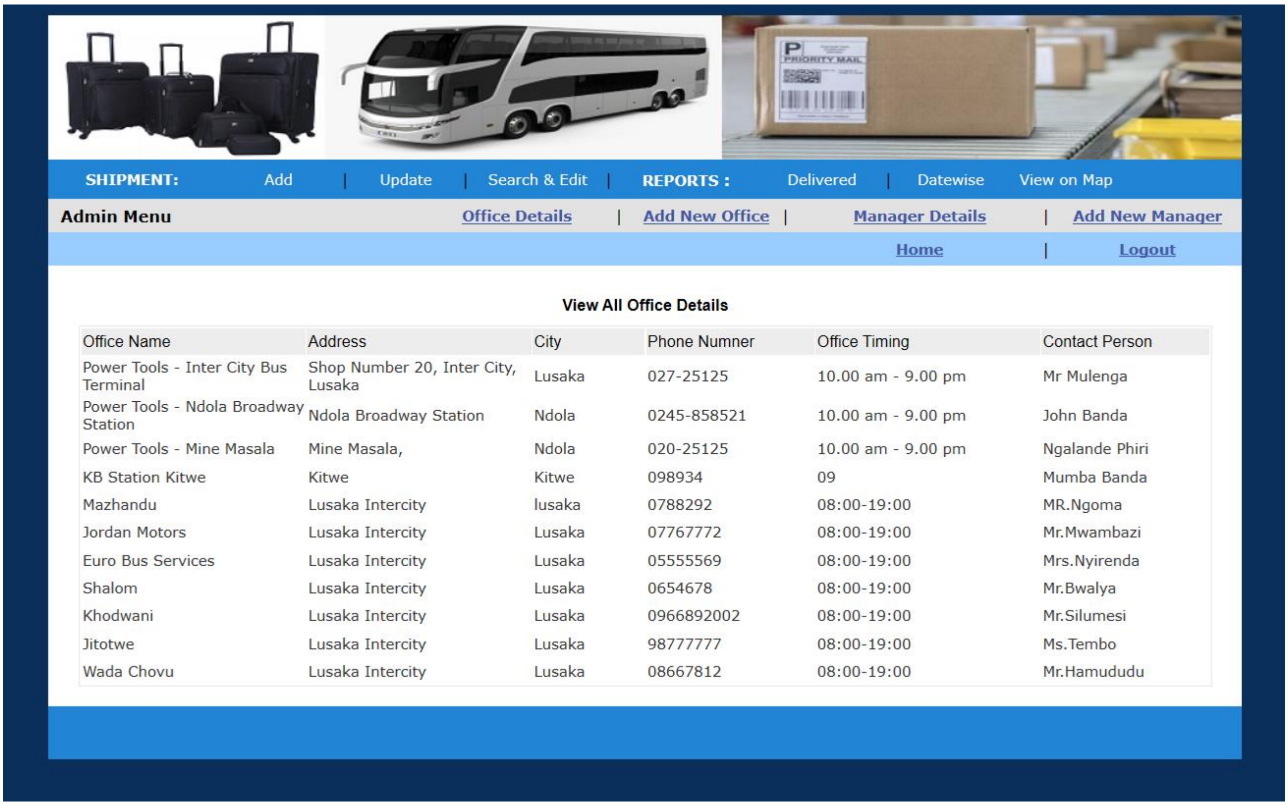


Figure 4.22: Parcel Delivery Status

The above screen in figure 4.22 outlines a delivery status form that is generated by the system, it captures information of the sender and receiver, description of the parcel or luggage cost of luggage, weight.



Office Name	Address	City	Phone Numner	Office Timing	Contact Person
Power Tools - Inter City Bus Terminal	Shop Number 20, Inter City, Lusaka	Lusaka	027-25125	10.00 am - 9.00 pm	Mr Mulenga
Power Tools - Ndola Broadway Station	Ndola Broadway Station	Ndola	0245-858521	10.00 am - 9.00 pm	John Banda
Power Tools - Mine Masala	Mine Masala,	Ndola	020-25125	10.00 am - 9.00 pm	Ngalande Phiri
KB Station Kitwe	Kitwe	Kitwe	098934	09	Mumba Banda
Mazhandu	Lusaka Intercity	lusaka	0788292	08:00-19:00	MR.Ngoma
Jordan Motors	Lusaka Intercity	Lusaka	07767772	08:00-19:00	Mr.Mwambazi
Euro Bus Services	Lusaka Intercity	Lusaka	05555569	08:00-19:00	Mrs.Nyirenda
Shalom	Lusaka Intercity	Lusaka	0654678	08:00-19:00	Mr.Bwalya
Khodwani	Lusaka Intercity	Lusaka	0966892002	08:00-19:00	Mr.Silumesi
Jitotwe	Lusaka Intercity	Lusaka	98777777	08:00-19:00	Ms.Tembo
Wada Chovu	Lusaka Intercity	Lusaka	08667812	08:00-19:00	Mr.Hamududu

Figure 4.23: View Offices of Bus operators

Each bus operator has an office defined to carry out operations, details of the operations manager is captured, operating hours and address as shown in figure 4.23.

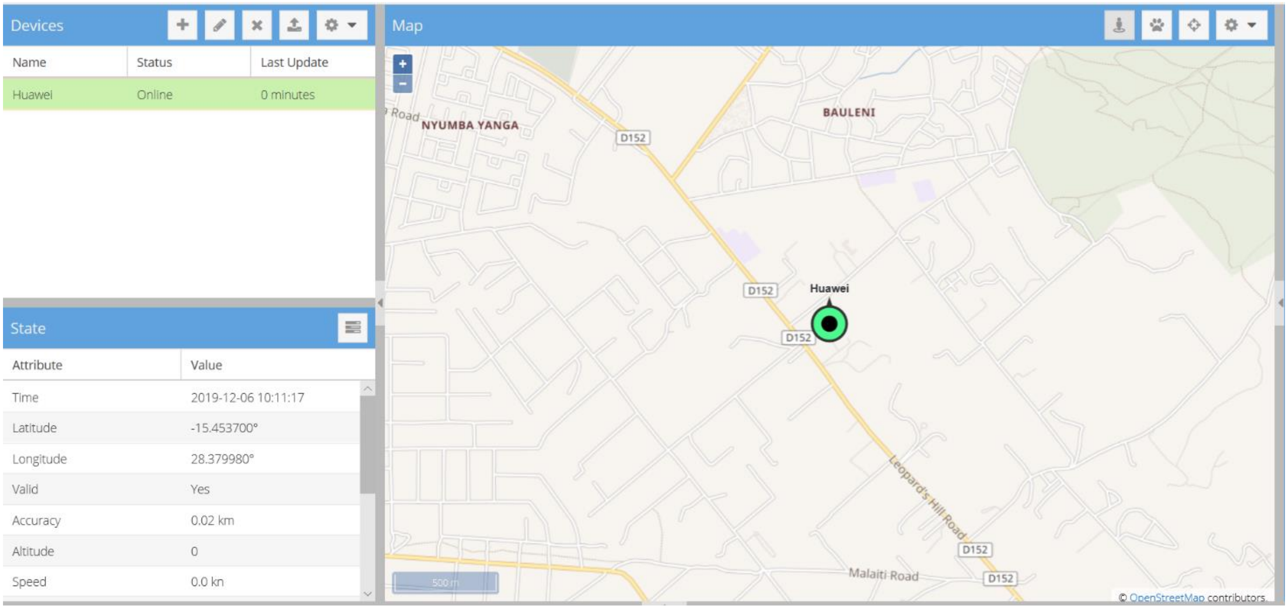


Figure 4.24 Real-Time location of the bus

As a bus is moving to the destination real-time location and speed are tracked and transmitted as viewed in figure 4.24.

