CRIME MAPPING MODEL BASED ON CLOUD AND SPATIAL DATA
A CASE STUDY OF ZAMBIA POLICE SERVICE

BY

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A Dissertation submitted to the University of Zambia in partial fulfillment of the requirements for the degree in Masters of Engineering in Information Technology and Communication - Security

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DECLARATION

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

Signature……………………………………Date:……………………………………

Supervisor's Name……………………………………………………...

Signature……………………………… Date……………………………………

CERTIFICATE OF APPROVAL

This dissertation by Jonathan Phiri is approved as fulfilling the requirements for the award of the degree of Master of Engineering in Information and Communication Technology Security (ICT-Security) of the University of Zambia

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Examiner 3.......................................Signature………… Date............................

Chairperson Board of Examiners .... …..…Signature …………… Date.....................................

ABSTRACT

Crime mapping is a strategy used to detect and prevent crime in the police service. The technique involves the use of geographical maps to help crime analysts identify and profile crimes committed in different residential areas, as well as determining best methods of responding. The development of geographic information system (GIS) technologies and spatial analysis applications coupled with cloud computing have significantly improved the ability of crime analysts to perform this crime mapping function. The aim of this research is to automate the processes involved in crime mapping using spatial data. A baseline study was conducted to identify the challenges in the current crime mapping system used by the Zambia Police Service. The results show that 85.2% of the stations conduct crime mapping using physical geographical maps and pins placed on the map while 14.8% indicated that they don't use any form of crime mapping technique. In addition, the study revealed that all stations that participated in the study collect and process the crime reports and statistics manually and keep the results in books and papers. The results of the baseline study were used to develop the business processes and a crime mapping model, this was implemented successfully using Use Case, Sequence, Entity Relationship and system architecture designing models. The proposed model includes a spatial data visualization of crime data based on Google map. The proposed model is based on the Cloud Architecture, Android Mobile Application, Web Application, Google Map API and Java programming language. A prototype was successfully developed and the test results of the proposed system show improved data visualization and reporting of crime data with reduced dependency on manual transactions. It also proved to be more effective than the current system.

Keywords—Zambia Police; web application; Mobile application; Cloud Model; Crime Mapping; Spatial Data

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DEDICATION

This work is dedicated to the God Almighty for the Grace upon my life, it is also dedicated to my family; My father Mr Phiri Samson,My mother Mrs Phiri Nelly, my brother Mr Phiri Lembani and my sister Miss Phiri Grace for their great support and encouragements.

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LIST OF ABBREVIATIONS

API	Application Programming Interface
DNA	Deoxyribonucleic Acid
CID	Criminal Investigation Officer
CAS	Case Administration System
CCTV	Closed Circuit Television
FBI	Federal Bureau of Investigation
GIS	Geographical Information System
DFD	Data Flow Diagram
CIO	Criminal Investigation Officer
ERD	Entity Relationship Diagram
ICT	Information and Communication Technology
ICICT	International Conference in Information and Communication Technology
MPLS	Multi-Protocol Label Switching
OOD	Object Oriented Design
OO	Object Oriented
OOP	Object Oriented Programming
OOSD	Object Oriented Software Development
OOSDM	Object Oriented System Development Methodology
RFID	Radio Frequency Identification
RSS	Reality Simple Syndication
SAPS	South African Police Service
SD	Sequence Diagram
SDLC	System Development Life Cycle
SDM	Software Development Methodology
SPSS	Statistical Package for Social Scientists
UML	Unified Modelling Language

SaaS	Software as a Service
PaaS	Platform as a Service
IaaS	Infrastructure as a Service
VSU	Victim support Unit

CHAPTER 1: INTRODUCTION

1.1 Background

Challenges in preventing and reducing crimes are what most governments around the world are struggling to deal with, every family and business have been directly affected by different kinds of crimes like robberies, vandalism, burglaries, sexual and other crimes [1].Crimes affect the quality of life, economic growth, and reputation of a Nation. There is need for the law enforcements to take tough preventive measures to reduce crimes in communities [2]. In Zambia, the Zambia Police Service is considered as the main law enforcement agency mandated to enforce law on Zambian citizens and combat crime thereby playing a critical role in the Zambian criminal justice system [3]. A criminal justice system comprises of government institutions mandated to detect and mitigate crime, it focuses on how criminal cases flow from the time they are reported and investigated up to when they are disposed off. A well established and effective criminal justice system is the key to the reduction of crime in a Nation [4] . Ordinary citizens and communities in a Government expect the criminal justice system and its general capacity to not only protect the communities and deal with criminal offenders but also interact with different various parties including victims, witnesses, accused as well as criminal justice professionals [5], therefore the Zambia police being the first to have contact with these people can be regarded as the gate keeper of the Zambian justice system. The Zambia Police was established in 1891 under British South African Company known as Northern Rhodesia police force, and later in 1964 upon attainment of independence was established then under Article 103 (3) of the constitution and now under Article 193 (2) of the 2016 amended constitution of Zambia and also under the Zambia police amendment act number 30 of 2016 of the laws of Zambia, the name was changed from Northern Rhodesia to Zambia Police force which later in 1994 changed to Zambia police service. Article 193 (2) of the 2016 amended constitution clearly outlines the roles and functions of the Zambia police service, it mandates the agency to ensure protection of life and property, preservation of peace, maintenance of law and order, upholding bill of rights and most importantly detect and prevent crime [6].One of the key strategies used to detect and prevent crime is crime mapping. The technique involves the use of geographical maps to help crime analysts identify and profile crimes committed in different residential areas, as well as crafting best methods of responding [7]. It facilitates visual and statistical analysis of spatial crime data for a specific area by linking it with geographical variables like bars, schools, streets and others. Crime does not spread across the space evenly or equally but rather clumps on some specific areas while absent in other areas. Crime mapping is devoted at identifying high crime areas or neighborhoods also known as hotspots, hotspots are areas with high criminal activities [8]. Proactive policing pushes police officers to identify areas with high concentration of crimes, determine what causes these concentrations and find methods of reducing these concentrations [9]. A well and clearly visualized crime hotspot map significantly helps police officers in aiding threat visualization, police resource allocation and crime prediction. The development of geographic information system (GIS) technologies and spatial analysis applications coupled with cloud computing have significantly improved the ability of crime analysts to perform this crime mapping function [10]. While it is clear that computerized crime mapping has emerged as an important focus of innovation in policing, there has been little scholarly review of the development of computerized crime mapping as an innovation and the factors that have influenced its adoption in most Law enforcement agencies worldwide [11]. The research study is set to design and develop a computerized crime mapping system for the Zambia Police to automate the processes involved in mapping crimes using spatial data.

1.2 Statement of the Problem

Literature reveals that computerized Crime mapping technologies have developed over the years however Zambia police is still using manual and traditional way of mapping crimes. This involves the use of physical geographical maps and pins to depict time and locations of reported crime incidents. Crimes are mapped using physical geographical maps and pins to establish the location of crime areas. The manual and paper based crime mapping system that is in place does not provide the needed efficiency and effectiveness to the management of crime maps and crime data.

1.3 Aim of the Study

To identify challenges in the current crime mapping system used by the Zambia Police Service and develop a model prototype to address the identified Challenges.

1.4 Objectives

i. To conduct a baseline study to identify challenges of the current crime mapping system used by the Zambia Police Service.

ii. Design a crime mapping model based on the current business processes.

iii. To develop a crime mapping system (prototype) based on spatial data cloud computing technologies.

1.5 Research Questions

i. What challenges does the Zambia police face when using the current crime mapping system?

ii. How can a crime mapping model be designed using the current business processes?

iii. How can a crime mapping system (prototype) be developed using cloud technologies and spatial data model?

1.6 Significance of Study

An automated crime mapping system should help the Zambia police to easily generate and monitor crime statistical maps of specific areas in real time as crimes are being reported by the general public. The research will also contribute to the usage of ICT in the Zambia Police and reduce the dependency on manual transactions

1.7 Scope

This research involved a baseline study that was conducted to identify the challenges in the current crime mapping system used by the Zambia Police Service. The study was conducted in nine (9) selected police stations in Lusaka city, the capital city of Zambia. The results of the baseline study which was conducted in the selected police stations were statistically analyzed and an automated crime mapping model and software prototype based on cloud and spatial data was also implemented in this study.

1.8 Research Contribution

The business processes that would enable automation of the Cloud Based Crime Mapping Model from the current manual based processes were mapped. Implementation of the automated Crime Mapping Model using cloud architecture, Google Map API and Java programming language for the Zambia Police Service was done. Some Parts of this work were firstly published in the proceedings of the International Conference in Information and Communication technology (ICICT2019) in Lusaka, Zambia [12]. Secondly, most parts of this work was published in the International Journal of Advanced Computer Science and Applications (IJACSA) [13].

1.9 Organization of the Thesis

This thesis is organized into five chapters; Chapter 1 is the introduction to the Research, in this chapter, a brief overview of the work in this thesis is given, it also presents the problem statement, aims and motivation of the research. This chapter concludes by giving an outline of the thesis. Chapter 2 looks at the background theory and related works, in this chapter, a comprehensive review and the background theory on crime mapping, crime mapping technologies and Cloud Computing are given. The chapter also includes related works regarding automated crime mapping systems. Chapter 3 presents the research methodology, in this chapter, the methods used to conduct the baseline study and implementation of the system are presented. Chapter 4 presents the research findings of the baseline study and the system implementation are presented. Chapter 5 presents the discussion and conclusion of the research.

1.10 Summary

In this chapter, the basic introduction of the work in this thesis was given. The motivation, significance and scope of the work in this study were then outlined. In addition, the problem statement, objectives, scope and research contributions were given. The chapter was closed with an organization of the thesis.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The chapter begins with an overview of crime mapping, followed by a brief review on usage of information Communication technologies in Policing as a general. Thereafter a review of crime mapping technologies and cloud computing. Also, a review of the software development methodologies is presented in this section. Lastly, this chapter closes by looking at related works to automated crime mapping systems.

2.2 Overview of Crime Mapping

A crime is defined as the breach of criminal law that govern a particular geographical area, the criminal law that aims at protecting the lives, property and rights of citizens within a particular jurisdiction [14].In addition ,Harries [15] describes a crime in four dimensions; **Legal** – a law must be broken, **Victim** – someone or something has to be targeted, **Offender** – someone has to do the crime and **Spatial** – a crime has to happen at a place somewhere in space and time, commonly referred to as crime spatial data. Spatial data is data that describes the location, shape and relationship of geographic features [16].In criminology it is called spatial crime data because it contains geographical referenced attributes like geographical coordinates (longitude and Latitude) that can be used to establish the exact location of an object or crime incident on the map [17].crime mapping seeks to answer the question of “where”?" for example, “where does crime happen?” or “Where should we focus efforts to catch a serial killer?” or “Where should we build a new police station to fight the crime?” or “Where is crime highest?” by analyzing the crime spatial data provided from various sources [18].Daglar and Argum [19] in their paper highlighted that a place of a crime and any other geographic information connected with a criminal incident can give a lot of information about characteristics of possible criminals, it can also assist in designing of assessment and prevention programs for the related crime incidents. They added that deciding a policing method is always influenced by some facts of place as jurisdictions, zones, and incident locations are all related to geography. Crime mapping has its own history, the use of traditional crime pin maps for data visualization dates back in early 1830s.The crime map was a representation of pins stuck on it, the pins on the map were useful for showing where crimes occurred

[15].There are three schools that were recognized and pointed out in the study by Philips [17] ,the first was called **cartographic/geographic school** which dominated between 1830s and 1880s originated from France and later spread to England. In this work governments begun to collect social data, the intended purpose was to center on the influence of variables such as wealth and population density on levels of crime. The second was called **Typological school,** its work dominated between 1880s and 1900s, it focused on the relationship between the mental and physical characteristics of people and crime. The third was called **Social ecological school which** has dominated from 1900s up to date, it concentrated on the geographical variations on social conditions assuming that they were related to crime patterns. It focused primarily on recognizing and classifying areas in the cities with similar social characteristics [15].Crime mapping also enhances effective criminal investigation especially when crimes are committed in known crime hot spot areas. criminal investigation can be described as the process of identifying, collecting, preserving and evaluating information or evidence about a crime in order to determine if the crime was committed, identify the perpetrator, apprehend the perpetrator and provide evidence to support conviction in the courts of law. All the activities and processes involved in criminal investigation are recorded and documented to form a case docket, a case docket is the compilation of detailed information pertaining to the sequences of events of an offence to a detection of crime to be tried in the courts of law .A case docket is regarded as the product of criminal investigation, Johan and Marcel [20] also define criminal investigation as the process of fact-finding of different crime information cases in a systematic manner both scientific and traditional in order to gather evidence for the purpose of assisting a court of law to come to a conclusion. There are three main objectives of criminal investigation, firstly is to identify the perpetrator, secondly is to apprehend the perpetrator and thirdly is to support a case by providing evidence in the courts of law [21].During crime investigation the police rely on the crime-related information left behind by the perpetrator ,this include fingerprints eye witness descriptions, murder weapon and other information that can lead to the identification and apprehension of the perpetrator .Collecting relevant information is one of the challenging task faced by police officers during crime investigation due to availability of massive inaccurate ,irrelevant and incomplete information [22].Police officers are required to collect information that is factual and admissible in the courts of law. The process of crime

investigation can be segmented into two categories namely reactive and proactive/intelligence based crime investigation processes [23]. When there is enough information and evidence arise from both types of criminal investigations lead to the prosecution of the suspect, otherwise no further action is taken.

2.2.1 Reactive Investigation/Policing

According to [24] the reactive investigation which is a common type of investigation process begins when there are received reports from general public or referral by other agency or reinvestigation of the case as a result of new information. In this category before commencing any criminal investigation the police must first discover that a crime occurred or the victim or witness must report to the police that the crime has occurred then the police is dispatched to the scene of crime. A scene of crime can be described as any location containing evidence that crime took place, the goal is to trace physical evidence left behind by the perpetrator [25] using forensic science .Investigation of the crime scene aims at recording the crime scene as it is first encountered, recognize and collect all physical evidence which is potentially relevant to the solution of the case. According to Locard's principle of Exchange by Dr. Edward Locard (1877-1960) [26] ,it states that "every time you come into contact with a person, place, object or anything, there is always an exchange of physical materials. He believed that as the criminal takes things away with him from scene of crime he or she also leaves some physical evidence he or she came into contact with, these include finger prints, DNA, hair, skin cells, blood, body fluids, chemical weapons, pieces of clothes and many others. He also believes that physical evidence cannot be wrong, cannot lie and cannot be wholly absent. The Locard's principle of exchange can mean that every incident be it a crime, accident, natural disasters and others leave traces at the scene therefore it is the duty and goal of an investigator to correctly interpret the facts, reconstruct the events and understand what exactly happened. The use of forensic science in criminal investigation is considered to be one of the most aspect of criminal justice. Forensic science is described by Uzabakiriho [27] as the practice of applying scientific methods in examining physical evidence collected from the scene of crime in order to supply accurate information reflecting the events that occurred at the crime scene. In situations where there are no eye witnesses, the use of forensic science plays a bigger role in solving different kinds of criminal cases including sexual, murder, burglary, and many others.

Physical evidence collected from the scene of crime can be categorized in three namely biological evidence, chemical evidence and trace evidence.

a) **Chemical Evidence –** Chemical evidences include all chemical substances found at the scene of crime, they include chemical weapons, biological toxins, radioactive substances, and drugs

b) **Trace Evidence –** Trace evidence is referred to objects found at the scene of crime, they provide clues to further lead towards the identification of suspects and victims of crime. Common traces found include fingerprints, footprints, criminal tools, guns, live bullets, empty bullet cartridges and many others.

c) **Biological Evidence –** This is the type of evidence that is commonly recovered from the scene of crime, it includes hair, tissue, bones, teeth, body fluids and many others. The samples collected from the scene of crime are analyzed and examined using forensic DNA analysis in order to determine the exact identification of the offender, the results also provide excellent indicators of what happened. **DNA** stands for Deoxyribonucleic Acid which is the genetic material that determines all characteristics residing in the cells of the living thing [28]. All living things have DNA in their cells and it is passed on to the next generation, each person has unique DNA except twins. DNA forensic experts use DNA analysis to identify the individuals by matching genes from person's items and stored samples with those from the criminal suspect.

When the physical evidence discovered at the scene of crime is properly handled, it provides valuable and reliable information about the incident being investigated, this is so because the physical evidence is factual and does not lie as believed by Dr. Edward Locard. Proper handling of evidence includes management of crime scene and maintaining chain of custody from scene of crime to the forensic laboratory. Management of crime scene is the process of ensuring that there is order, accuracy and effectiveness in collecting and preservation of physical evidence from scene of crime so that the evidence can be used and presented in the courts of law [29]. A team of first responders to the crime comprising of different forensic experts including ballistics, fingerprints, DNA and others are expected to perform three common major tasks when they arrive at the scene of crime. First is to control and secure the physical area where the crime took place by using physical barriers like identity tapes this is done in order to prevent the physical evidence from destruction, disturbance or contamination. The second task is to establish a command center to be used for communications and administrative functions, statements from identified witnesses are recorded and also information about suspects is gathered and compiled. The third task is to maintain a chain of custody from the scene of crime to the forensic laboratory. The value of the evidence that has been carefully collected and preserved form the scene of crime can be lost if the chain of custody is not properly maintained. According to EC-Council [30] chain of custody is about recording and documenting the acquired physical evidence including all the procedures involved from the scene of crime up to the forensic laboratory. Any change to this chain calls into question the admissibility of the evidence in the courts of law. It is very crucial to demonstrate every single step undertaken to ensure traceability and custody of the evidence from the scene of crime to the court room, this is why the chain of custody is the considered as the weakest link in criminal investigation [31]. The challenge is that in most cases, first responders to the crime scenes are non-forensic experts, [32]. According to the study carried out by Tilley and Ford [33] on the use of forensic science in the United Kingdom Police service, the findings revealed that there was luck of awareness due to lack of training , communication ,equipment and materials for forensic science within the police service [34]. The findings in the study carried out by Julien and Kelty on risk factors in the forensic process from crime scene to court in Australia [35] also shows that forensic science is still not fully and well embedded in the criminal justice. The authors revealed and high-lightened five (5) risk factors

a) Low level of forensic awareness among first responders

b) Lack of professionalism among crime scene investigators/examiners

c) There is no enough forensic literacy among actors in the criminal justice system.

d) Poor communication among actors in the criminal justice system

e) Lack of forensic and financial material resources.

Reactive type of criminal investigation has been criticized for failing to prevent crime, in this type of investigation the police only respond to the citizens call for service and go where the crime has occurred otherwise they will keep distance from the community without any intrusion [36] .However it is argued that theoretically the reactive investigation has the preventive effects in two possible ways [37] ,firstly is that the possibility of police arriving at the scene of crime in progress after a report or a call from citizens is thought to deter crimes. Secondly is that successful prosecution of the offender after a successful investigation is also thought to be a deterrent to would be offenders.

2.2.2 Proactive Investigation/Policing

Proactive or intelligence based criminal investigation is the methodology which is essential in producing efficient and effective intelligence for the purpose of open investigation. This approach is essential as it does not only shortens the completion time of investigation bust also enables effective pooling of various expertise needed in dealing with complex investigations [38]. Law enforcement agencies use intelligence based criminal investigation to deal with ongoing criminal cases where there are no witnesses to report the matter or where there are no calls for service from community citizens. Some common types of crimes dealt under this type of criminal investigation include drugs, organized crimes, terrorism and fraud. Intelligence can be described as the collection and analysis of information, this definition can be expressed using a formula of information plus analysis equals intelligence. This means that intelligence is the final product after analysis and evaluation of the collected data or information. The history of intelligence based investigation is traced back in early 1990's in the Great Britain after two reports from the Audit commission in 1993 and Her majesty's inspectorate of constabulary 1997 commended in order for the police to effectively fight organized crimes [39],there was need to introduce and increase the usage of intelligence, surveillance, informants and deep cover operations in the police by mostly targeting the recidivists. A recidivist is a criminal who commits a criminal offence repeatedly, these people can also be utilized and used as informants. An informant is a person who has more knowledge about the crimes which are being investigated. Informants are useful in dealing with type of crimes which are hard to penetrate using normal or open investigation, information provided by them is also valuable to the officers in the deep cover operation. The task of deep cover officers is to penetrate organized crime circles then collect and gather information to be later used as a strong starting point for an open investigation. This call was firstly implemented by the Kent police force hence named as the "kent policing model". The investigations of highly profiled crimes were entirely carried out by the intelligence unit, then after completing the intelligence investigations, all the criminals would be handed over to the open investigations ready for prosecution. According to the report authored by Dato and Abdu on intelligence based investigations in Malaysia [40] reveals that the law enforcement agencies faces quiet protests from both legal scholars and members of the prosecution against the introduction of undercover operations in policing. Their argument was that there is no adequate legal basis for the systematic use of undercover methods which is believed to be an infringement in the private lives of citizens. The courts in Malaysia have not yet set a binding precedent due to uncertainty and less development law in the area of undercover operations. The recommendations in Peterson's paper [41] reveals that in order to effectively implement intelligence-led policing ,police organizations need to reevaluate their current policies and protocols. Intelligence must be incorporated into the planning process in order to reflect the community problems and issues. Information sharing must become a policy not an informal practice. There is also need to support the development of analytical techniques, training and technical assistance to officers [42].The paper further identified four levels of intelligence capabilities that can be utilized to help agencies incorporate intelligence-led policing strategies, firstly is adopting mission statements, secondly is writing intelligence policing and procedures, thirdly is participating in information sharing and establish appropriate security and fourthly is adopt legal safeguards to protect the public's privacy and civil liberties.

Like any type of criminal investigation, crime mapping has the ability to help investigators to separate the numerous numbers of suspects in order to reach at the most perfect and likely suspect. Crime mapping proves to be an effective strategy in preventing crimes as it helps the police to deploy resources like police patrols to crime hot spot areas or locations where crime is unusually concentrated.

2.3 Information and Communication Technology (ICT) in Policing

According to Sethi in his study on the roles of ICT in Indian Police force [43],describes ICT as generally a range of technologies for gathering, storing, retrieving, processing, analyzing, and transmitting information. The police force makes use of ICT in many areas of its operation such as records maintenance, surveillance through the CCTV technology and traffic through the speed cameras that are usually mounted on the police cars. The use of ICT in the police force has greatly enhanced service delivery to public. In a similar study by Zaharchuk et al. on the police management systems in Canada reveals that the technological advancement through the miniaturization and improvement in communication systems and devices have prompted the use of information systems in police forces [44]. Laudon and Laudon defines information system as a set of interrelated components that collect, retrieve, process, store and distribute information to support decision making and control in an organization. Information systems contain information about significant people, places and things within an organization or environment surrounding it, therefore one of the benefits of information systems can be emphasized on information as a resource [45]. Information adds value to the operations of the police and information systems improve information sharing and communication between police officers by making it easy to remotely access central criminal records databases in municipal police forces. Central criminal records are stored in one spot for documentary purposes and they are accessed by police officers who wish to know anything about a particular case. The challenge is that information systems demand extra budgeting and well trained personnel to implement manage and secure the IT infrastructure [46]. The study conducted by Sethi on the role of ICT in Police in India also identifies two common advanced technologies among others implemented in the Police in India these are radio frequency identification (RFID) and biometrics [47].

2.3.1 Radio Frequency Identification (RFID) Technology in Policing

Radio frequency identification (RFID) is a type of technology that uses radio frequency or waves to identify read and capture information stored on a tag attached to an object [48].This technology can be used to identify, track monitor , and collect pieces of data from different tagged objects, people, animals in different environment and situations for the purpose of accountabilities without any physical human intervention [49]. Information of an object or person is transmitted wirelessly using radio waves inform of unique serial number. RFID technology is under the group of automatic identification technologies, among others in this group include voice recognition, smart cards, and barcode technology [50]. The architecture of a typical

RFID system consists of four basic components namely; tag, reader, antenna and central node computer as shown in figure 2.1 below.

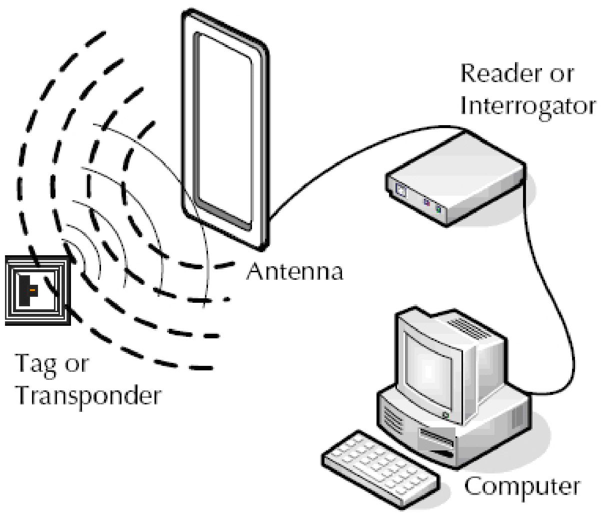

Figure 2.1: Components of RFID system [50]

a) **Tag/Transponder -**

An RFID tag is a data carrier that transmits information to the RFID reader (transceiver) within a given range of distance through a microchip and antenna imbedded in it.The tag's microchip also known as the integrate circuit (IC) delivers performance, memory and other extended feature of the tag [51]. Figure 2.2 shows an internal structure of a tag.

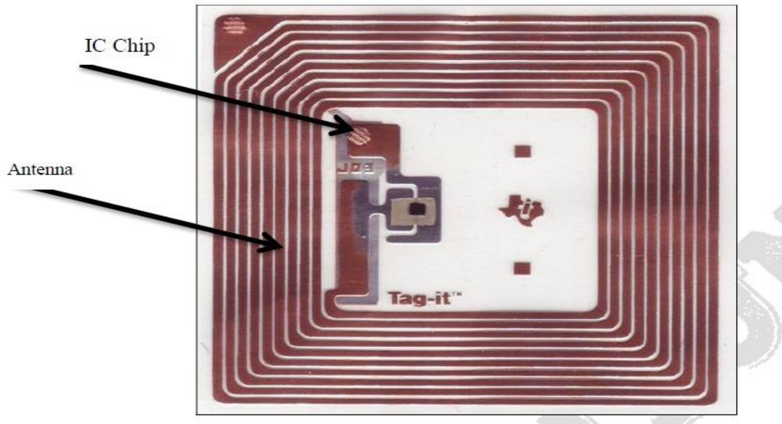

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Figure 2.2 Internal structure of a tag [51]

The chip in a tag is programed with a tag identifier, unique serial number and a memory bank to store unique tracking identifier of an item .The antenna attached to the microchip is used to transmit information from the chip to the reader [52] .The tag can be scanned by a mobile or stationary reader using radio waves and forward the information to the host computer housing the database. RFID tags are grouped in three categories namely active, passive and battery assisted passive also known as semi-passive, table 2.1 shows some detailed features of each of them.

Table 2.1: Features of active, passive and battery assisted passive tags [52]

	Active Tag	Passive Tag	Battery assisted passive (BAP) tag
Power Source	Internal	Energy transfer from reader via radio frequency	Uses internal power source to power on, then uses energy transferred from reader via radio frequency to backscatter
Tag Battery	Yes	No	Yes
Availability of tag power	Continuous	Only within field of reader	Only within field of reader
Required signal strength from reader to tag	Very Low	Very high to power the tag	Moderate for powering backscatter
Required signal strength from tag to reader	High	Low	Moderate
Communication Range	Long range of 100m or more	Short range of up to 10m	Moderate range of up to 100m
Storage	128 kilobytes read/write	128 bytes read/write	128 kilobytes read/write

b) **RFID Reader**

An RFID reader is a device that is used to interrogate an RFID tag, it queries the tag and receive data from it. The RFID reader has an in-belt antenna that emits radio waves used for communications with the tag, then the tag responds by sending back its data [53]. RFID readers do not only accomplish the task of querying a tag but also sending and receiving commands from the application software which helps them to interpret radio waves into digital information [54] .

c) **RFID Antenna**

The RFID antenna is also regarded as an important element in RFID systems, its role is to emit radio wave and receive them back from the transponder. An antenna transmits and receives electromagnetic waves to activate a tag and a reader [55].

d) **Central Computer Node (Middle ware/Database server)**

RFID middleware at the central note plays a vital role in RFID system operation ,management filtering and making sense of data coming g from RFID tags [56]. It is server software that supports the RFID reader's capability to extract unique information from the data being read. Middleware also provides management information exchange between the readers and the backend database server. The database server is mainly used not only for storage of data but also for management and read-write control of radio frequency tags [57].

RFID technology is being utilized to transform different business process in deferent areas in the modern police and other law enforcement agencies. A report published by U.S.A Tech Beat Summer report [58] further illustrate that the RFID technology can not only be utilized by police but also all other types of law enforcement agencies. There are two major areas that this technology can be used in police namely chain of custody and property control. As mentioned earlier, Chain of custody involves the handling of evidence from the scene of crime to where it will be stored securely. An RFID tag can be used to track and keep record of who, what, when and where each piece of evidence was taken from a scene of crime up to a place of custody or storage. Property control involves management and protection of evidence in custody or in secured storage. An RFID tag can be used to automatically send a notification and an alarm if anyone illegally attempts to temper with the evidence in custody. For example, in Netherlands one of the law enforcement agencies known as Netherlands forensic institute which collects and analyzes crime scene evidences implemented an RFID system to provide property and evidence management. The system enables the users to easily document each item's chain of custody and provides warning if items are moved without permission. The Documentation of item's chain of custody include; the individuals involved in the process of acquiring, collecting, analyzing of evidence and time recordings as well as contextual information, which includes case labeling [59].

2.3.2 Biometrics Technology in Policing

vacca [60] describes the term 'biometric' as the statistical analysis of biological observations and phenomena. The author further describes Biometric technology as the use of systems to recognize and authenticate users using human characteristics like eyes, voice, fingerprints and many others. People routinely use biometrics to recognize other people, commonly using the shape of a face or the sound of a voice to do so. Biometrics can also be used to create automated ways of recognizing a person based on her physiological or behavioral characteristics, each human being is unique in terms of characteristics, which make him or her different from all others. A biometric system is the system that recognize and authenticate its users using human features like eyes, voice, finger prints etc ,Users present their biometric data as identity and the biometric system decides whether or not the data presented is correct [60]. Some of the benefits of using biometrics include;

a) Solves the problem of forgetting user login credentials, as users do not require to memorize their usernames and passwords

b) Law enforcements agencies like Police can use it to track criminals

c) Airports can automatically capture images for airline passengers to track suspicious passengers

2.3.2.1 Biometrics System Architecture

All biometric systems have a number of common subsystems, these are ; data capture subsystem ,signal processing subsystem, matching subsystem , data storage subsystem and decision subsystem [60] [61] [62] .Figure 2.3 shows the biometrics system architecture.