4.3 Summary

This chapter presented the results of the baseline study and the development of the passenger and luggage tracking System. It covers the successful implementation of a prototype that can successfully register a passenger and bus operator, send notifications, track luggage and all information about the luggage.

CHAPTER FIVE
DISCUSSION AND CONCLUSIONS

5.1 Introduction

In this chapter, based on the empirical results and findings from this research project, the researcher presents a prototype system for the luggage tracking to help the public transportation sector, integrate operations with technology and the implementation considerations.

5.2 Discussion

The research was guided by objectives and research questions as outlined in chapter one, the Government of the Republic of Zambia has been making strides in improving service provision to members of the public by embracing technology, this was set in motion by the implementation of the National ICT policy in the year 2006 by the Ministry of Communications and Transport [121] which identifies ICTs as enablers of social and economic development. In the year 2016, the seventh national development plan was developed, a multi-sectoral development blueprint for the country[7], with special interest on the technology sector to improve the production of technology and innovation through the use of research and development, putting in place appropriate laws, policies and regulations to support the provision of electronic services, improve ICT infrastructure, As part of achieving the National development plan, Zambia is currently undergoing computerization of some of the key infrastructures (data centres, servers, and computers)in health, judiciary, road tolling, defence and security, financial institutions, education, utility services and more, the development plan runs from 2017-2021[7]. The research attempted to assess the level of usage of technology among members of the public, and understand the challenges that can affect the adoption of technology among bus operators for daily operation.

From the findings of the research, it was established that 90.8 per cent of respondents had at least two years' experience with usage of a computer and mobile phones which involves looking up information online, checking emails and sending SMS, with 59.8

per cent spending at least 4hours accessing the internet when carrying out daily tasks, the findings agree with other research studies conducted in the Zambian context regarding the usage of technology [93][7][35][37]. Furthermore, challenges of infrastructure to support the operationalisation of a luggage tracking system were also identified, such as lack of access to the internet, end devices such as desktop computers, laptops and printers, capable trained IT staff to manage and support systems, the infrastructure is also comprised of software that will provide secure electronic services to citizens and businesses, the observed prices of security application software are high including, but not limited to desktop antivirus, Network firewalls and web application firewalls which require perpetual renewal. Such findings are in agreement with other Technology adoption studies conducted [22] [122].

Local authorities from the Lusaka city council are currently managing the operations of intercity bus terminus having over 300 bus operators [123], with the help of officials and observations, the luggage management business process was understood and documented, it was also brought to the attention of the researcher that out of the many operators only 5 are currently making using a computerised bus ticketing solution provided by Afrobus. The research, therefore sought to understand how the implementation of a luggage tracking systems can be achieved, design considerations and supporting technologies including but not limited to RFID technology, sensors, Arduino microcontrollers and GPS were interrogated.

According to the reviewed literature, there are several automatic identification devices [54] used in luggage tracking namely barcode, QR code, RFID.RFID was adopted due to its reader's ability to scan dozens or hundreds of items at once up to 15 to 20 times faster than barcode or QR code scanning, information is more secure, new information can be written on the old tag and low cost. Most luggage tracking designs have adopted a client-server architecture [6] [117] [118] [119] with sensors installed strategically and a communication interface through the internet. The model was formulated based on the already existing luggage tracking system [6] [117] [118][119].

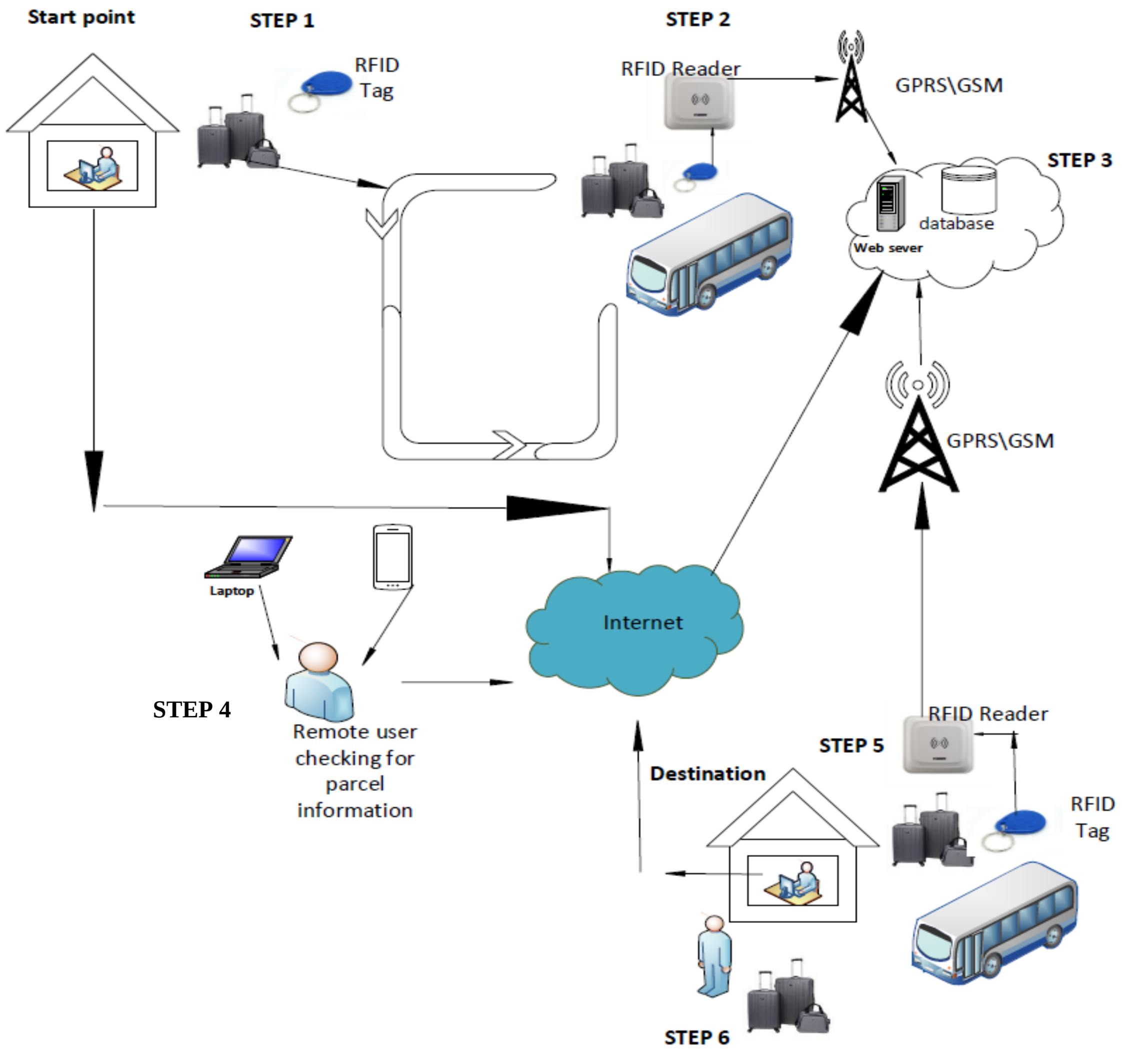


Figure 5.1: Proposed luggage tracking business model

The proposed luggage tracking business model in figure 5.1 was used to develop the passenger luggage tracking prototype by making use of RFID tags, RFID readers, servers GPRS\GSM and GPS technology.

5.2.1 How the Model Operates

At the starting point in figure 5.1, the passenger purchases the ticket at the ticket generation booth information is captured such as names, seat number, the destination and phone number are saved in the tag in step 1 every tag has a unique identifier, the luggage is then moved to the loading bay in step 2 the tag is scanned as luggage is loaded on the bus, changing the status of luggage to on-board also capturing the vehicle plat number. this information is then relayed using GPRS [113] with the aid of our SIM808 board to the server hosting the database in step 3 as the bus journeys the GPS tracking module updates the location of the bus, in step 4 the passenger or receiver of a parcel can monitor the real-time location of the also checking at which points the luggage was checked in.

In step 5 the luggage is scanned at the destination changing the status to arrive and send a notification the phone number linked to the luggage.

5.2.3 Prototype development

Development of the prototype was the final phase of the research study, OOSDM [61] development methodology was adopted based on literature, ease of development and module testing, the methodology was followed from the Analysis phase through to the Testing phase in the implementation.

Information gathered in the early stages of the study was analysed and formulated into useful system requirements. The system requirements were derived from observation of operations, interviews with local authorities from the Lusaka city council, members of the public and operational managers for different bus operators that provided insight into their preferences. According to the literature reviewed [62] [63] [65], system requirements afford a way to understand the business needs of an entity, code was developed for each module beginning with the user interface developed using PHP, the front end of the system was tested for usability and readability.

A database was created using MySQL to house all system information and linked to the frontend to also provide data validation and authentication, the information in the database was not served in plaintext but was run through an encryption function to produce cipher text [39]. Arduino IDE was used to programme the individual system components using C++ and tested before integration, the Arduino UNO R3 boards been the heart of the project are limited to the number analogue and digital pins hence a breadboard was introduced. Once the Prototype was functional data was input to test system responses, error handling and performance.

Appendix III provides code developed

5.4 Recommendations

We put forward the following recommendations to improve the efficiency of luggage tracking and parcel monitoring at intercity bus terminal:

i. Infrastructure support there is a need for increased investment in telecommunication infrastructure with is the backbone for online services, availability of affordable end devices such as computers and smartphones.

ii. Providing cheaper and faster internet broadband packages for bus operators to encourage the provision of most services online, this also implies increased access to internet service by the general public.

iii. An improved legal framework that protects data privacy, and upholds data security standards to security breaches and intrusive behaviour.

iv. Marketing institutions need to highly market the advantages of having self-service online-based platforms to change public perception towards online services. This also entails improved availability, usability and customer experience when using online platforms

ii) Automating the courier services and luggage management using automatic identification such as RFID and sensor network technologies to effectively monitor and track luggage inventory from source to destination.

iii) Computerising the record management and daily operations to significantly reduce inefficiencies, time wastage, errors, brought about by the use of paper-based systems.

iv) For the paradigm shift of manual to automate to take place there is a need to build the capacity of computer skills among bus operators and supporting for them to easily transfer these skills to others.

5.5 Future Works

The research implemented several functionalities in the application but the following was not considered due to time and financial limitations;

i) Using GPS enabled tags to provide real-time tracking of each bag, and in an event that it gets misplaced or stolen the location can still be tracked.

ii) Development of a mobile Application would be a good advancement of the solution.

iii) Installation of Perimeter sensors and alarms that can scan for tags leaving the station without been deactivated.

iv) The ability to query the location of the luggage using an SMS and receiving the location name and coordinates without internet.

v) Installation of a Camera in the luggage compartment that takes pictures once it senses infrared emission can help capture faces of thieves.

Furthermore, the study was limited to Bus operators at Intercity in Lusaka, Zambia. Hence, there is a need to study other bus stations in other parts of Zambia. The study only focussed on Bus operators at Intercity Bus Terminal and did not consider other areas outside Lusaka, future research can be done in other areas to compare the findings.

5.6 Summary

The study brought out important points on the fact that there were challenges in the management of luggage by bus operators and also infrastructure challenges to accommodate new technologies were common among various bus operators that operate from intercity. All participants agreed to the need to find a solution to solve passenger luggage mismanagement. Bus owners also expressed interest in providing the tracking feature to help improve service delivery and gain a competitive advantage.

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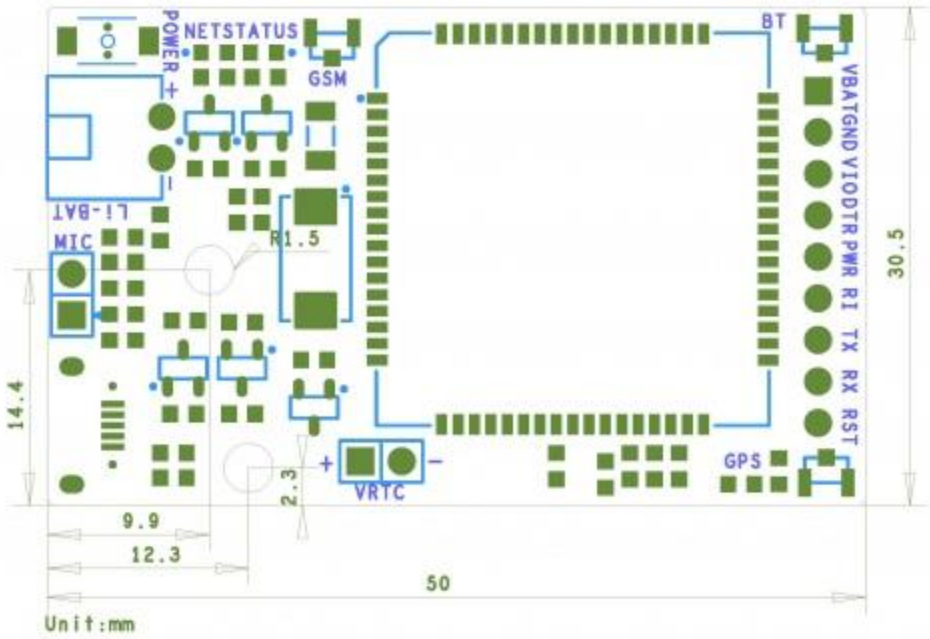
APPENDIX I SIM808 Features

- Quad-band 850/900/1800/1900MHz
- GPRS multi-slot class12 connectivity: max. 85.6kbps(down-load/up-load)
- GPRS mobile station class B
- Controlled by AT Command (3GPP TS 27.007, 27.005 and SIMCOM enhanced AT Commands)
- Supports charging control for Li-Ion battery
- Supports Real Time Clock
- Supply voltage range 3.4V ~ 4.4V
- Integrated GPS/CNSS and supports A-GPS
- Supports 3.0V to 5.0V logic level
- Low power consumption, 1mA in sleep mode
- Supports GPS NMEA protocol
- Standard SIM Card

Electronic Characteristics

'	**Min**	**Typical**	**Max**	**Unit**
Voltage Input（VBAT）	3.4	-	4.4	VDC
Input voltage VinH(Target Voltage = 3.3V)	3	3.3	3.6	V
Input voltage VinH(Target Voltage = 5V)	4.5	5	5.5	V
Input voltage VinL	-0.3	0	0.5	V
Peak Current	0	-	2	A
Average Current	2	-	500	mA