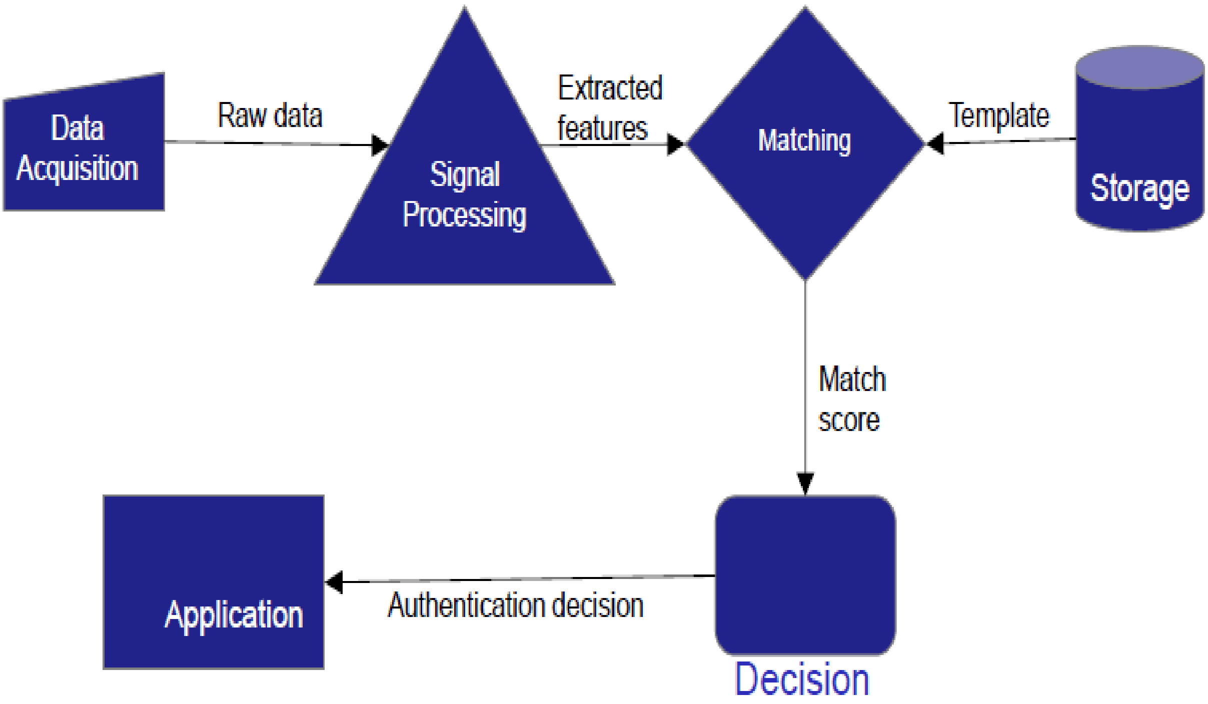


Figure 2.3: Biometrics system architecture [60]

a) Data Capture

Collects captured biometric data from a user, to do this to do this, it performs a measurement of some sort and creates machine-readable data from it. This could be an image of a fingerprint iris, a signal from a microphone, voice and others. Performance of data capture can negatively be affected by, sensor/capture being used for example dirtiness or scratchiness and also Noise can affect voice capture [61].

b) Signal Processing

Takes the captured biometric data from the data capture subsystem and transforms the data into a form suitable for use in the matching system The transformed data is known as **reference or template** .The signal processing subsystem firstly checks the quality of the captured data before transforming it [61].

c) Matching

A matching subsystem receives a reference from a signal processing subsystem, and then compares it with the one from the data storage system. The output of the matching subsystem is a numeric value called **comparison score**, Comparison score indicates how closely the two match and it is passed to the decision subsystem for decision making [61].

d) Data Storage

It stores data templates that are used by the matching subsystem, a data storage can be a database, or even any other including portable storage device like flash, smartcard can be used to store templates [61].

e) Decision

It takes a comparison score which is the output of matching system and returns a binary yes or no decision from it. The decision subsystem indicates whether or not the matching subsystem made a comparison which resulted in a match or not. The value **"YES"** is returned if the comparison was probably a match, the value **"NO"** is returned if the comparison was probably incorrect [61].

2.3.2.2 Biometrics Systems

There are many different types of biometric systems, Saini and Rana in their paper [63] highlighted some common biometric systems including their advantage and disadvantages, these were; face recognition, Iris, Finger print and voice.

a) Face Recognition – Face Recognition is a computer system application for automatically determining or verifying an individual from a digital image or video framework from the image/video source. One of the techniques to do this is simply by evaluating selected facial features like nose, eyes, ears and others from the image as well as from facial database as shown in figure 2.4 below [61] [63].

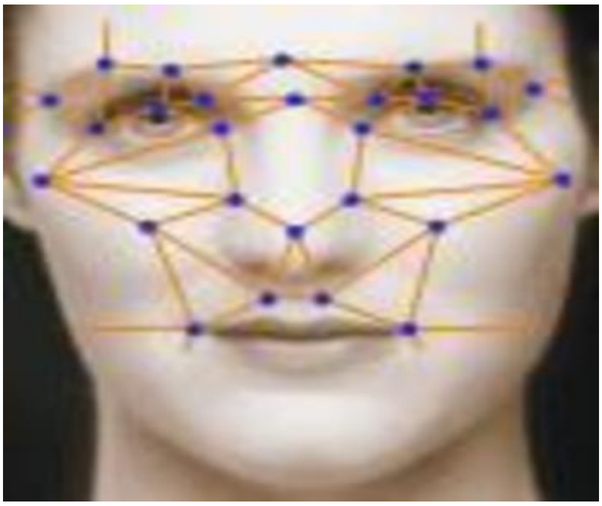


Figure 2.4: Facial Recognition [63]

Advantages

- Non intrusive (contactless authentication)

-Cheap technology

- User-friendly design

Disadvantages

- Not perfect in bad/poor lighting
- Some viewing positions can be an obstacle
- Not effective for low resolution images

b) **Iris Recognition –** Once the impression of an iris has been taken using a standard digital camera, the authentication process involves evaluating the present subject’s iris with the stored version. The pattern of the human iris is determined by the chaotic morphogenetic processes during embryonic development and is believed to be unique for each person and each eye. Once stable, the pattern does not change with age, and rarely suffers damage. The technology can now be installed as software into either a computer or digital camera infrastructure without the need for specialist hardware. Iris matching systems are considered to more accurate than other biometric systems, they are capable of operating in a one-to-many (identification rather than verification) mode at all times. This is possible because of its ability to search accurately and extremely quickly across large databases.   Figure 2.5 shows the position of iris [64].

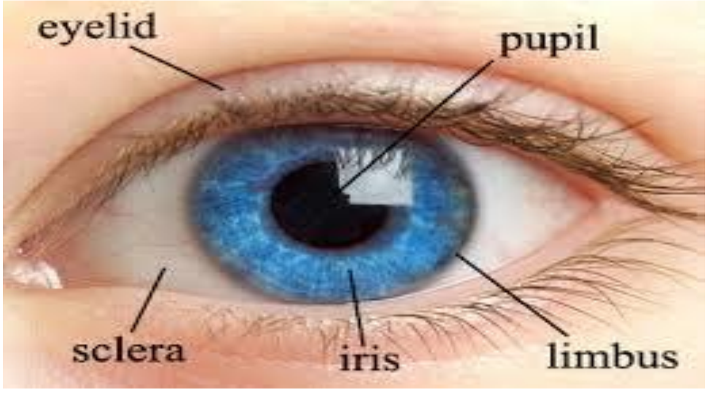


Figure 2.5: position of iris [63]

If well implemented, iris recognition system offers one of the most secure strategies of authentication and recognition.

Advantages

i. Very high accuracy
ii. high recognition speed
iii. Easy detection of fake iris
iv. Non intrusion

Disadvantages

i. Iris scanners are very expensive to acquire
ii. Requires a lot of memory for data to be stored and processed

f) Finger print – A finger print consists of ridges, valley loops, arches and many others which are unique to each and every human. Fingerprints are one of the most mostly used biometric technologies used in forensics and thus have a stigma of criminality associated with them. In the past the capture ring and identification of finger prints was purely based on ink and paper traditional methods mostly practiced in law enforcement agencies. Developments in sensing technology have resulted in several ink-less (often referred to as livescan) fingerprint scanners. The technology focuses on improving ease, accuracy and security of fingerprint capture. In addition, the introduction of integrated circuits and other technologies has made it possible to shrink the sensor size to the area of a postage stamp so that the sensors fit in laptops, mobile telephones and personal digital assistants [64]. Figure 2.6 below shows a sample finger print recognition.

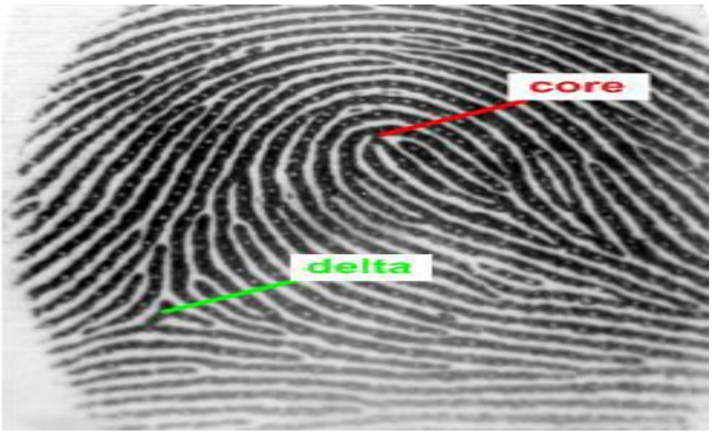


Figure 2. 6: Sample finger print recognition [63]

Advantages

i. Very high accuracy

ii. Simple to install

iii. Most preferred biometrics

iv. Very hard to fake

Disadvantages

i. Prone to errors due to dirtiness, dryness or marks on the finger

ii. It is intrusive

g) **Voice Recognition** – This is the technology through which sounds, phrases and words voiced be human-beings are transformed into electrical signals, then these signals are converted into code design. Figure 2.7 below shows a sample voice recognition.

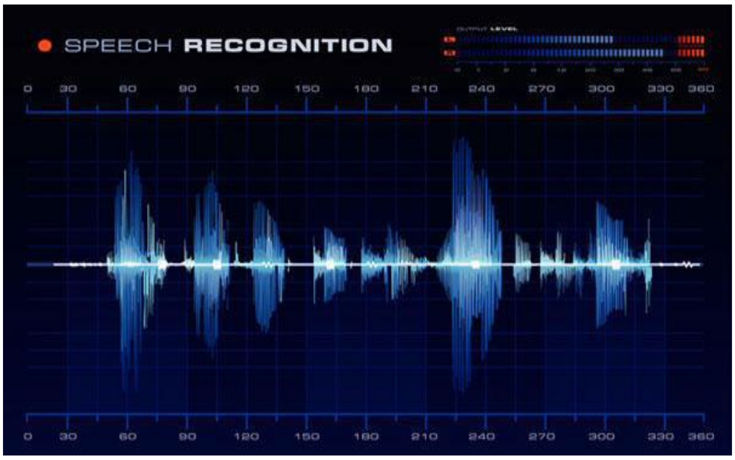


Figure 2.7: Sample voice recognition [63]

Advantages

i. Does not require training for users

ii. Offers advantage to the physically challenged (disabled or leprosy)

iii. Non intrusive

iv. Cheap technology

Disadvantages

i. A person's voice can easily be recorded

ii. low accuracy

iii. Some conditions for example fever can change someone's voice making it difficult to log in

Generally Biometrics systems have been world widely accepted and attracted in all sectors including financial institutions, government institutions and many others as the best security measure [65] .Mobile application have not been left out, according to [66] a survey conducted by Ericsson1 in 2014, 52% of surveyed smart phone users would prefer to use their fingerprints instead of passwords and 50% would prefer to use their fingerprints to authorize payments online. In addition, 61% would prefer to use fingerprints to unlock their phones and 48% would be happy to use eye recognition. Biometric methods are often presented as a better approach to user recognition. They help to avoid the need to carry tokens or remember passwords to achieve authentication in an access control system because of their properties, such as uniqueness, universality, permanence, collectability and usability [67]. Biometric technologies, such as fingerprinting and DNA matching, have played a large role in policing over the centuries. In 2008, The Federal Bureau of Investigation (FBI) which is the main law enforcement agency in USA started the process of developing a new biometrics database known as the Next Generation Identification system (NGI). The system would combine data like fingerprints, iris scans, photographs, and voice data into a searchable platform for use by federal and state agencies. However, with such kind technological advancements in biometrics, her have been concerns about the conditions under which an individual's biometric data can or should be entered into such kind of databases. Depending on the state, biometric data can be collected at different moments of someone's entry into the criminal justice system, other states allow data to be collected immediately one becomes a suspect and other states will wait until an individual has been charged or convicted of crime [68].

2.4 Crime Mapping Technologies

The manual and traditional pin maps had a number of limitations among them were loss of data as they were updated and also the maps were static, they could not be manipulated or queried. Mapping of crimes has become a primary function in law enforcement agencies, the advancements in computing have facilitated the development of geographical system and spatial technologies. There are three main categories of spatial technologies that can be used for crime mapping [69]; the first one is **open source maps ,**these are maps that available over the internet for free, examples of common open source maps are google maps, Bing maps and open-street maps. Crime analysts are able to perform basic crime mapping duties at free cost. The disadvantage of open source maps is that crime analysts cannot perform complex queries. The second one is **GIS-Software,** these tools are commercial, they provide the necessary geospatial analytical functions needed for basic, intermediate and advanced mapping queries. The main disadvantage of GIS-software is the high cost of acquiring a license, it also requires special training.

The third one is **Online Dashboard,** in this category, law enforcement agencies outsource the crime mapping duties from agencies outside the law enforcement. Agencies like Bair Analytics can provide crime mapping services at a nominal fee.

The main advantage of outsourcing is that it reduces the workload of geocoding and data organization. It also provides better data storage and security as data is stored via cloud–storage.

The advancement in computing has also led to the use of artificial intelligence technologies like machine and deep learning models to predict future crime occurrences [70] , this approach is known as predicting policing . Predictive policing involves the use of analytical techniques to identify either likely places of future crime scenes or past crime perpetrators, by applying statistical predictions [71]. Machine Learning can be described as a field of computer science that evolved from studying pattern recognition and computational learning theory in artificial intelligence. It is the learning and building of algorithms that can learn from and make predictions on data sets [72]. It is regarded as the field of study that gives computers the ability to learn without being explicitly programmed. The main purpose of machine learning is to make computers or software programs to learn from the data without any human intervention [73]. There are three main categories of machine learning algorithms namely supervised, unsupervised and semi-supervised machine leaning algorithms. The algorithms in the Supervised Machine learning are those that need external assistance, in this category, the provided input dataset is divided into train and test dataset. The train dataset has output variable which needs to be predicted or classified. All algorithms learn some kind of patterns from the training dataset and apply them to the test dataset for prediction or classification [74]. There are three types of supervised machine learning algorithm, the first is Decision trees - Decision tree is used mainly for classification purpose where attributes of groups are sorted based on their values. Each decision tree consists of nodes and branches, a node represents attributes in a group that is to be classified and a branch represents a value that the node can take. The second is Naïve Bayes -This algorithm manly focuses on classification of text, it mainly depends on conditional probability of events. The third is Support Vector Machine (SVM)-It mainly focuses on calculation and classification of margins, it basically draws the margins between the classes. The algorithms in the Unsupervised Machine Learning learn few features from the input pattern or data, the learning data is divided into different clusters hence referred to as a clustering algorithm. When new data is introduced, it uses the previously learned features to recognize the class of the data. It is mainly used for clustering and feature reduction [75] . There are two types of unsupervised machine learning algorithms, the first one is K-Means Clustering- is a type of unsupervised learning technique that automatically create groups when initiated. The items which possesses similar characteristics are put in the same cluster creating K-district clusters hence called K-means clustering algorithm. The second is Principal Component Analysis or PCA, in this algorithm, the dimension of the data is reduced to make the computations faster and easier. The algorithm in the semi-supervised machine is the combination of both the power of supervised and unsupervised learning. It is mostly ideal and fruitful in areas such as data mining where there is a presence of unlabeled data and getting the labeled data is deemed a tedious process. Some of the semi-supervised models include generative model, self-training model and transductive model.

Deep Learning is also utilized to predict crimes using different techniques [76].It is regarded as the newly introduced area of machine learning and artificial intelligence comprising of multiple hidden layers of artificial neural networks. Its roots are derived from an Artificial Neuron Network (ANN) introduced by Kunihiko Fukushima in 1980. An ANN can be described as an interconnected network of processing units emulating the network of neurons in the brain [73]. Deep learning has two main categories namely deep neural networks and convolutional neural networks. A Deep Neural Network (DNN) is an artificial neural network (ANN) that has multiple hidden layers of units between the input and output layers capable of modeling complex non-linear relationships [77]. convolutional neural networks (CNNs) is an artificial neural network that use convolution in place of general matrix multiplication in at least one of their layers. They use uses tied weights and pooling layers, this allows them to take advantage of the 2D structure of input data. They are can be used in both image and speech applications [78] .

2.5 Cloud Computing

The other technology that has emerged, developed so fast and contributed to the spatial data technology is cloud computing. The evolution of GIS technology and of spatial information acquisition technology have led to more and more collection of spatial data through various approaches for different services like emergence services, crime mapping and other reasons, this has caused the demand for high information processes and computing environment [79]. Cloud computing has emerged as a technology primarily focusing on large scale resource sharing and low cost for big data storage technology. Cloud computing has proved to be an emerging technology capable of providing business models for organizations to utilize deferent computing services at a minimum cost. Cloud is defined as a metaphor describing a web as a space where computing has been preinstalled and exist as a pool of services such as information, infrastructure, applications, storage and processing power on the web ready to be shared [80]. The cloud computing architecture consists of the front end and back end components [81] as shown in figure 2.8, an internet connectivity is required to effect communications between the client and the backend.

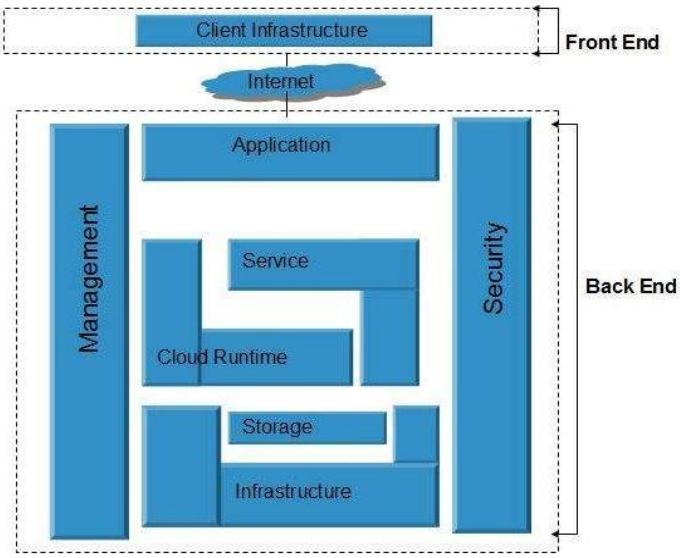


Figure 2. 8 : Cloud computing Architecture [82]

The front end is referred to as a client part of cloud computing system which It consists of interfaces, networks and applications that are required to access the cloud computing platforms. The back End also referred to as a cloud itself, consists of all the resources required to provide cloud computing services. It comprises of huge data storage, virtual machines, security mechanism, services, deployment models, servers and many others that can be accessed securely accessed over the internet or private connection [83].Cloud computing offers three key service models namely Software as a Service (SaaS), Platform as Service (PaaS) and Infrastructure as a Service (IaaS) [84] as shown in figure 2.9 below .

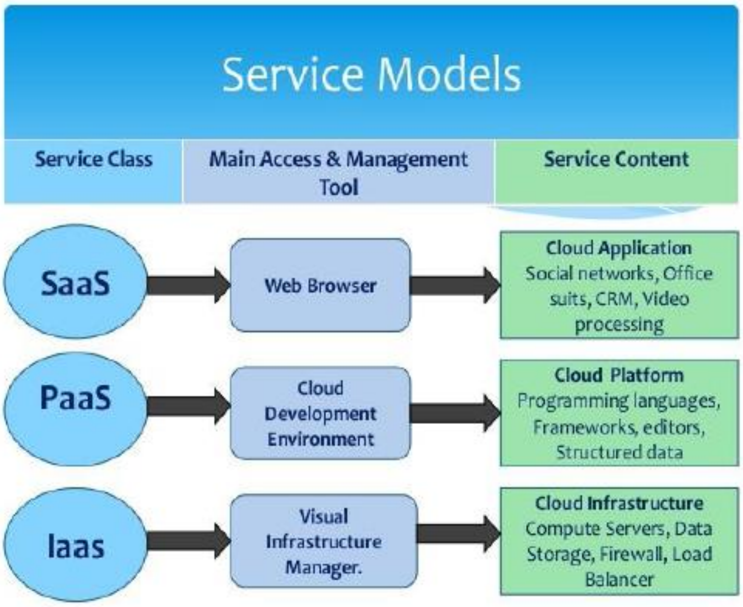


Figure 2. 9: Cloud Service Model [85]

Software as a service (SaaS) is a delivery model in which software applications are hosted by a vendor or service provider and made available to customers over a network, typically the Internet, the clients can purchase and install the application onto personal computers. Platform as a service (PaasS) is a delivery model in which clients are provided with the environment for development and deployment of web based applications using required tools like already created library, pattern, services, programming language and many others. Clients cannot manage the servers, operating system, storage and network but they have control over the deployed web applications including re-configuring the applications. Infrastructure as a service (IaaS) delivery model is where users are allocated with computing resources like operating system, servicers, networks, storage media and others in order to run their applications [85]. There are five models in which cloud computing can be deployed namely public cloud, private cloud, community cloud and hybrid cloud models [86]. The public cloud is where all the computer systems and services are accessible and available to the general public or a large industry group. The private cloud is where computer systems and services are available and restricted to only an organization and that organization is given greater control, security and privacy. The hybrid cloud is where both public and private cloud are combined to offer a common service, on-critical activities are performed using public cloud and critical activities are performed using private cloud. It is mostly used for archiving and backing up of data by replicating local data to a public cloud. The community cloud is used and controlled by a group of organization from specific communities that have similar and common computing requirements and interests [86].

With the continuous historic advancement in technology and high demand for data sharing, cloud computing has been recognized as the most flexible delivery model for ICT resources [87].According to [88]in their paper they proposed an approach which employs cloud-based service to solve the big spatial data technology in emergence management for better spatial analysis. Mwansa and phiri in their paper [89] developed a model for the inventory system based on quick response and cloud computing integrated with mobile application for real-time capture of grain bags brought in by farmers at the setline depot. The results of the system showed an improved and acceleration of grain stock statistics in real-time.

2.6 Evaluating Software Development Methodologies

A Software Development Methodology (SDM) is a framework or sequence of processes that leads to the development of a software. The Software Development Methodologies are also viewed as the means for organizing the various methods of software development in a timely and orderly execution manner. In addition, the software development methodologies have been termed as a collection of phases, procedures, rules, techniques, tools, documentation, management, and training that can be utilized for the development of a system [90]. It mainly consists of a set of modeling conventions comprising of a modeling language and a process, a process does not only provide guidance to the order of the activities but also offers criteria for monitoring and measuring a project's activities. In addition, the process determines what activities should be carried out in order to develop the system. The modeling language helps in modeling the different aspects of the system [91]. The common methodology used to develop information systems is system development life cycle (SDLC) which can be described as a process of understanding how an information system can support business needs or requirements of an organization on, modelling the business processes, designing the system's components and building the system. Any system development project goes through a sequence of fundamental phases of planning ,analysis, design and implementation [92]. There two main approaches in software development methodologies namely; Traditional SDM and an Object-Oriented SDM (OOSDM).

2.6.1 Traditional Software Development Methodology

Traditional approaches to system development view software as a collection of programs or functions and isolated data. The approach primarily focuses on the functions of the system and data algorithm structures make up a program. The most common example of a traditional approach to system development is a structured methodology that is based on the Waterfall Model. The Waterfall Model adopts a very formal approach to the System Development Life Cycle (SDLC) phases and activities where every stage starts only after the previous has been completed, each stage has its own deliverables. The Waterfall methodology is predictable and values rigorous software planning and architecture. In this approach, the project owner's feedback is received after the software application is completely developed and tested [93]. Figure 2.10 shows the water model.

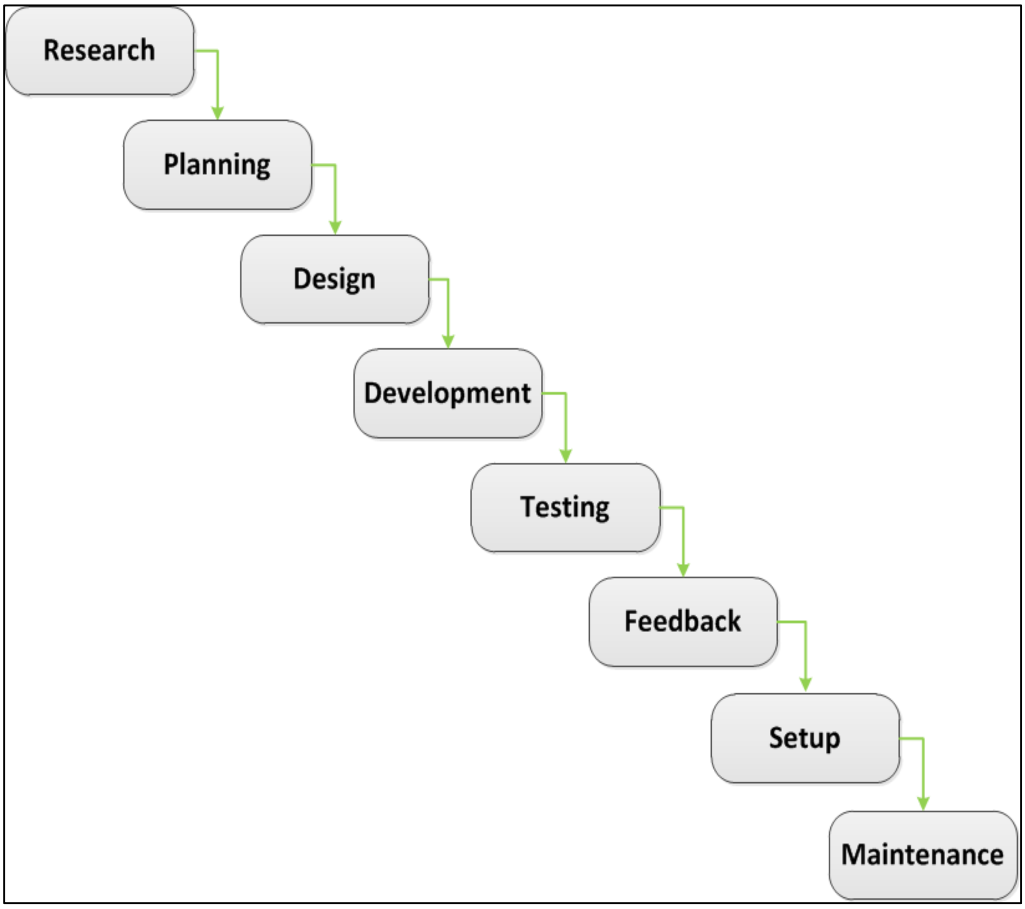


Figure 2.10: Waterfall Model [93].

a) Research - This is the stage where required information is gathered and objectives and goals of the system are formulated that include evaluation is system requirements. The system developer also researches market characteristics and user behavior patterns.

b) **Planning –** This is the stage where all the elements are set in order to develop the software product. Planning starts with defining the overall flow of the application. Established from the required functionalities, a database structure is designed taking into account the overall flow of the application, the subassemblies, functionalities and database structure.

c) **Design -** Design is the stage where the layout of the application is produced, the nature of the application determines the type of design to adopt, designs can range from rough and functionality driven to complex and artistic.

d) **Developing –** This is the stage where code is written and the software application is actually built.

e) **Testing** – This is the stage where programming and design errors are identified and fixed. Programming errors are type of errors were the application crashes or behave in a way it was not supposed to according to the designed architecture. Design errors are type of errors that causes inconsistency between what the project owner requested and what the project team ended up implementing. Design errors usually occur in the planning stage hence very difficult to fix.

f) **Setup** – This is the stage where the application is installed on the live environment this includes configurations in terms of security, hardware and software resources, it also includes defining and testing of back-up procedures.

g) **Maintenance** – This is the stage responsible for ensuring that the application is running within the planned parameters, it also provides the opportunity to add new features of functionality to the software application.

The waterfall model just like other traditional system methodologies like spiral, incremental and others purely adopt the structured type of system development methodology which has been used for so many years. The center of the structured approach is the process model that depicts the business process of a system, the model is presented using data flow diagram (DFD) in which it depends on. The data flow diagram (DFD) and its associated data dictionary contain the information about the system's components that need to be designed and ultimately built [94] . Javanmard and Alian in their paper [95] further highlighted that Traditional methodologies are plan driven in which work begins with the elicitation and documentation of a complete set of requirements, followed by architectural and high level design development and inspection. Some Software developers found this process centric view to software development as frustrating and pose difficulties when there are inevitable changes to the developed software. This resulted to the introduction of Agile software methodology which did not depend on phases but interactive enhancements with the view to embrace and respond to the inevitable changes that may arise to the software. Although there are many benefits of using agile methodologies, but these methodologies cannot be fully used in all projects as they are not suitable for projects where requirements are not well defined or are frequently changing [96].

2.6.2 Object Oriented Software 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). In object-oriented approach, a system is viewed as a set of objects. OOSD provides a way to develop software by building self-contained modules or objects that can be easily replaced, modified and reused [97]. Object–oriented methodologies for software development were developed specifically with the aim of viewing, modeling and implementing the system as a collection of interacting objects using the specialized modeling languages, activities and techniques needed to address the specific issues of the object-oriented paradigm [91]. The main aim of Object Oriented Design (OOD) is to improve the quality and productivity of system analysis and design by making it more usable. The approach promises to improve systems developers' abilities to model increasingly complex problems and to develop higher-quality, more economical software more efficiently [98]. An important goal of object- oriented development is to change the nature of current software development-from designing and writing modules from scratch to building systems through the assembly of high-level reusable software objects. In this methodology, a system is divided into sets of interacting objects; Objects are abstractions of elements in a problem domain and are designed to reflect their behavior [99]. Object Orientation (OO) is a way of viewing and modeling the world or system as a set of interacting and interrelated objects. An Object may be a tangible physical entity or intangible. Examples of an Object include an agency, a job, location or person [100]. Figure 2.11 shows an example of objects in real world.

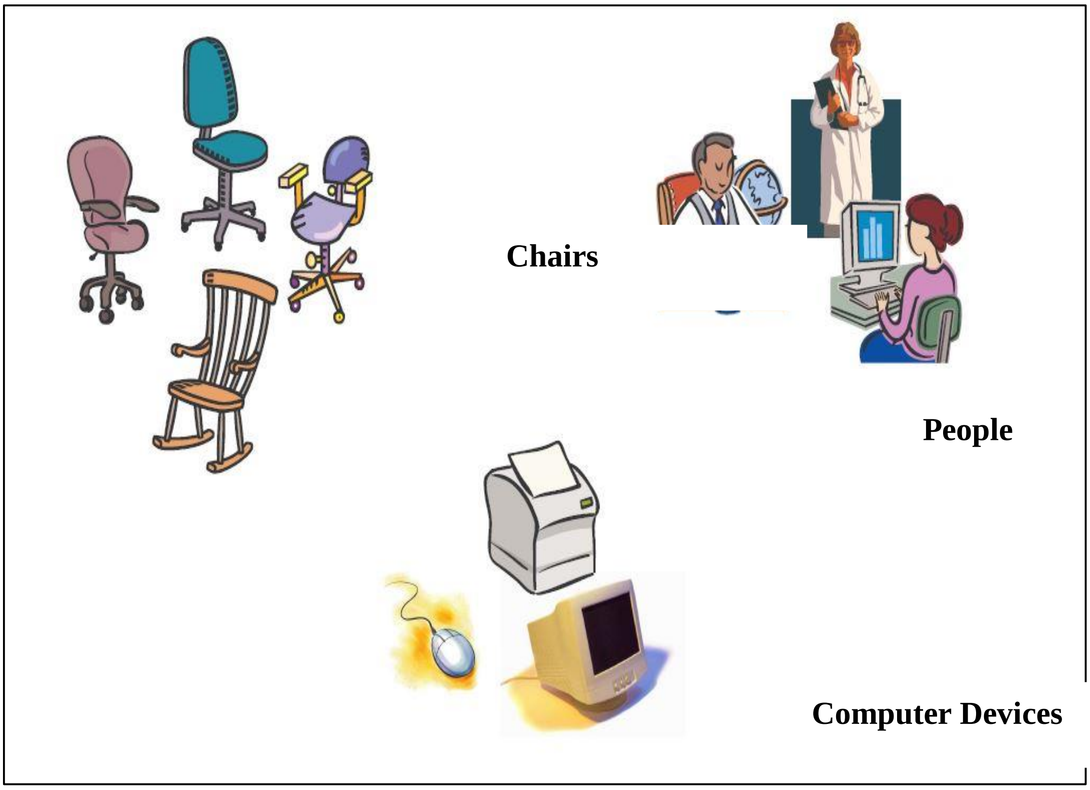


Figure 2. 11: Example of Objects [100].

a) Benefits of Using Object-Oriented System Development

Advantages of using an OOSD approach to system development as opposed to using a traditional approach are [99].