POWER
NETSTATUS
GSM
BT
VBAT GND VIO DTR PWR RI TX RX RST
LI-BAT
MIC
R1.5
VRTC
GPS
30.5
14.4
2.3
9.9
12.3
50
Unit:mm

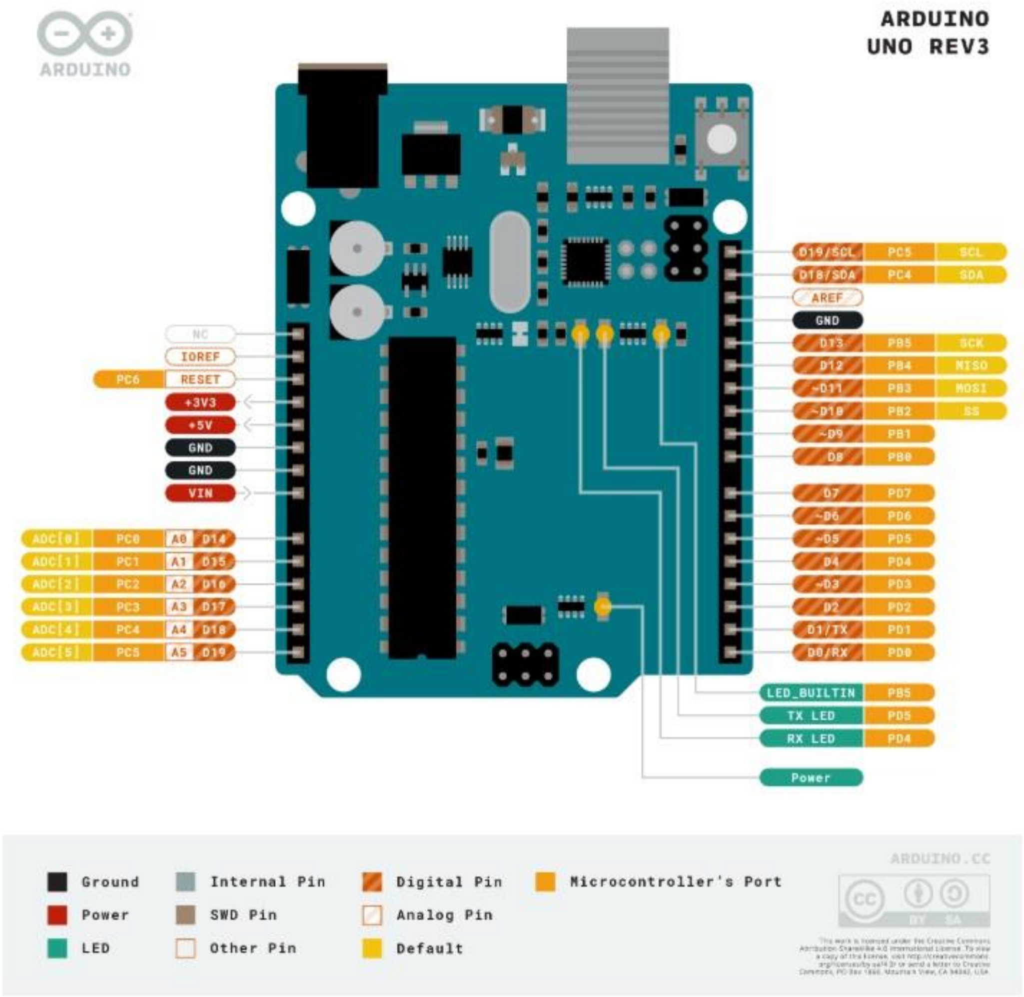

Indicators
Power Button
GSM Antenna
Bluetooth
Li-ion Bettery
Socket
SIM808
Micro USB
debugging port
GPS Antenna

APPENDIX II Arduino UNO R3 Features

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Hardware

Pinout Diagram



APPENDIX III SOURCE CODE

PIR SENSOR, BUZZER AND LED CODE

```
const int motionpin = A0;
const int ledpin = 6;
const int buzzpin = 7 ;
int motionsensevalue = 0;
void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  pinMode(ledpin, OUTPUT);
  pinMode(motionpin, INPUT);
  pinMode(buzzpin, OUTPUT);
}
void loop() {
  // put your main code here, to run repeatedly:
  motionsensevalue = analogRead(motionpin); //
  if (motionsensevalue >= 200) {
    digitalWrite(ledpin, HIGH);
    tone(buzzpin, 200);
  }
  else {
    digitalWrite(ledpin, LOW);
    noTone(buzzpin);
  }
}
```

Snip Code for web Front End

```html
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN" "http://www.w3.org/TR/html4/loose.dtd">
<html>
<head>
<meta http-equiv="Content-Type" content="text/html; charset=ISO-8859-1">
<title> luggage Tracking Module</title>
<meta name="description" content="A Simple Solution to enable Tracking.">
<meta http-equiv="Content-Type" content="text/html; charset=ISO-8859-1">
<link href="css/aalpha.css" rel="stylesheet" type="text/css">

<style type="text/css">
<!--
.style1 {color: #CCCCCC}
-->
</style>
</head>

<body>
<table border="0" cellpadding="0" cellspacing="0" align="center" width="900" style="padding-top:20px;">
  <tbody><tr>
    <td width="900"><img src="images/trheader.JPG" ></td>
  </tr>
  <tr>
    <td><table border="0" cellpadding="0" cellspacing="0" width="900">
      <tbody><tr>
        <td bgcolor="#FFCC00"> </td>
      </tr>
    </tbody></table></td>
  </tr>
</tbody></table>
<table border="0" cellpadding="0" cellspacing="0" align="center" width="900">
  <tbody><tr>
    <td bgcolor="#FFFFFF" width="900"><table border="0" align="center" width="99%">
      <tbody><tr>
        <td width="22%"><table border="0" align="center" width="185">
          <tbody><tr bgcolor="#EFF7FC">
            <td class="aalpha" bgcolor="#0066CC" height="19" width="179"><img src="home_files/navig.gif" height="24" width="113"></td>
          </tr>
          <tr bgcolor="#EFF7FC">
            <td class="aalpha" height="19"><strong><img src="home_files/arrow_right.gif" height="9" width="9"> Features</strong></td>
          </tr>
```

```
Zambia, like other developing countries, in its quest to improve public service and efficiency in national
resources utilisation, has also embarked on infrastructure development, most notably in the road infrastructure,
we have had the link Zambia 8000, and many road expansions country wide, this has attracted many bus operators in
the provision of the service, to meet the growing demand for more bus schedules. Each bus operator has its own parking slot,
 ticketing system and luggage handling mechanism. </p>
<p>The aim of the study is to design and develop a passenger luggage system, system models and a prototype to aid bus operators
in managing passenger luggage to improve accountability and reduce lost customer luggage incidences. The study also aimed
 at accessing the challenges faced by bus operators and passengers in adopting new technology, this also included
 how the business processes and models required to manage Passenger luggage be designed.</p>
<p>The baseline study was carried to access technology adoption from bus operators and passengers perceptive.
25% of the passengers attested to have had a case misplaced or lost luggage, furthermore 49.3% of passengers
agreed that proposed system would bring sanity in luggage handling. 48.5% of the Bus operators expressed
interest in having this feature as part of their operations. Using RFID reader, Arduino GPS module,
GUI and other hardware a prototype that addresses these challenges is currently being
 developed.</p>
 </p></td>
        <td class="aalpha" width="2%"><div align="center"><img src="home_files/l2.gif" height="292" width="1"></div></td>
        <td class="aalpha" width="21%"><table border="0" align="center" width="89%">
          <tbody><tr bgcolor="#EFF7FC">
            <td class="aalpha" bgcolor="#008C00" height="19"><img src="home_files/whoca.gif" height="24" width="140"></td>
          </tr>
          <tr bgcolor="#EFF7FC">
            <td class="aalpha" height="19"><img src="home_files/arrow_right.gif" height="9" width="9"> Courier Company </td>
          </tr>
          <tr>
            <td class="aalpha"><img src="home_files/arrow_right.gif" height="9" width="9"> Bus Operators </td>
          </tr>
          <tr bgcolor="#EFF7FC">
            <td class="aalpha"><img src="home_files/arrow_right.gif" height="9" width="9"> Any Logistics </td>
          </tr>
          <tr>
            <td class="aalpha"><img src="home_files/arrow_right.gif" height="9" width="9"> Shipping Company </td>
          </tr>
          <tr bgcolor="#EFF7FC">
            <td class="aalpha"><img src="home_files/arrow_right.gif" height="9" width="9"> Delivery Companies </td>
          </tr>
        </tbody></table>
              <br>
              <table border="0" align="center" width="90%">
```