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 the 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 modeled directly from a real-world problem domain. Each object stands by itself or within a circle of other objects. The reuse of pre-developed, pretested software components is widely accepted as an important means for improving software development productivity and overall system quality. By using existing building blocks, developers can assemble new and more complex systems faster and more economically than by designing and constructing system components from scratch.

iv. object-oriented system is generally easier to maintain and enhance than its traditional counterpart because it can facilitate system maintenance through its inherent modularity and structure and through its natural insulation of objects from each other.

v. The object-oriented approach provides increased modeling flexibility and expressive power, allowing more complex designs to be implemented.

b) Unified Modeling Language

The Modeling Language used in an Object-Oriented SDM is the Unified Modeling Language (UML), it is regarded as is a standard, object-oriented, component-based software system modeling tool used to draw a visual description for the software system model. The UML is a set of diagramming techniques that uses graphical notations to express the design of software developments. UML aims to be a standard modeling language which can model concurrent and distributed systems. UML is an industry standard, and is evolving under the auspices of the Object Management Group (OMG) [101]. In addition, UML combines best techniques from data modeling (entity relationship diagrams), business modeling (work flows), object modeling, and component modeling. It can be used with all processes, throughout the software development life cycle, and across different implementation technologies. Zheng et al. [102] further explain that the use of UML enables various staff, such as the users, analysts, developers and designers to communicate efficiently and enhance mutual understanding, which can improve the efficiency of the software development and the quality of the software design. It enables software developers to draw a clear model which is conducive to communication and makes the software development easy to implement. 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 while diagrams provide mechanisms to group together the collections of elements and relationships. Examples of elements in UML, include [100] [103] ;

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

b) Behavioral: represent behavior over time and space. Interaction and state depict behavioral elements.

UML is characterized by nine major diagrams, a diagram can be described as 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, state chart, activity, component and deployment [100] [103].

c) Object Oriented Programming Languages

In Utmost cases, computer applications fail as a result of poor and lack of effective communication between the user and the application. Each and every interaction between an application and the user take place at the interface of the system. But with the application of object oriented programming, such problems are minimized because of the use of objects, this makes communication very effective due to its visual nature of the interface system during the design of any application for use [104]. Object oriented programming is an approach which is mainly focused on the way object interacts to communicate and share the information. It is an improvement of the traditional procedural oriented programming which mainly focuses on the procedure of execution. The object oriented approach brings a new path, giving more importance to the objects Object oriented programs are strictly type checked and flexible outlined, modifications on one object have no impact on the other related objects, which is one of the most important features in OOP [105]. Object oriented Programming languages support the development of graphical user interfaces, by providing toolkits of useful interface controls, some examples of OOP languages include Java, C-sharp (C#), and C-plus-plus (C++) [104] . Java is a portable OOP language introduced by Sun Microsystems. 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 [106].

Due to their modularity, extensibility, and reusability in nature, Object Oriented Programming languages provide improved software-development productivity over traditional procedure-based programming techniques. Object oriented softwares are also easier to maintain this owes to the modularity of the system design as part of the system can be updated in case of problems without the need to make large-scale changes. In addition, Object Oriented Programming languages come with rich libraries of objects which allow codes developed during projects to be reusable in future projects.

2.7 Related Works

Most Police stations and other law enforcement agencies in developed countries like USA and UK already migrated from traditional pin maps to computerized crime mapping systems [107].The police in most developing countries like Africa are not equipped with infrastructure like GPS and GIS technologies for mapping of crime. The infrastructure is not only expensive to acquire but also time consuming when setting it up, it requires trained people to operate and manage it. But the benefits of viewing data in the form of a map are massive as compared to grasping tabular or manual data of crime incidents [108]. In Africa, South Africa is considered as more progressive than any other country in Africa in terms of usage of ICTs. In 2000 the South African Police Service (SAPS) through the crime information center developed the National crime GIS database that could allow SAPS to link crime statistics with police boundaries as well as exploring the relationship between crime types and social demographic variables through the use of multivariate statistical techniques. In addition, the author highlights that currently the predominant information system used by SAPS is Case Administration System (CAS) which is regarded as the primary source of information on victims and offenders. It is integrated with a case docket management system that gathers information at a police station level on crime cases such as address and time of crime. The challenge is that CAS is not yet fully accessible country wide and it has not been linked with any GIS technology making crime spatial description and interpretation of criminal activities impossible [109].

Tong in her paper [110] also proposed a crowdsourcing based crime mapping system, it's a system based on cloud architecture integrated with iPhone mobile application. The system composed of a server running in the cloud and a client application that includes a website and iPhone mobile application to enable users to interact with crime contents. The system gathered both crime reports from the crowd together with crime contents and displayed them on a crime map. Users of the system are able to review and comment on crime incident on a digital crime map.

Singh et al. [111] in their paper proposed and developed a cloud GIS crime mapping blog that could be used by the police for crime mapping. The system generates daily, weekly and monthly crime maps which would help to identify crime patterns and clusters. The crimes in the blog are categorized into theft, murder, snatching and other classes, the system was developed on a cloud architecture using google cloud and google maps as source of spatial data. The system uses RSS (Really Simple Syndication) feeds from various news websites as a source of crime data, meaning that crime related news is manually extracted from the collection of news and formatted into desired format with attributes like location, type of crime, details and link to the news web page. The location data is further transformed into georeferenced data, the process commonly known as geocoding. Geocoding is described as the process converting or transforming a description of a location such as pair of coordinates, an address into a location on the earth's surface and used to point a location in the GIS digital map [112]. Depending on the details of the address, this could be a specific building, the center point of a road, or the center point of an area [113].Geocoding technique requires special skills and training. The limitation of this system is that the location of the crime specified in the news is generalized therefore the generated point location is not very accurate.

Mwiya et al. [114] proposed and developed a public crime reporting system for the Zambia Police, a cloud & GSM based android mobile application (prototype) to help the general public to only report crime cases using mobile devices. The limitation of this system is that it does not map crime areas.

2.8 Summary

In this chapter, a comprehensive overview of the background theory and some examples of the related works to crime mapping was given. Some of the solutions provided by applications in the related works would be of great benefit if adopted in the crime mapping model for the Zambia Police. Due to unavailability of digital historical crime dataset from the Zambia Police, the source of crime data for the proposed system is the live crime reports from the general public, to achieve this a crime reporting component would be added to the system consisting of a web application and mobile application. In order to enhance accuracy, users would specify crime location by selecting a name of the location from the google map, then the system saves the georeferenced data into the cloud database. The benefit of this approach is that it does not require crime data to be geocoded to produce crime maps as everything would be done by the system.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The chapter outlines the methodology that was used to conduct the research. A research methodology can be described as a systematic way of solving a research problem. It provides the researchers focus and required approach for the study thus includes the process through which they pinpoint the methods that will be used in order to address their specific question. Firstly, the chapter presents the research methods and materials that were used to conduct a baseline study. Research methods maybe understood as methods or techniques used to conduct a research [115]. Secondly the chapter presents the methodology used to design and implement the model or system prototype that includes mapping of business processes system modeling.

3.2 Baseline Study

A baseline study can be described as a descriptive cross-sectional survey that is done at the beginning of a project to establish the status quo before a project is rolled out. It provides quantitative information on the current status of a particular situation or study area in a given population. The data gathered in the bassline study consist of indicators that can be chosen to monitor project performance on regular basis [116]. In this research study, the purpose of the baseline study was to identify challenges in the current crime mapping system used by the Zambia Police. To archive this, the research study adopted a mixed methods research methodology which comprises of a combination of qualitative and quantitative research types. A quantitative research method is a type of approach towards research that involves collection and analysis of information is conducted by utilizing mathematically based methods like surveys polls and others to gather numerical data and generalize it across groups of people. Qualitative method is a type of approach towards research that involves collection and analyzing of information by focusing and drawing experiences and opinions of participants. It is mostly used when on assumption that reality is a social construct or that variables are difficult to measure, complex and interwoven or that there is a primacy of subject matter and that the data collected will consist of an insider's viewpoint. A mixed method is a type of research method approach in which a researcher combines elements of qualitative and quantitative research approaches for example use of viewpoints, data collection, interviews, surveys, analysis, inference techniques and many others for the purposes of broad and depth of understanding and corroboration of the study [117]. This research study also utilized a descriptive research design. A descriptive research design is the type of research study that is concerned with describing the characteristics of a particular individual, or of a group or state of affairs as they exist at present. The aim of the descriptive research design is to obtain complete and accurate information in the particular study [115]. In order to conduct the base line study, different methods and materials were utilized this includes data collection, study setting, sampling and data analysis.

3.2.1 **Study Setting**

The study was conducted in Lusaka City, the capital city of Zambia at nine (9) selected major police stations namely Lusaka Central, Woodlands, Kabwata, Chilenje, Chelstone, Kanyama, Chawama, Matero and Emasdel. The targeted Lusaka based police stations in this study were purposively sampled.

3.2.2 **Sampling and Population**

Sampling methods and population are regarded as critical factors that can affect the overall external validity of results of any research study. Population can be described as the number of people living in a particular country or area or region. Sampling can be -described as processes of taking a subset from chosen sampling frame or entire population, it is used to make inference about a population or to make generalization in relation to existing theory or study [118]. Sampling can also be described as the process of obtaining information about an entire population by examining only a part of it. The population considered for this study was the Lusaka based police officers. Purposive sampling method was used to select 88 police officers as a sample size from ten different police stations across Lusaka District specifically those working under criminal investigation department including victim support units. Police officers working under criminal investigation department are commonly known as criminal investigators, these are police officers who do not only perform crime mapping but also investigates and document all crime cases. The officers working under victim support unit are also called criminal investigators, they are police officers who only and specifically deal with sexual and gender based violence (GBV) related cases. A purposive sampling can be described as a non-probability sampling technique where a researcher selects a sample basing on characteristics of a population and the objective of the study. In this sampling technique, persons or events deliberately selected in order to provide the important information required which cannot be obtained from other sources or choices. The type of purposive sampling used in this study was homogeneous purposive sampling. homogeneous purposive sampling involves selection of individuals, race, groups or participants that share similar characteristics or attributes [119]. Homogenous purposive sampling was chosen because the researcher's focus was on particular characteristics of the population that are of interest to enable the researcher answer the research questions which are related to crime mapping. Further, a convenient sampling method was used to select members of public who were visiting the targeted police stations in the study for various reasons, the sample size selected was 100 participants. Convenient sampling Can be described as the type of sampling technique in which a researcher selects participants, individuals or groups that happen to be available at the time and a willing to participate in the research survey. This type of sampling was chosen because it is inexpensive, easier and requires little planning.

3.2.3 **Inclusion Criteria**

As mentioned earlier, the target area for the study was the Police officers from nine (9) major police stations in Lusaka District. Crime investigation and victim support unit officers were key to this study because they provided hands-on information on not only crime mapping but also investigation, documentation and storage of crime cases. Members of the General public were included in this study to provide an insight on the nature of the mobile devices commonly in use.

3.2.4 **Data Collection**

Primary data was simultaneously collected from police officers and members of the general public through the use of interviews, surveys, and structured questionnaires. Data collection was carried out over a period of eight weeks starting from the third week of November 2016 to the last week of January, 2017. During data collection, the researcher distributed 100 self-administered questionnaires to the respondents who were police officers working under criminal investigations department at all the target Police Stations in Lusaka. The researcher then gave the respondents sufficient time of one week to answer the questionnaires. In addition, the researcher conducted interviews with senior criminal investigation officers including records officers. Records officers are officers who have the responsibility of keeping and storing records of all crime cases. The researcher also interviewed and distributed 100 questioners to the members of general public found in those areas of the targeted police stations. Both Open-ended and closed-ended questions were included in the questionnaires to capture both the qualitative and quantitative responses. The researcher collected the questionnaires in the first second week of February, the qualitative data collected through interviews and from documents such as occurrence Books, geographical crime maps and crime registers that are used for day-to-day recording and mapping of crimes were used to form a design phase of the automated cloud based crime mapping model using spatial data.

3.2.5 **Data Analysis & Presentation**

Data was entered, processed, analyzed and presented using the computerized software called IBM Statistical Package for Social Scientists (SPSS). Descriptive analysis was applied to the processed data showing variable frequency distributions from the responses obtained. The summarized data was presented in form of tables and figures such as pie charts and bar charts to facilitate understanding.

3.2.6 **Ethical Consideration**

The researcher obtained an introductory letter as part of the guidance by the University of Zambia research ethics. Through the University of Zambia, the Zambia Police High Command granted the researcher a permission to undertake the study at the various selected Police Stations in Lusaka. In order to gain trust and confidence, 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. The researcher did not only ask the participants for their willingness to take part in the research but also assured them of their confidentiality and anonymity.

3.2.7 **Limitations of the Baseline Study**

The best ideal situation would have been to collect data from all the Police Stations and the general citizens from all provinces and districts. This was hindered by time, logistics and financial limitations as the researcher did not have any sponsorship or monetary financial assistance to carry out the research, everything was done using his personal resources. The study also faced apathy from the respondents as some of them believed that the survey was compelling the Police to release too much information to the public hence hesitated to respond to the questionnaires.

The system requirements specification and model design phase of the research study employed the use of qualitative data which was supplied from the results of the baseline study through interviews with police criminal investigation and records officers. As earlier indicated, the researcher was provided with sample copies vital documents/forms that shows the documentation of different crime cases, the documents were; crime register, investigation diary, Lusaka geographical map and Occurrence book. The interviews with the criminal investigation officers provided a perspective of the current business processes that Zambia Police uses in not only crime mapping but also in capturing and recording of crime cases. Additionally, the interviews with the criminal Investigation officers including obtaining of vital forms/documents provided the qualitative data needed to specify requirements for the system, design models and finally, develop the system prototype. The methodology that was used for the analysis, design and development of the software prototype system is the Object-Oriented Systems Development Methodology (OOSDM). This research study utilized some of the diagrammatic representations that are present in the Unified Modeling Language to visualize the system from various perspectives. The Object-Oriented System Development (OOSD) approach that was used in the system development process is one that is Use Case driven. The Object-Oriented System Development Life Cycle (OOSDLC) was used for the system development in this research study. Multiple iterations were carried out throughout the entire development cycle and the system was gradually built in small modular increments.

3.3.1 **Mapping Business Processes**

Based on the results of the baseline study, the researcher was able to map the business processes, Figure 3.1 below shows the crime mapping business processes for the current crime mapping system

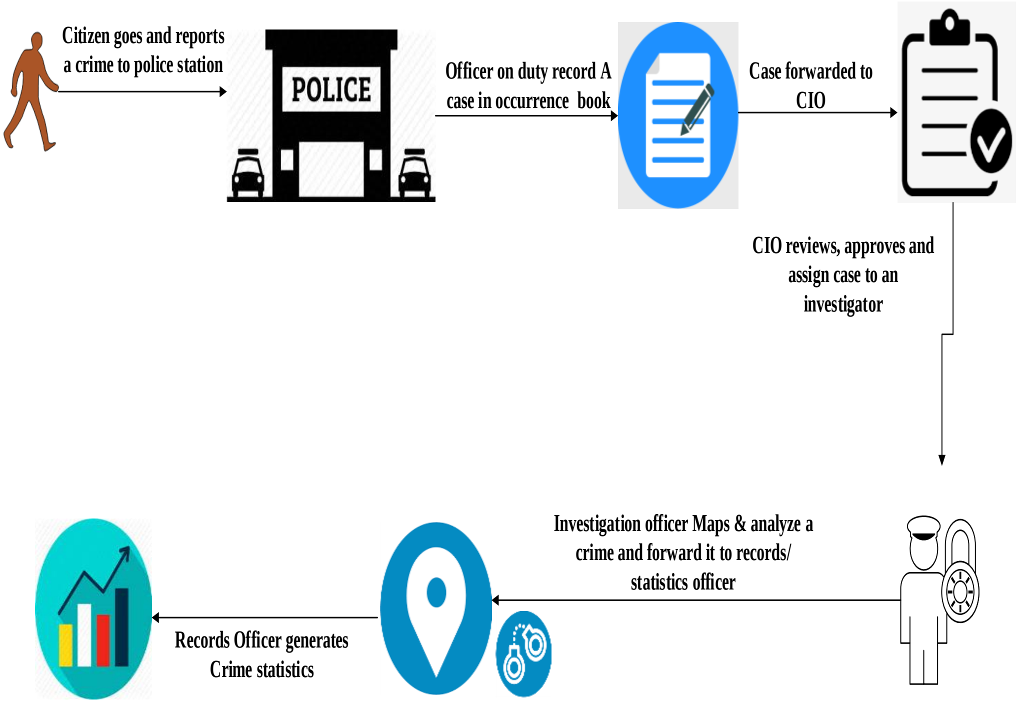


Figure 3. 1: Current crime mapping business processes.