Code for Scanning RFID and Tag

```
#include <SPI.h>
#include <MFRC522.h>

#define RST_PIN         9          // Configurable, see typical pin layout above
#define SS_PIN         10         // Configurable, see typical pin layout above

MFRC522 mfrc522(SS_PIN, RST_PIN);   // Create MFRC522 instance

//*****************************************************************************************//
void setup() {
  Serial.begin(9600);                                        // Initialize serial communications with the PC
  SPI.begin();                                               // Init SPI bus
  mfrc522.PCD_Init();                                              // Init MFRC522 card
  Serial.println(F("Read personal data on a MIFARE PICC:"));    //shows in serial that it is ready to read
}

//*****************************************************************************************//
void loop() {

  // Prepare key - all keys are set to FFFFFFFFFFFFh at chip delivery from the factory.
```

```
  MFRC522::MIFARE_Key key;
  for (byte i = 0; i < 6; i++) key.keyByte[i] = 0xFF;

  //some variables we need
  byte block;
  byte len;
  MFRC522::StatusCode status;

  //-------------------------------------------

  // Reset the loop if no new card present on the sensor/reader. This saves the entire process
when idle.
  if ( ! mfrc522.PICC_IsNewCardPresent()) {
    return;
  }

  // Select one of the cards
  if ( ! mfrc522.PICC_ReadCardSerial()) {
    return;
  }

  Serial.println(F("**Card Detected:**"));

  //-------------------------------------------

  mfrc522.PICC_DumpDetailsToSerial(&(mfrc522.uid)); //dump some details about the card

  //mfrc522.PICC_DumpToSerial(&(mfrc522.uid));      //uncomment this to see all blocks in
hex

  //-------------------------------------------

  Serial.print(F("Name: "));

  byte buffer1[18];

  block = 4;
  len = 18;

  //------------------------------------------- GET FIRST NAME
  status = mfrc522.PCD_Authenticate(MFRC522::PICC_CMD_MF_AUTH_KEY_A, 4,
&key, &(mfrc522.uid)); //line 834 of MFRC522.cpp file
  if (status != MFRC522::STATUS_OK) {
    Serial.print(F("Authentication failed: "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    return;
  }

  status = mfrc522.MIFARE_Read(block, buffer1, &len);
  if (status != MFRC522::STATUS_OK) {
```

```
    Serial.print(F("Reading failed: "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    return;
  }

  //PRINT FIRST NAME
  for (uint8_t i = 0; i < 16; i++)
  {
    if (buffer1[i] != 32)
    {
      Serial.write(buffer1[i]);
    }
  }
  Serial.print(" ");

  //---------------------------------------- GET LAST NAME

  byte buffer2[18];
  block = 1;

  status = mfrc522.PCD_Authenticate(MFRC522::PICC_CMD_MF_AUTH_KEY_A, 1,
&key, &(mfrc522.uid)); //line 834
  if (status != MFRC522::STATUS_OK) {
    Serial.print(F("Authentication failed: "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    return;
  }

  status = mfrc522.MIFARE_Read(block, buffer2, &len);
  if (status != MFRC522::STATUS_OK) {
    Serial.print(F("Reading failed: "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    return;
  }

  //PRINT LAST NAME
  for (uint8_t i = 0; i < 16; i++) {
    Serial.write(buffer2[i] );
  }


  //----------------------------------------

  Serial.println(F("\n**End Reading**\n"));

  delay(1000); //change value if you want to read cards faster

  mfrc522.PICC_HaltA();
  mfrc522.PCD_StopCrypto1();
}
```

Code for Gps and Sms

```
#include <SoftwareSerial.h>
SoftwareSerial sim808(7,8);

char phone_no[] = "0979205756"; // replace with your phone no.
String data[5];
#define DEBUG true
String state,timegps,latitude,longitude;

void setup() {
sim808.begin(9600);
Serial.begin(9600);
delay(50);

sim808.print("AT+CSMP=17,167,0,0");  // set this parameter if empty SMS received
delay(100);
sim808.print("AT+CMGF=1\r");
delay(400);

sendData("AT+CGNSPWR=1",1000,DEBUG);
delay(50);
sendData("AT+CGNSSEQ=RMC",1000,DEBUG);
delay(150);

}

void loop() {
sendTabData("AT+CGNSINF",1000,DEBUG);
if (state !=0) {
Serial.println("State  :"+state);
Serial.println("Time  :"+timegps);
Serial.println("Latitude  :"+latitude);
Serial.println("Longitude  :"+longitude);

sim808.print("AT+CMGS=\"");
sim808.print(phone_no);
sim808.println("\"");

delay(300);

sim808.print("http://maps.google.com/maps?q=loc:");
sim808.print(latitude);
sim808.print(",");
sim808.print (longitude);
delay(200);
```

```
sim808.println((char)26); // End AT command with a ^Z, ASCII code 26
delay(200);
sim808.println();
delay(20000);
sim808.flush();

} else {
Serial.println("GPS Initializing…");
}
}

void sendTabData(String command , const int timeout , boolean debug){

sim808.println(command);
long int time = millis();
int i = 0;

while((time+timeout) > millis()){
while(sim808.available()){
char c = sim808.read();
if (c != ',') {
data[i] +=c;
delay(100);
} else {
i++;
}
if (i == 5) {
delay(100);
goto exitL;
}
}
}exitL:
if (debug) {
state = data[1];
timegps = data[2];
latitude = data[3];
longitude =data[4];
}
}
String sendData (String command , const int timeout ,boolean debug){
String response = "";
sim808.println(command);
long int time = millis();
int i = 0;

while ( (time+timeout ) > millis()){
```

```
while (sim808.available()){
char c = sim808.read();
response +=c;
}
}
if (debug) {
Serial.print(response);
}
return response;
}
```

Snip of integrated code

```
#include <SPI.h>
#include <MFRC522.h>
#include "U8glib.h"

#define buzz 6
//RFID
#define RST_PIN    5   //
#define SS_PIN    3    //
MFRC522 mfrc522(SS_PIN, RST_PIN);  // Create MFRC522 instance

U8GLIB_ST7920_128X64_1X u8g(9, 8, 7); //SCK = en = 18, MOSI = rw = 16, CS = di = 17
const char *menu_strings[10] = { "EXPECTATION", "  GO THERE", " 3 PLAYER", " THREE", " FOUR", " FIVE", " SIX", "SEVEN", "  CHECK", " MISTAKE" };
#define OK 1
#define NOTOK 2
#define TIMEOUT 3
#define SIM808board Serial
char end_c[2];
int dosend=0, dosendgps=0, dosendbalans=0;
int a2;
float balans=0.0;
String str, str1;
String signal_level_str;
float longitude, latitude;
```

```
unsigned long long prev_ms_balans, prev_ms_gps;

void setup() {
//  Serial.begin(9600);
//  pinMode(7, INPUT_PULLUP);
  SIM808board.begin(9600);

//  Serial.println("S E T U P");
  delay(1000);
  SIM808board.println("AT");
  delay(100);
  SIM808board.println("AT");
  delay(100);
  SIM808board.println("AT");
  delay(100);

  A6command("AT+CGPSPWR=1", "OK", "ERROR", 5000, 1);

  SPI.begin();      // Init SPI bus
  mfrc522.PCD_Init();

  if ( u8g.getMode() == U8G_MODE_R3G3B2 ) {
    u8g.setColorIndex(255);     // white
  }
  else if ( u8g.getMode() == U8G_MODE_GRAY2BIT ) {
    u8g.setColorIndex(3);         // max intensity
  }
  else if ( u8g.getMode() == U8G_MODE_BW ) {
    u8g.setColorIndex(1);         // pixel on
  }
  else if ( u8g.getMode() == U8G_MODE_HICOLOR ) {
    u8g.setHiColorByRGB(255,255,255);
  }

```

```
  rfidtimer();
  u8g.firstPage();
  do {
    draw(0);
  } while( u8g.nextPage() );

    A6command("AT+SAPBR=3,1,\"CONTYPE\",\"GPRS\"", "OK", "ERROR", 2000, 1);
    A6command("AT+SAPBR=3,1,\"APN\",\"Airtel\"Internet", "OK", "ERROR", 2000, 1);///////////////www.ab.kyivstar.net

//    A6command("AT+SAPBR=3,1,\"USER\",\"\"", "OK", "ERROR", 2000, 1);
//    A6command("AT+SAPBR=3,1,\"PWD\",\"\"", "OK", "ERROR", 2000, 1);
    A6command("AT+SAPBR=1,1", "+SAPBR:", "ERROR", 2000, 1); //start up the connection
    A6command("AT+HTTPINIT", "OK", "ERROR", 5000, 1);
    pinMode(buzz, OUTPUT);
    tone(buzz, 1000);
    delay(100);
    noTone(buzz);
    prev_ms_gps = millis();
    prev_ms_balans = millis();
//  attachInterrupt(digitalPinToInterrupt(7), func_start, FALLING);
}

void loop() {

    func_gps();
    //A6command("AT+SAPBR=4,1", "OK", "ERROR", 2000, 1);
   // if (jeka==1) digitalWrite(LED_BUILTIN, !digitalRead(LED_BUILTIN));
    //A6command("AT+HTTPINIT=?", "OK", "ERROR", 5000, 1);
    delay(40);
    if (dosend==1) {func_gprs();}
    dosend=0;
}
```

```
// funtion to execut Gps funstions
void func_gps() {

  if (millis() - prev_ms_gps >= 300000){ //chastota otpravki danih msec
    prev_ms_gps = millis();
    if (dosend==1) return;
    A6command("AT+CGPSPWR=1", "OK", "ERROR", 5000, 1);
    if (dosend==1) return;
    A6command("AT+CGPSSTATUS?", "OK", "ERROR", 5000, 1);
    if (dosend==1) return;

    if ((signal_level_str.indexOf("Location 3D Fix")>-1)||(signal_level_str.indexOf("Location 2D Fix")>-1)){
      A6command("AT+CGPSINF=2", "+CGPSINF:", "ERROR", 5000, 1);
      if (dosend==1) return;
      signal_level_str = signal_level_str.substring(signal_level_str.indexOf(",")+1, signal_level_str.length());
      signal_level_str = signal_level_str.substring(signal_level_str.indexOf(",")+1, signal_level_str.length());
      String part;
      part = signal_level_str.substring(0, signal_level_str.indexOf(","));
      latitude = part.toFloat();
    Serial.print("latitude="); // de commented
     Serial.print(latitude,4); // de commented
      signal_level_str = signal_level_str.substring(signal_level_str.indexOf(",")+1, signal_level_str.length());
      signal_level_str = signal_level_str.substring(signal_level_str.indexOf(",")+1, signal_level_str.length());
      part = signal_level_str.substring(0, signal_level_str.indexOf(","));
      longitude = part.toFloat();
      dosendgps = 1;
   //Serial.print(" longitude="); // de commented
     // Serial.println(longitude,4);  // de commented
    }
  }
```

```
}


void func_gprs() {

    tone(buzz, 1000);
    delay(100);
    noTone(buzz);

    str1 = "RFID.php?";
    str1 += "a=";
    str1 += str;
    str1 += ";";
    if (dosendgps==1){
      str1 += "L1=";
      str1 += String(longitude, 5);
      str1 += ";L2=";
      str1 += String(latitude, 5);
      str1 += ";";
      dosendgps = 0;
    }
    if (dosendbalans==1){
      str1 += "B=";
      str1 += String(balans, 2);
    }

    A6command("AT+HTTPPARA=\"URL\",\"https://www.unilus.ac.zm/RFID/" + str1 + "\"", "OK", "ERROR", 10000, 1);
    A6command("AT+HTTPPARA=\"CID\",1", "OK", "ERROR", 10000, 1);

    A6command("AT+HTTPACTION=0", "+HTTPACTION:", "ERROR", 20000, 1);

    if (signal_level_str.indexOf("+HTTPACTION: 0,200,")==-1){
      A6command("AT+HTTPTERM", "HTTPTERM", "ERROR", 20000, 1);
```

```
      A6command("AT+SAPBR=0,1", "+SAPBR:", "ERROR", 2000, 1);

      A6command("AT+SAPBR=1,1", "+SAPBR:", "ERROR", 2000, 1); //start up the connection
      A6command("AT+HTTPINIT", "OK", "ERROR", 5000, 1);
      A6command("AT+HTTPPARA=\"URL\",\"https://www.unilus.ac.zm/RFID/" + str1 + "\"", "OK", "ERROR", 10000, 1);
      A6command("AT+HTTPPARA=\"CID\",1", "OK", "ERROR", 10000, 1);
      A6command("AT+HTTPACTION=0", "+HTTPACTION:", "ERROR", 20000, 1);
      if (signal_level_str.indexOf("+HTTPACTION: 0,200,")==-1){
        u8g.firstPage();
        do {
          draw(9);
        } while( u8g.nextPage() );
        tone(buzz, 200);
        delay(600);
        noTone(buzz);
        delay(3000);
        return;
      }
    }
    signal_level_str = "";
    A6command("AT+HTTPREAD", "HTTPREAD", "ERROR", 20000, 1);
    parse_dani(signal_level_str);
}

void parse_dani(String &outstr)
{
  if (outstr.indexOf("a=")>-1){
    outstr = outstr.substring(outstr.indexOf("a=")+2, outstr.length());

    a2 = outstr.toInt();
      u8g.firstPage();
  do {
```

```
    draw(a2);
  } while( u8g.nextPage() );
  if (a2==1){
    tone(buzz, 1000);
    delay(500);
    tone(buzz, 2000);
    delay(400);
    noTone(buzz);
  }else{
    tone(buzz, 200);
    delay(600);
    noTone(buzz);
    delay(2000);
  }
    u8g.firstPage();
  do {
    draw(0);
  } while( u8g.nextPage() );
//    Serial.print("a2=");
//    Serial.println(a2);
/*    u8g.firstPage();
  do {
    draw(a2);
  } while( u8g.nextPage() );*/
  }
}

byte A6waitFor(String response1, String response2, uint16_t timeOut) {
  uint16_t entry = 0;
  uint16_t count = 0;
  String reply = A6read();
  byte retVal = 99;
  do {
    reply = A6read();
```

```
    delay(1);
    entry ++;
    } while ((reply.indexOf(response1) + reply.indexOf(response2) == -2) && entry < timeOut );
  if (entry >= timeOut) {
    retVal = TIMEOUT;
  } else {
    if (reply.indexOf(response1) + reply.indexOf(response2) > -2) retVal = OK;
    else retVal = NOTOK;
  }
  signal_level_str = reply;
  return retVal;
}

byte A6command(String command, String response1, String response2, uint16_t timeOut, uint16_t repetitions) {
  byte returnValue = NOTOK;
  byte count = 0;

  while (count < repetitions && returnValue != OK) {
    SIM808board.println(command);

    if (A6waitFor(response1, response2, timeOut) == OK) {
      returnValue = OK;
    } else {returnValue = NOTOK;}
    count++;
  }

  return returnValue;
}

String A6read() {
  char c;
  String reply = "";
```

```
  if (SIM808board.available())  {
    reply = SIM808board.readString();
  }

/*  if (reply!=""){
    Serial.print("Reply: ");
    Serial.println(reply);
  }
  */
  //signal_level_str = reply;
  return reply;
}

void Decode7bit(String &instr, String &outstr)
{
   String part1 = outstr.substring(outstr.indexOf("rahunku")+8, outstr.indexOf(" grn.")); //parsing balance from operator text
  if (part1.indexOf(".")>-1) {balans = part1.toFloat(); dosendbalans = 1;}
}

void func_balans() {
  if (millis() - prev_ms_balans >= 600000){
    prev_ms_balans = millis();
    signal_level_str = "";
    A6command("AT+CUSD=1,\"*114#\"", "grn", "ERROR", 10000, 1); //CSSD balance check
    String inputstr;
    String decodestr="";

    inputstr = signal_level_str;
    decodestr=inputstr;
    Decode7bit(inputstr, decodestr);
  }
}
```

```
 void rfidtimer() {
//set timer1 interrupt at 1Hz
TCCR1A = 0;// set entire TCCR1A register to 0
TCCR1B = 0;// same for TCCR1B
TCNT1  = 0;//initialize counter value to 0
// set compare match register for 1hz increments
OCR1A = 15624;// = (16*10^6) / (1*1024) - 1 (must be <65536)
// turn on CTC mode
TCCR1B |= (1 << WGM12);
// Set CS12 and CS10 bits for 1024 prescaler
TCCR1B |= (1 << CS12) | (1 << CS10);
// enable timer compare interrupt
TIMSK1 |= (1 << OCIE1A);
}

ISR(TIMER1_COMPA_vect){//timer1 interrupt 1Hz toggles pin 13 (LED)
//generates pulse wave of frequency 1Hz/2 = 0.5kHz (takes two cycles for full wave- toggle high then toggle low)
if ( ! mfrc522.PICC_IsNewCardPresent()) {
  return;
}

// Select one of the cards
if ( ! mfrc522.PICC_ReadCardSerial()) {
  return;
}

// Dump debug info about the card; PICC_HaltA() is automatically called
//  mfrc522.PICC_DumpToSerial(&(mfrc522.uid));
str="";
for (byte i = 0; i < mfrc522.uid.size; i++) {
  if(mfrc522.uid.uidByte[i] < 0x10) str+="0";

  str+=String(mfrc522.uid.uidByte[i], HEX);
```

```
  }
// Serial.println(str);
  u8g.firstPage();
  do {
    draw(8);
  } while( u8g.nextPage() );
  dosend=1;
}
void draw(int i) {
  //u8g.setFont(u8g_font_unifont_0_8);
  u8g.setFont(u8g_font_unifont_72_73);
  u8g.drawStr( 10, 35, menu_strings[i]);
}
```