As shown in figure 3.1 above, crime mapping process begins at the time when a crime is officially reported by a member of public. The case including all the details of the complainant and suspect if any are recorded into an occurrence book by an officer on duty at the front desk known as inquiries. Thereafter the case is forwarded to the CIO for review, approval and assigning of case to an investigator. The investigating officer investigates & analyze a crime by placing a pin on a geographical map depicting its location. The investigating officer forward the case details to the Records/Statistics officer who enters the case into the crime register for record purposes. The records/Statistics officer generates crime statistics and share the information with an investigation officer and others.

The Proposed automated crime mapping business processes are derived from the current business processes presented in figure 3.1. The proposed model is designed in two parts, the mobile application to be used by the general public to report crimes and also the Web application to be used by the police to not only capture and view crime reports but also generate crime statistics and crime maps. Figure 3.2 shows the proposed web application.

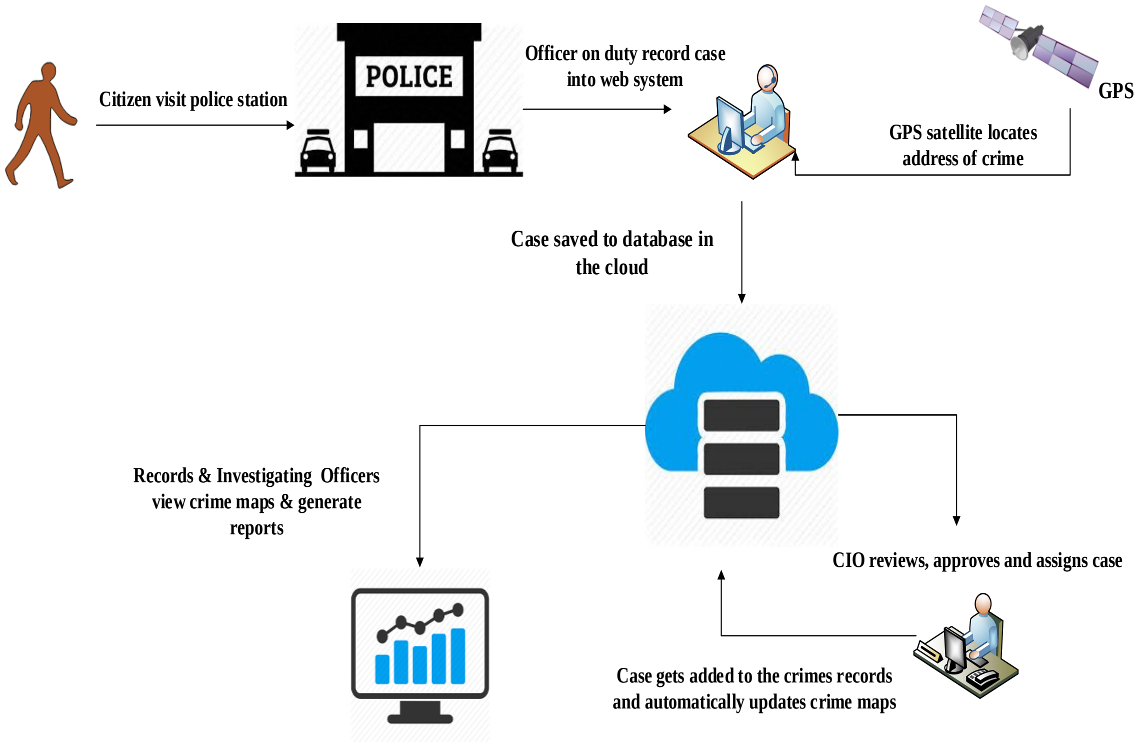


Figure 3. 2: Proposed Business processes - Web application

A crime is directly reported by a member of the public, the officer on duty records the crime case into the system, the GPS satellite through google maps captures not only the actual location of crime but also residential address of both the complainant and suspect, the case details including geo-referenced data will be saved into the cloud database. The case is automatically forwarded to the CIO for assigning, upon assigning the case to the investigator, the case is added to the crime register and automatically updates the crime map. Both the crime investigator & statistics/records officers will be able to view and generate crime maps & reports. Figure 3.3 below shows the proposed mobile application business processes.

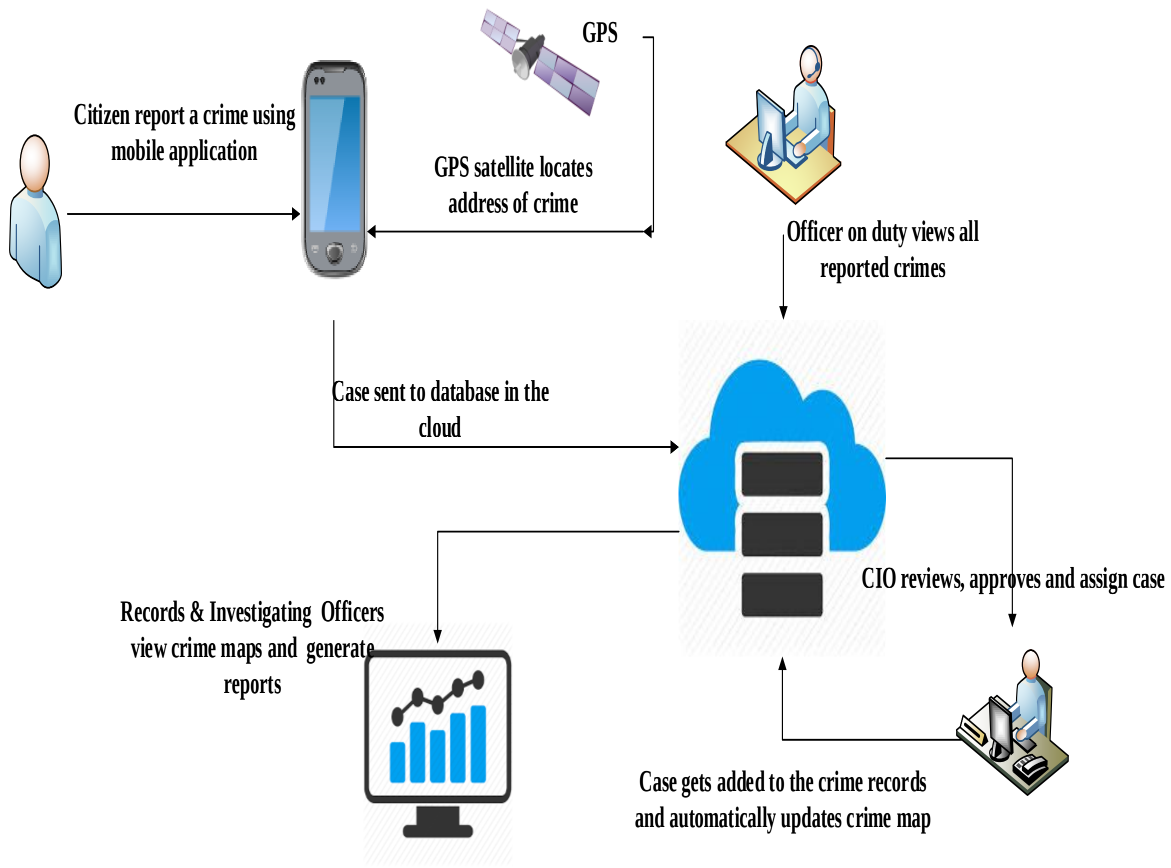


Figure 3. 3 :Proposed Business processes – Mobile application

The mobile application allows the citizen/user to report crime case using a mobile device. The police will use the web platform to view the reported crimes and map them. The citizens are also able to view the status of the case they reported.

3.3.2 **Proposed System Architecture**

The proposed system architecture shown in figure 3.4 below utilizes the private cloud infrastructure where ZAMTEL the largest telecommunications company in Zambia provides the MPLS (Multi-Protocol Label Switching) network while Zambia Police provides the private cloud services. The MPLS backbone comprises of fiber and microwave communication media.

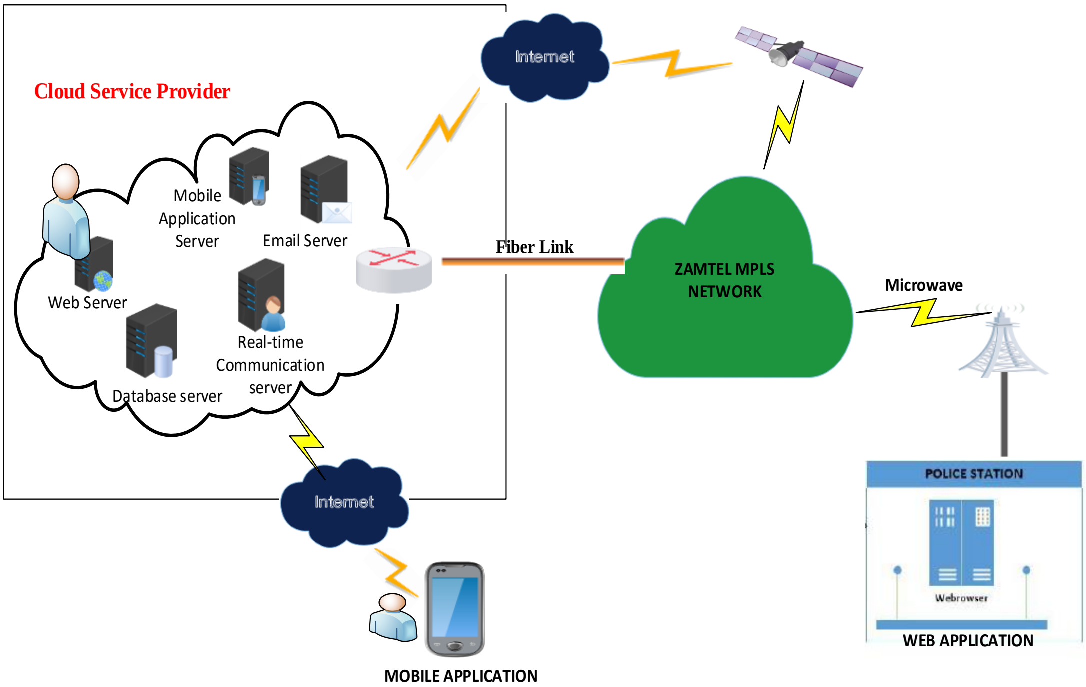


Figure 3. 4: Proposed System Architecture

As shown in fig 6 above, Zambia Police exclusively operates computing resources in the cloud in which different servers are installed such as Email server, Database server, Application server, Web server, Real-time communication server and many others. The rationale herein is to make sure the system is accessed by different police stations located across the country thus include the general public who are the mobile application users with less convenience of configuring hardware, software and security of information. The proposed architecture will allow Zambia Police to have complete control of the system including how data is managed and what security measures are to be put in place.

3.3.3 **System Design Materials**

The proposed model was designed using Cloud Architecture, Android Mobile Application, Web Application, Google Map API and java Programming Language. The web application platform was developed using HyperText Makeup Language (HTML), Cascading Style Sheets (CSS) and Vuejs for front end and Java Server Page (JSP) for backend. HTML is the standard markup language for creation of Web pages. CSS is a language that describes the style of an HTML document, it describes how HTML elements should be displayed. Vue-JS is a progressive JavaScript framework used to develop interactive web interfaces, it was included in order to make the web application more dynamic and responsive. Java Server Pages (JSP) is a Java serverside standard programming technology that is used to write dynamic and data-driven web pages for web applications. The Mobile application platform adopted in this study was android which was developed using android studio IDE and Java programming Language. In order to map locations of crimes, the researcher used Google maps through google map API. For data storage and server services, the study utilized firebase development platform. Firebase is a mobile and web application development platform consisting of services such as: Firebase Clouding, Firebase Authentication, Real-time Database, and Firebase Hosting. In order to secure and protect user password and names from unauthorized access, the study utilized password hashing technique using SHA-256 hash function imbedded in the code. Hashing in general cryptographic terms can be described as a mathematical algorithm that maps data of any kind t a bit of string of any size. Password hashing enables user passwords to be stored in hash format instead of clear text. In order to secure data transmission between a user and a system, the study utilized Hypertext transfer protocol secure (HTTPS) which is the secure version of HTTP. The primary role of HTTP is to send data between a web browser and a web site. HTTPS enables encryption of this data thereby securing it. It uses two keys to encrypt communication between a browser and a server namely: the private key which is in the server, it is used to decrypt information encrypted by the public key. The public key is available to user browsers intending to interact with the server, information encrypted by a public key can only be decrypted using a private key.

3.3.4 **System Requirements Specification**

In the system requirements specification phase of the research study the researcher utilized Object-Oriented Analysis (OOA). Mukherjee in his paper [120] basically describes Object Oriented Analysis (OOA) as a collected works of concurring or cascading system modelling, incorporate various requirements and pre and post analysis methodology for software systems. These methodologies are primarily influenced by different object oriented programming, data modelling and systematic interconnections. Fundamental idea behind OOA is a streamline software design and development by considering all model as a discreet objects, classes, methods and by linking these one can designs and implement all kind of business requirements [121]. Somerville in his book [122] describes System Requirements as descriptions of what the system should do, the services provided by that system and the constraints on its operation. Requirements reflect user needs for a system that serve a certain purpose. A requirement may also be understood as a high-level abstract statement of a service that a system should provide or a constraint on the system. Software system requirements can be categorized into functional and non-functional requirements. Functional requirements are statements of services the system should provide, how the system should react to particular inputs, and how the system should behave in particular situations. Nonfunctional requirements are constraints on the services or functions offered by the system such as usability, flexibility, efficiency, availability and portability, and often apply to the system as a whole, rather than individual system features or services [122]. This section of the study will provide both the functional and non-functional system specification for the proposed Zambia Police Crime Mapping model.

A) Functional Requirements

Table 3.1 below shows the details of the functional requirements required for the mapping system web application module which shall only be used by the Zambia Police.

Table 3.1: Functional requirements (FR) - Web Application Module

FR 1	Users with the relevant access rights shall have the ability to capture and record details of crime cases reported by members of the general public, such users include criminal investigation officers.
FR 2	Users with the relevant access rights shall have the ability to edit crime records, this may include deletion, changing or adding details of both complainant and accused persons.
FR 3	Users with administrative rights shall be able to view and assign new cases to the available dealing/investigation officer, these may include officer in-charge and CIO
FR 5	Users with relevant rights shall be able to generate crime maps and crime reports/statistics on either daily, weekly, monthly or yearly.
FR 6	The system administrator shall be the super user and will have all the privileges for the entire system
FR 7	Users with relevant privileges shall be able to query and filter the crime maps using dates, locations and name of the crime.
FR 8	The system administrator shall have the ability to create a new system user
FR 9	The system administrator shall have the ability to remove a user from the system.
FR 10	The system administrator shall have the ability to edit a user's system access properties
FR 11	System will have different types of users and every user will have access constraints
FR 12	The system shall only be accessible on a Zambia Police WAN which is managed by Zamtel
FR 13	Users shall be asked to provide login credentials like username and password before accessing the system,
FR 14	The system administrator shall have the ability to block or revoke access rights to system users, all blocked users with active sessions shall automatically be logged off.
FR 15	Zambia Police High Command shall have full access to the application but with restriction to server and database access

Table 3.2 below shows the details of the functional requirements required for the mapping system Mobile application module which shall only be used by members of the General Public.

Table 3. 2: Functional requirements (FR) - Mobile Application Module

FR 1	User shall firstly download the mobile app from google play-store and install it in the mobile device .
FR 2	A user shall create and open an account before using the application .
FR 3	Users shall have the ability to access the application anytime and anywhere to not only view the status of reported crimes but also report a new crime case.
FR 4	Users shall have the ability to change their password anytime .

B) Non Functional Requirements

Table 3.3 below shows the details of the Non-Functional Requirements required for the mapping system web application module which shall only be used by the Zambia Police.

Table 3.3: Non Functional Requirements (NFR) - Web Application Module

NFR 1	All software application modules shall be debugged
NFR 2	Database backup and recovery plan should be proper in order to avoid any unexpected downtown of application
NFR 3	All users using the system shall login using some form of unique identification like username and password
NFR 4	All login attempts shall be done in a secure manner. (e.g., encrypted passwords)
NFR 5	System should not be easily breakable
NFR 6	The system shall provide the documentation that shall have all functionality and any user maintenance for the system administrators
NFR 7	The system failure shall not affect data integrity
NFR 8	Database backup and recovery plan should be proper in order to avoid any unexpected downtown of application
NFR 9	The system shall be user-friendly and intuitive. Context sensitive help screens, prompts and meaningful error messages shall be provided.
NFR 10	The system shall be self-monitoring. It will be capable of detecting and reporting on any failures, warnings or errors.
NFR 11	Full documentation for all functionality and any user maintenance of the system shall be provided.
NFR 12	Any future upgrades to the system shall be accompanied by full explanatory documentation.

Table 3.4 below shows the details of the Non-Functional Requirements required for the mapping system Mobile application module which shall only be used by members of the General Public.

Table 3.4: Non-Functional Requirements (NFR) - Mobile Application Module

NFR 1	All users using the system shall login using some form of unique identification like username and password
NFR 2	All login attempts shall be done in a secure manner. (e.g., encrypted passwords)
NFR 3	The system shall be capable of operating in offline mode if connection to the internet is lost.
NFR 4	Data captured whilst in offline shall be uploaded to the cloud server when the connection is restored.
NFR 5	The software shall only operate on android mobile device
NFR 6	A system administrator shall have unrestricted access to all aspects of the system
NFR 7	A Full documentation for all functionalities shall be provided

3.3.5 **System Modelling and Design**

System modeling is the process of developing abstract models of a system whereby each model presents a different view or perspective of that system by using graphical notations based on Unified Modeling Language (UML). Unified Modelling Language (UML) is a modeling language in the field of software engineering which aims at setting standard ways to visualize the design of a system. UML describes the behavior and structure of a system program that includes interaction of components in the system. UML Diagrams are very useful in not only understand the requirements and specifications of the system but also to understand the complexity of system [123]. In order to design system models for the crime mapping system, the research used Object-Oriented Analysis and Design (OOAD). Object-Oriented Analysis and Design (OOAD) can be described as a globally accepted and popular technical approach for analyzing, designing an application, system, or business by applying the object oriented paradigm and visual modeling throughout the development life cycles in order to foster better stakeholder communication and product quality improvement [121]. Different system modeling techniques where utilized in this study.

a) Interaction Models

All systems involve interaction by design, interactions involve user inputs and outputs, interaction could also be between the system being developed and other systems or interaction between the components of the system. It is important to model the user interaction of the system as it helps to identify user requirements [121]. In this study the researcher utilized two interaction model techniques namely use case modeling and sequence diagram.

i. Use Case Modeling

The Use Case modelling basically is the common method of any kind of system ‘s functions modelling related to any business events or processes. It basically correlated between all events creators, and also how the system provides responds for any particular events. Good understandability of the Use Case Diagram is necessary so as to have effective contribution of the artifact in process of software development. The quality Use Case Diagrams plays an important role in effective and right implementation and execution of the system requirements [124]. Usually the Use Case behaviorally correlates all sequence of scenario s or steps among both the automated and manual procedure for implementation a particular business task. This could be triggered or initiated by any external users or by any systems, popularly known as Actors. Actors represents anything that is required to interact or communicate with the system for information exchange, these could be people or system communication devices. The use cases in the proposed system depict how the users or actors interact, in the proposed system there is a web and mobile application use cases. Table 3.5 below shows the description of actors in the web application.

Table 3.5: Description of Actors – Web Application

ACTOR	DESCRIPTION
Officer On Duty	An Officer on duty also known as a General Duties Officer is the police officer who is found at the inquiries or front desk of the police station. The responsibility of this officer is to record crime cases reported by members of the public visiting the station. The crime reports are recorded into the occurrence book. The officer firstly needs to login into the system thereafter enter the details of the crime report include details of complainant, suspect and location of the crime. The officers can only enter and view the recorded cases.
C.I.O	The Criminal Investigation Officer (CIO) is the senior officer in-charge of all officers under criminal investigation department at the station. The CIO verifies, approves and assigns cases to the available investigating officers(detectives).
Investigating Officer	An investigating officer also known as a detective is an officer who carries out investigations of crime cases and mapping of crimes. Other responsibilities of the detectives including analyzing and detecting crime hotspot areas using crime maps. The detective must first login into the system before viewing the details of the case and generation of crime maps.
Records Officer	The responsibility of the records officer is to store and keep records of all the crime cases. The other responsibility is to is to generate crime statistics recorded at the station.
Administrator	The Administrator is responsible for the administration of the entire system and has access to all aspects of the system.

Figure 3.5 below shows the use case for the web application.

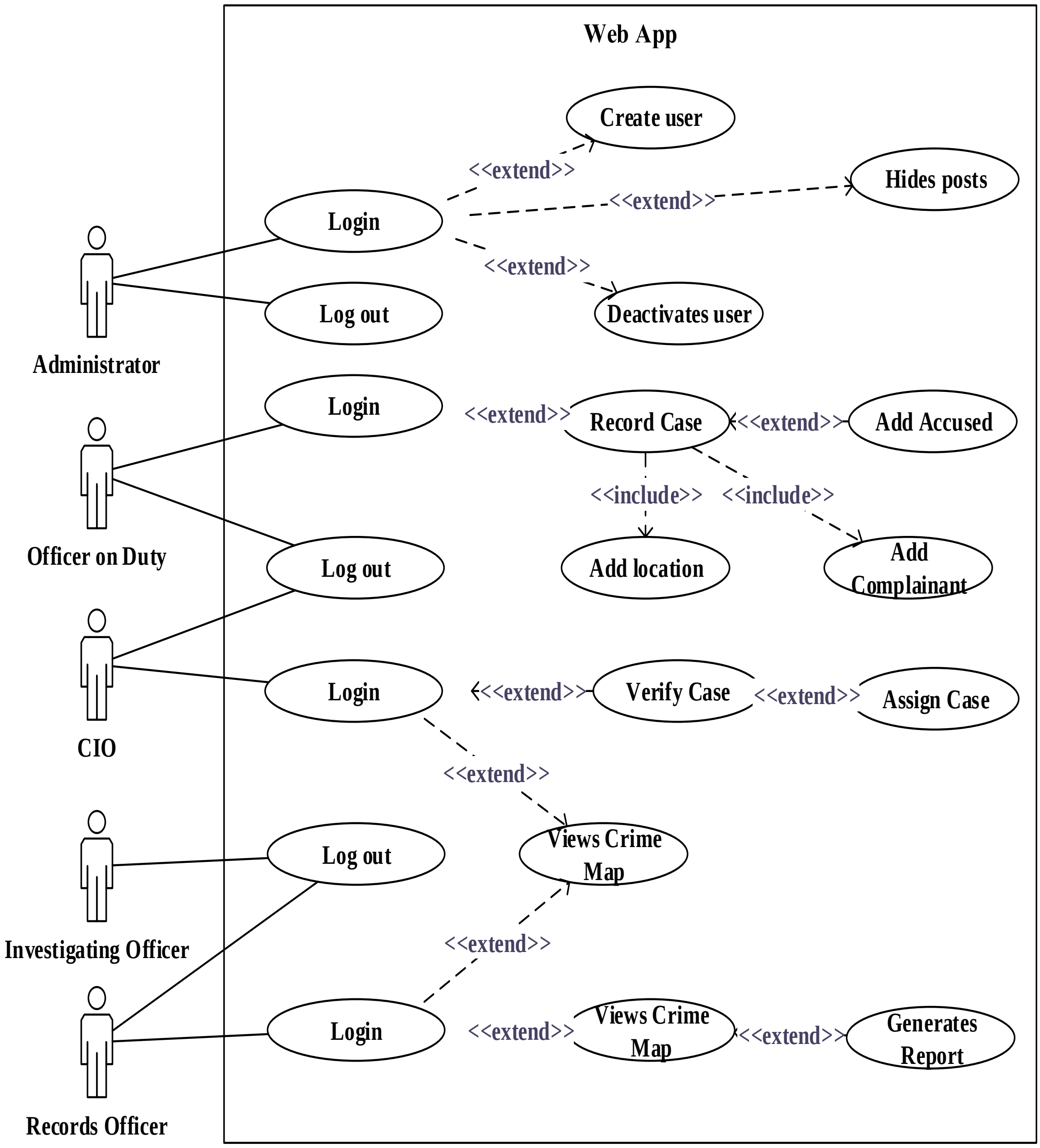


Figure 3. 5: Use case - web app

As shown in figure 3.5 above, the main actors in the web system are; officer on duty, CIO, investigating officer & records/statistics officer and system administrator. The users at the web application first log into the system and then perform transactions like creating and updating crime cases, view reported crimes and also view generated crime maps.

The use case for mobile application is shown in figure 3.6 below.

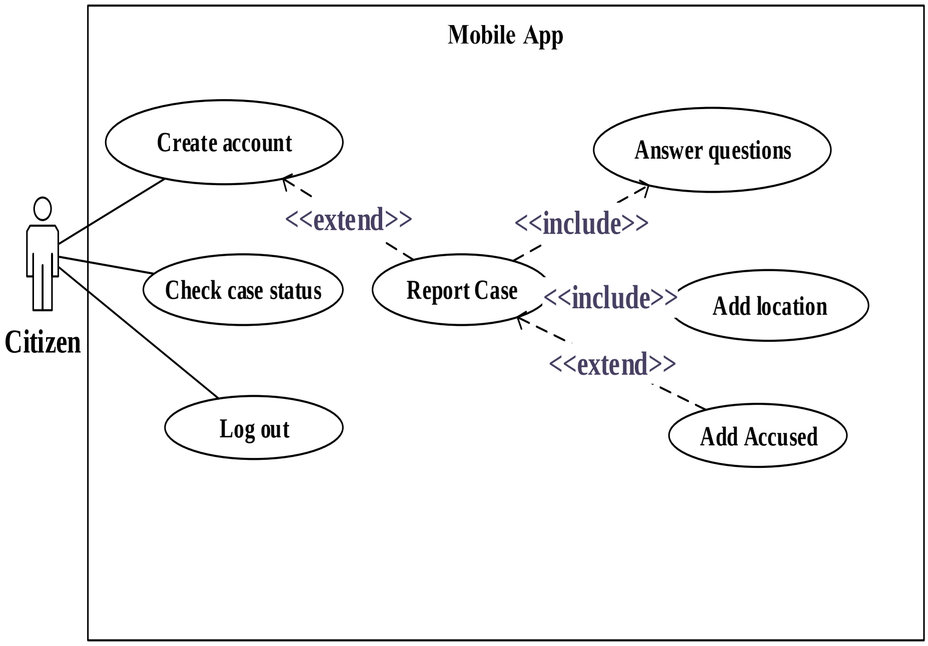


Figure 3. 6: Use case – Mobile App

As shown in fig.6 above the main actors in the mobile app are the citizens. Users of the mobile app would be able to create an account, login, report a crime incident, add a location of crime using google map and check the status of crime case.

ii. Sequence Diagram (SD)

A sequence diagram simply depicts interaction between objects in a sequential order and how the objects in the system function. They represent the flow of messages, events and actions between objects or components of a system. Sequence diagrams are primarily used to design, document and validate the architecture, interfaces and logic of the system by describing the sequence of actions that need to be performed to complete a task [125]. The sequence diagrams depict the flow of events in the proposed system both web and mobile application module are presented in this section, Figure 3.7 below shows the sequence diagram (SD) for recording a case in the web application.

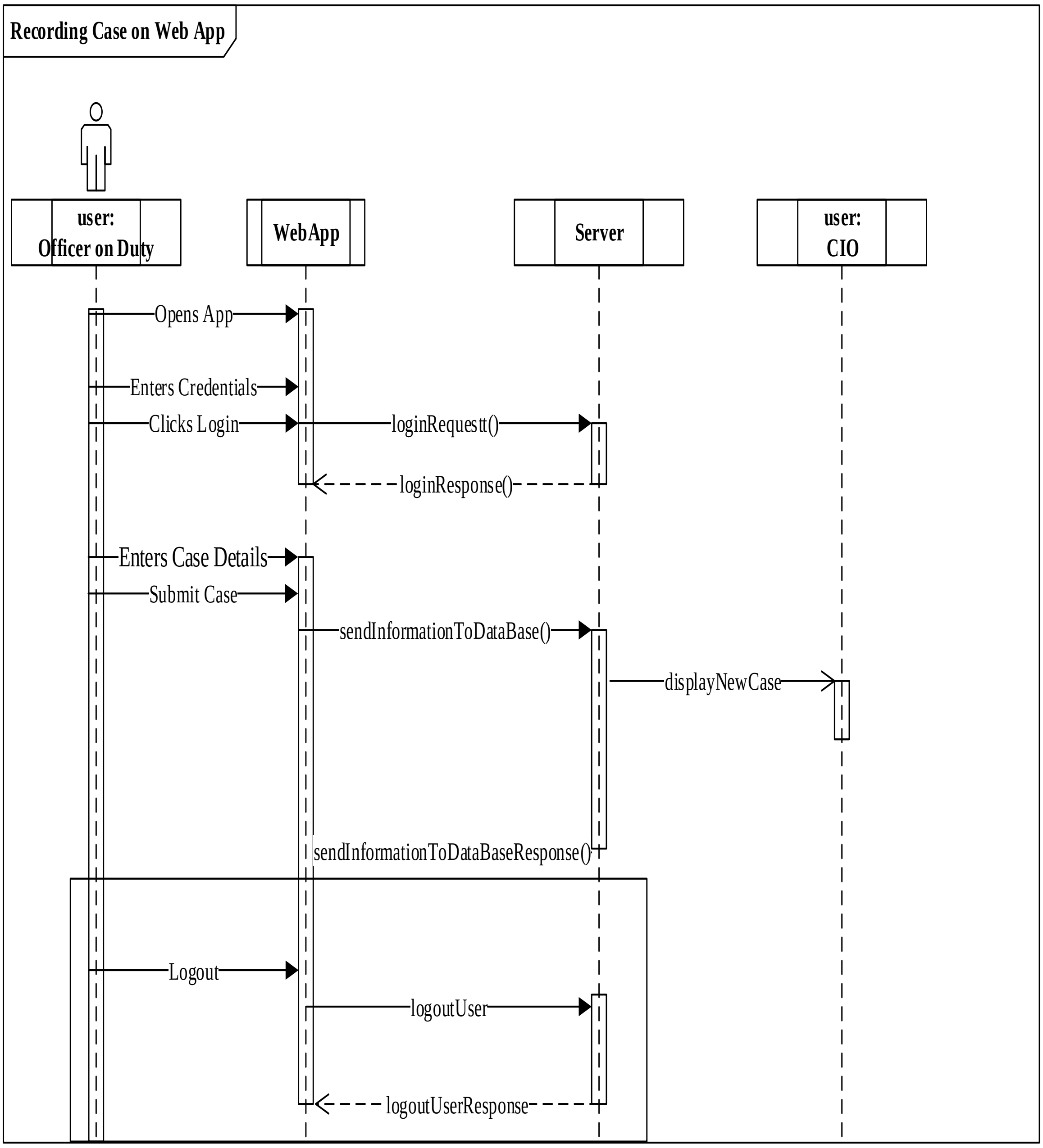


Figure 3. 7: Sequence Diagram for Case Recording on Web Application

As shown in figure 3.7 above, before doing any transaction, the user firstly opens a web application and logs into the system using his or her login credentials after the authentication of the user by the system server. Crime cases entered by the user are sent and saved into the central database from which a station CIO can access, approve and assign a particular case to the appropriate investigator. At the end, the user is able to log out of the system. Figure 3.8 below shows a sequence diagram (SD) for assigning of cases by the CIO on a web application.