PHP Database Functions

```
<?php
// database connection config
$dbHost = 'localhost';
$dbUser = 'root';
$dbPass = '';
$dbName = 'traccardemo';
$dbConn = mysqli_connect ($dbHost, $dbUser, $dbPass, $dbName);
mysqli_select_db($dbConn, $dbName) or die('Cannot select database. ' . mysqli_error());
//$con = mysqli_connect($server_name, $mysql_username, $mysql_password, $db_name);
```

```
if($dbConn){
//echo "DB connection success!";
}

else {
echo "Connection failed!";

}



function dbQuery($con, $sql)
{

   global $dbConn;
    $result = mysqli_query($con, $sql) or die(mysqli_error($dbConn));

    return $result;
}

function dbAffectedRows()
{
    global $dbConn;

    return mysqli_affected_rows($dbConn);
}

function dbFetchArray($result, $resultType = mysqli_NUM) {
    return mysqli_fetch_array($result, $resultType);
}

function dbFetchAssoc($result)
{
```

```
    return mysqli_fetch_assoc($result);
}

function dbFetchRow($result)
{
    return mysqli_fetch_row($result);
}

function dbFreeResult($result)
{
    return mysqli_free_result($result);
}

function dbNumRows($result)
{
    return mysqli_num_rows($result);
}

function dbSelect($dbName)
{
    return mysqli_select_db($dbName);
}

function dbInsertId()
{
    return mysqli_insert_id();
}
?>
```

APPENDIX IV QUESTIONNAIRE.

B.1: Respondent Questionnaire

The University of Zambia

School of Engineering

Passenger luggage tracking system using Sensor Networks for Livingstone and Lusaka Intercity Bus Terminal

George Kasanga

MEng ICT Security

For more information or any queries, kindly get in touch on ygkasanga@gmail.com

Dear Respondent,

I am a student at the University of Zambia in my final stage pursuing a MEng in ICT Security. As partial fulfilment for the award of a Master's degree, I am conducting a baseline study on: "***Passenger and luggage tracking system using Sensor Networks."***

Research Summary

There has been an increase in the number of bus operators, which has led to many options for users when travelling however there has been no computerised mechanism to manage, monitor and track luggage information by mapping it to the rightful owner at bus stations. This research seeks to obtain factors that influence the use and non-use of technology in tracking passenger luggage throughout the journey.

You have been purposefully sampled to provide information for the topic indicated above. The information being collected is purely for academic purposes as such, it will be treated with maximum confidentiality. Subsequently, you are not supposed to indicate your name or any personal information that can lead to revealing of your identity.

Your co-operation will be greatly appreciated.

For more information or any queries, kindly get in touch with the following:

Project Supervisor: Dr. Jackson Phiri (0966 693 731) or

Assistant Dean Postgraduate: Dr. Charles Kahanji

Survey Questionnaires

Have you used Bus transportation when travelling to another town? Yes [ ] No [ ]

Name of Bus Operator/s____

Part One: Demographic information (Please tick [√])

1. Gender: Male [ ] Female [ ]

2. Marital Status: Single [ ] Married [ ] Divorced [ ] Other [ ]

3. Age: 20 or under [ ] 21-30 [ ] 31-40 [ ] 41-50 [ ] 51-60 [ ] 61+ [ ]

4. Highest level of education: SHS and below [ ] Diploma [ ] First degree [ ] Masters [ ] Ph.D. [ ]

5. Type of employment: Not working [ ] Salaried worker [ ] Self-employed [ ] Pensioner [ ]

6. Occupation (Please specify, e.g. "University lecturer in Engineering")

Part Two: Computer Knowledge and Experience (Please tick [√])

7. How do you describe your general knowledge about computers? Very poor [ ] Poor [ ] Moderate [ ] Good [ ] Very good [ ]

8. How would you describe your Internet knowledge? Very poor [ ] Poor [ ] Moderate [ ] Good [ ] Very good [ ]

9. How long have you been using the Internet? Don't use [ ] Less than 1yr [ ] 1- 2 yrs. [ ]

More than 2 yrs. [ ]

10. How often do you use the Internet per day? Don't use [ ] Less than 1hr [ ] 1-2 hrs. [ ] 3- 4 hrs. [ ] More than 4 hrs. [ ]

11. Your preference when using services from a provider? Don't Use [ ]Short code (e.g. *101#) [ ]

Mobile Application [ ] Web Application [ ]

Part Three: Travelling Experience (Please tick [√])

13. Have you ever made a bus ticket reservation online?

No [ ] Yes [ ]

12. How often do you travel with luggage on a journey when using a bus?

Never [ ] Always [ ] Most times [ ]

13. Have you ever misplaced your luggage at a bus station or along the journey?

No [ ]   Yes [ ]

Part Four: Passenger Luggage Tracking Adoption Factors

Using a rating scale from the lowest point of 1 to the highest point of 5, please circle the number that indicates your level of agreement or disagreement with the following statement.

No	Statement					
	Perceived Usefulness	**strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1	I think the system would make it easier to monitor my luggage.	1	2	3	4	5
2	I think cases of missing luggage can easily be settled.	1	2	3	4	5
3	I think using the system can help bus operators identify owners of missing luggage.	1	2	3	4	5
4	I think using the system would improve the performance of courier services.	1	2	3	4	5
	Perceived Ease of Use	**strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1	I think that interaction with a luggage tracking system is clear and easily understandable.	1	2	3	4	5
2	I think it's easy to become skilful at using the luggage tracking system	1	2	3	4	5
3	I would find tracking my luggage progress with the system to be flexible to interact with.	1	2	3	4	5
4	I think that learning to operate a luggage tracking system is easy for me.	1	2	3	4	5
	Perceived Risk	**strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1	I think using the system puts my privacy at risk.	1	2	3	4	5
2	I think using the system in tracking luggage has potential security risks.	1	2	3	4	5
3	I think bus operators adaption to change and start-up cost can prevent usage.	1	2	3	4	5
4	I think using the system connected to the internet has the potential of being hacked.	1	2	3	4	5

Thank you for taking the time to participate in our survey. We truly value the information you have provided.

B.2: Operator Respondent Questionnaire

The University of Zambia

School of Engineering

Passenger luggage tracking system using Sensor Networks for Livingstone and Lusaka Intercity Bus Terminal

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George Kasanga

MEng ICT Security

For more information or any queries, kindly get in touch on ygkasanga@gmail.com

Dear Respondent,

I am a student at the University of Zambia in my final stage pursuing a MEng in ICT Security. As partial fulfilment for the award of a Master's degree, I am conducting a baseline study on: "***Passenger and luggage tracking system using Sensor Networks.***"

Research Summary

There has been an increase in the number of bus operators, which has led to many options for users when travelling however there has been no computerised mechanism to manage, monitor and track luggage information by mapping it to the rightful owner at bus stations. This research seeks to obtain factors that influence the use and non-use of technology in tracking passenger luggage throughout the journey.

You have been purposefully sampled to provide information for the topic indicated above. The information being collected is purely for academic purposes as such, it will be treated with maximum confidentiality. Subsequently, you are not supposed to indicate your name or any personal information that can lead to revealing of your identity.

Your co-operation will be greatly appreciated.

For more information or any queries, kindly get in touch with the following:

Project Supervisor: Dr. Jackson Phiri (0966 693 731) or

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Survey Questionnaires

Have you used Bus transportation when travelling to another town? Yes [ ] No [ ]

Name of Bus Operator/s____

Part One: Demographic information (Please tick [√])

1. Gender: Male [ ] Female [ ]

2. Marital Status: Single [ ] Married [ ] Divorced [ ] Other [ ]

3. Age: 20 or under [ ] 21-30 [ ] 31-40 [ ] 41-50 [ ] 51-60 [ ] 61+ [ ]

4. Highest level of education: SHS and below [ ] Diploma [ ] First degree [ ] Masters [ ] Ph.D. [ ]

5. Type of employment: Not working [ ] Salaried worker [ ] Self-employed [ ] Pensioner [ ]

6. Occupation (Please specify, e.g. "University lecturer in Engineering")

Part Two: Computer Knowledge and Experience (Please tick [√])

7. How do you describe your general knowledge about computers? Very poor [ ] Poor [ ]

Moderate [ ] Good [ ] Very good [ ]

8. How would you describe your Internet knowledge? Very poor [ ] Poor [ ] Moderate [ ] Good [ ] Very good [ ]

9. How long have you been using the Internet? Don't use [ ] Less than 1yr [ ] 1- 2 yrs. [ ]

More than 2 yrs. [ ]

10. How often do you use the Internet per day? Don't use [ ] Less than 1hr [ ] 1-2 hrs. [ ] 3- 4 hrs. [ ] More than 4 hrs. [ ]

11. Your preference when using services from a provider? Don't Use [ ] Short code (e.g. *101#) [ ]

Mobile Application [ ] Web Application [ ]

Part Three: Travelling Experience (Please tick [√])

13. Do you provide online bus ticket reservation?

No [ ] Yes [ ]

12. How often do you have cases of misplaced or lost luggage on a journey when using your buses?

Never [ ] Daily [ ] Weekly [ ] Monthly [ ] Quarterly Half Yearly [ ] Yearly [ ]

13. Have you ever misplaced or lost passenger luggage at a bus station or along the journey?

No [ ] Yes [ ]

14. Do you have the following at the office? Computers [ ] printers [ ] firewall [ ] IT personnel [ ] internet [ ]

Part Four: Passenger Luggage Tracking Adoption Factors

Using a rating scale from the lowest point of 1 to the highest point of 5, please circle the number that indicates your level of agreement or disagreement with the following statement.

No	Statement					
	Perceived Usefulness	**strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1	I think the system would make it easier to monitor my luggage.	1	2	3	4	5
2	I think cases of missing luggage can easily be settled.	1	2	3	4	5
3	I think using tracking client luggage progress will enable bus operators to get the information of the passenger luggage quickly.	1	2	3	4	5
4	I think using the system can improve bus operator's provision of services.	1	2	3	4	5
	Perceived Ease of Use					
1	I think that interaction with luggage tracking system is clear and easily understandable	1	2	3	4	5
2	I think it's easy to become skillful at using the luggage tracking system	1	2	3	4	5
3	I think Integrating the system with current work practices will not be very difficult.	1	2	3	4	5
4	I think that learning to operate luggage tracking system is easy for me	1	2	3	4	5
	Perceived Risk					
1	I think using the system puts passage privacy at risk	1	2	3	4	5
2	I think using the system in tracking luggage has potential of bringing job losses.	1	2	3	4	5
3	I think bus operators adaption to change and start-up cost, can prevent usage.	1	2	3	4	5
4	I think using the system connected to the internet has potential of being hacked	1	2	3	4	5

Thank you for taking the time to participate in our survey. We truly value the information you have provided

LIST OF PUBLICATIONS

1. George Kasanga, Jackson Phiri, "Passenger and Luggage Tracking System Using Sensor Networks for Public Transport", Proceedings of the 3rd international conference in ICT (ICICT2019).

2. Kasanga, G. and Phiri, J. (2020) Factors Affecting the Adoption and Usage of Luggage Tracking System by Public Transporters Based on TAM Model. *Open Journal of Business and Management*, **8**, 855-865. Doi: 10.4236/ojbm.2020.82052.