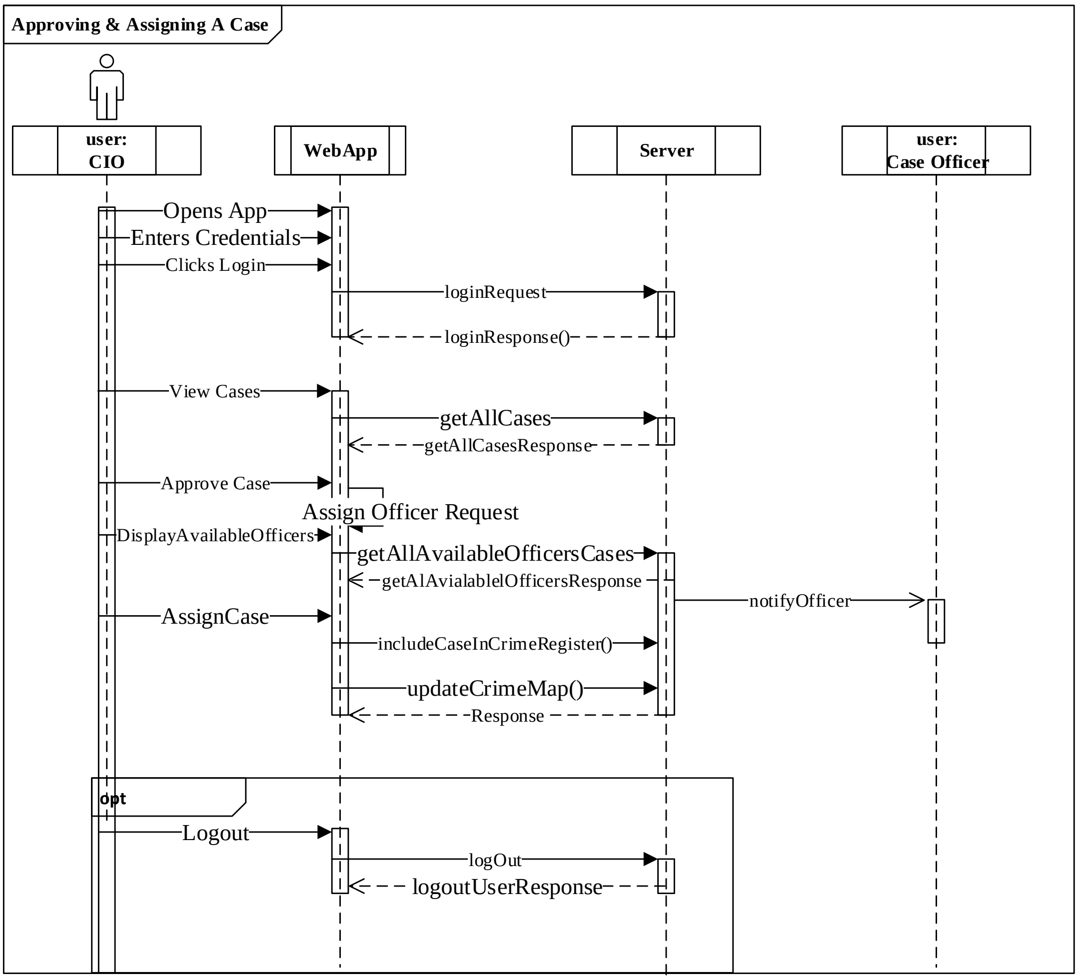
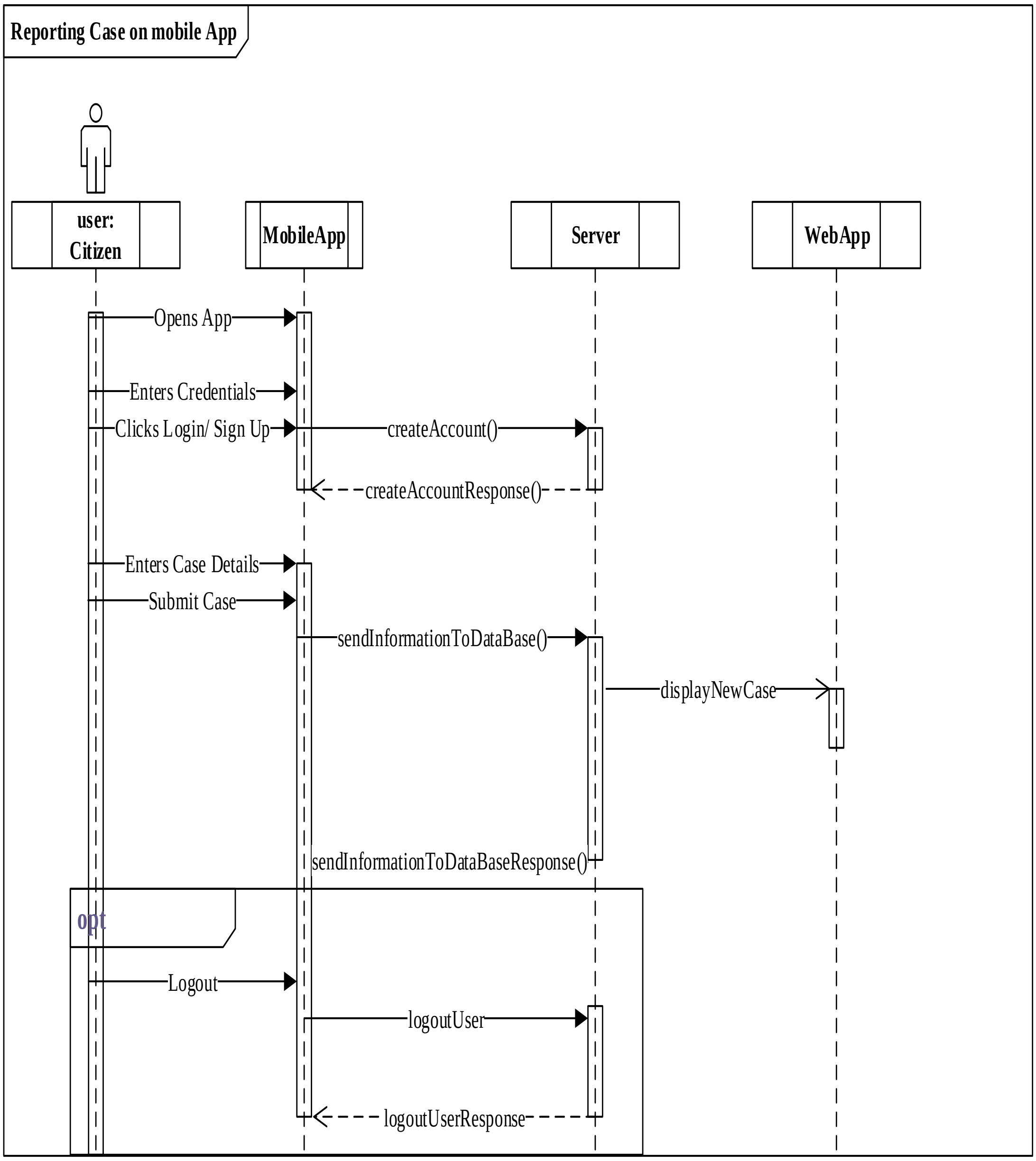


Figure 3. 8: Sequence Diagram for Assigning Cases by CIO

As shown in figure 3.8 above, the CIO user needs to log into the web system using his/her login credentials before performing any transaction. When the system server authenticate the login credentials the CIO is successful logged into the system and able to view all the crime cases recorded by the officer on duty at the inquiries. The CIO views, verifies, approves and assigns a crime case to an appropriate investigator. A notification of the case assignment is automatically generated and sent to the investigating officer, at the end, the user is able to log out of the system. Figure 3.9 below shows a sequence diagram (SD) for crime case reporting by a citizen on a mobile application.



*F*igure 3. 9: S.D for Reporting Cases by citizen on Mobile Application

As shown in figure 3.9 above, the mobile user is required to download and install a mobile application into his/her mobile device. Thereafter the user is required to open and log into the system using his/her logging credentials. If the user does not have the login credentials, he or he is required to sign up and create the account. All the details of the crime cases entered by the user are saved into a central database the information which can only be accessed by the Police using a web application.

b) Data Modelling

Data modeling is a technique to documents and attempts to provide a representation of user reality in a software system by using diagrams and symbols. It is used to represent communication of data in the system. The data modeling techniques presented in this study are entity relationship diagram and data dictionary.

i. Entity Relationship Diagram (ERD

The highest level of abstraction for the data model is called the Entity Relationship Diagram (ERD) also known as entity relationship model. An ERD is a graphical representation of data requirements for a database, it consists of entities, attributes and relationships [126]. **Entities** are a collection of objects or concepts that are identified by an enterprise as having an independent existence and share common characteristics. An entity could be tangible or definable thing like person, object, building or business concept in which data is stored. In a database, the entities are presented as tables. **Attributes** can be described as pieces of information at an atomic level. They are facts and properties of entities. In ER modeling, only a subset of an entity's attributes which are directly related to the application are of interest. In a database, the attributes are presented as table columns. **Relationships** are an association among entities. Relationships are often characterized by degrees, also known as, the degree of the relationship. The degree of the relationship denotes the number of entities involved with the relationship. There are three main types of relationships namely; one-to-one relationship (1:1), one-to-many relationship (1:M) and many-to-many relationship (M:M). A one-to-one relationship (1:1) is where A single entity instance in one entity class (parent) is related to multiple entity instances in another entity class (child). A one-to-many relationship (1:M) [127].

The entity relationship diagram (ERD) for the proposed system is shown in figure 3.10 below.

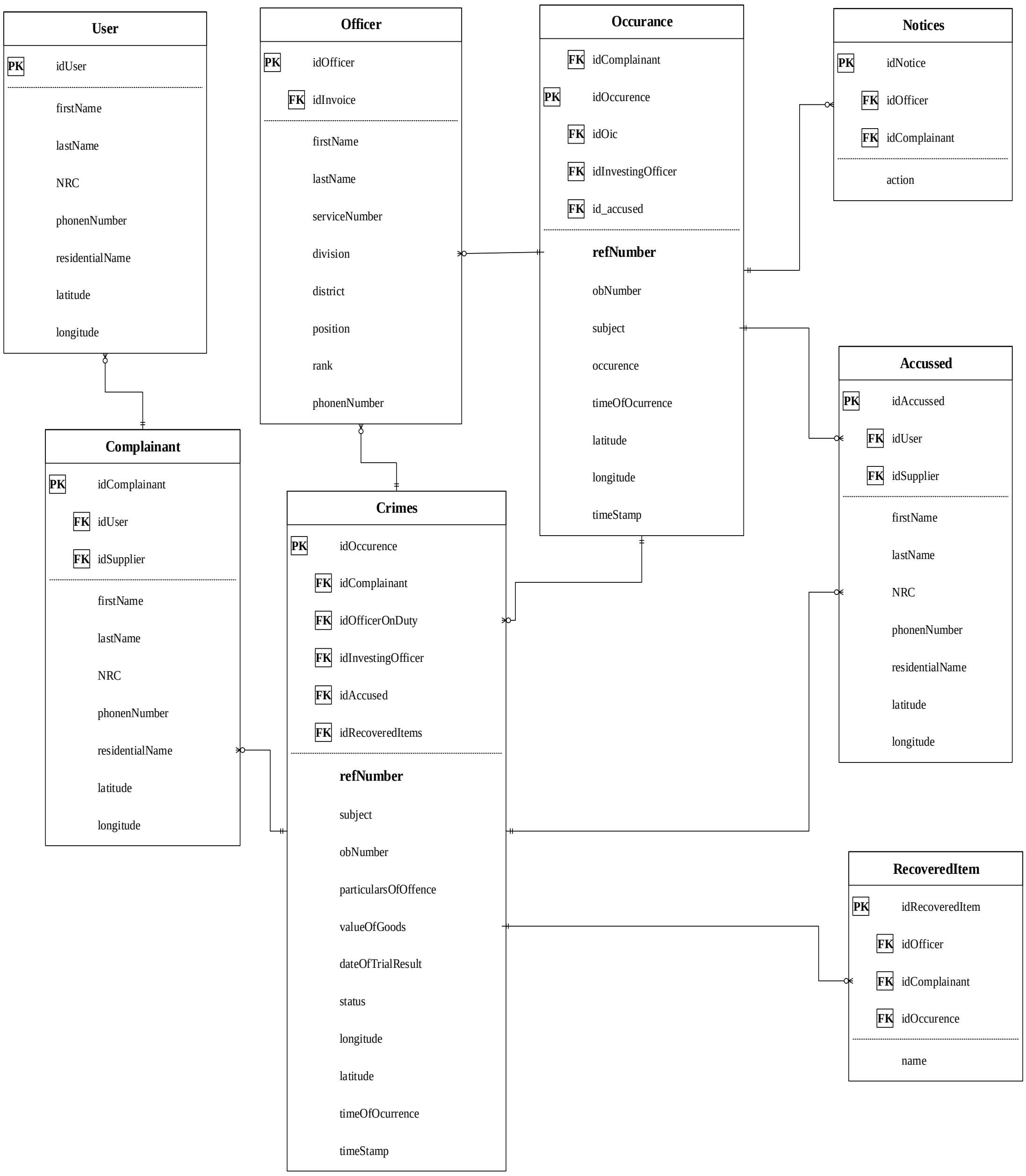


Figure 3. 10: Entity Relationship Diagram

The ER model diagram in fig.3.10 above shows the relationships between entities and attributes in the proposed system.

ii. Data Dictionary

A Data Dictionary is a collection of names, definitions, and attributes about data elements that are being used or captured in a database, it does not only provide a textual description of data objects and their inter-relationships but also provides metadata like physical and logical attributes of data elements. It is commonly used in confirming data requirements in or order for database developers to create and maintain a database system [128]. A data dictionary provides similar information to the relational database schema, however it is considered to be more detailed than a Relational Database Schema, a Relational Database Schema is a blueprint of how the database is logically constructed. A relation is a table with columns and rows. Columns have named attributes of the relation while rows contain the records of the relation. Table 3.6 below shows the data dictionary for user table;

Table 3.6: Data Dictionary for User table

USER (stores information about a citizen that has created an account on the mobile app)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idUser	String	Primary Key, Unique	For mapping the records
firstName	String	Not Null	First name of the citizen
lastName	String	Not Null	Last name of citizen
nrc	String	Not Null	NRC of citizen
phoneNumber	String	Not Null	Phone number of citizen
residentialName	String	Not Null	Residential name of citizen
latitude	String	Not Null	Latitude of residential
longitude	String	Not Null	Longitude of residential

Table 3.6 above is the data dictionary for the user table, it depicts the attributes of the user table, it further shows idUser as the primary key for the table. The table generally stores information about the user of the system.

Table 3.7 below shows the data dictionary for officer table;

Table 3.7: Data Dictionary for Officer table

OFFICER (stores information about a police officer who is also a user of web app)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idOfficer	Long	Primary Key, Unique	For mapping the records
firstName	String	Not Null	First name of the citizen
lastName	String	Not Null	Last name of the citizen
serviceNumber	String	Not Null	Officer service number
division	String	Not Null	Division of officer
station	String	Not Null	Place where the officer is stationed
position	String	Not Null	Role of officer
rank	String	Not Null	Rank of officer

Table 3.7 above is the data dictionary for the officer table, it depicts the attributes of the officer table, it further shows idOfficer as the primary key for the table. The table generally stores information about the officer.

Table 3.8 below shows the data dictionary for notice table;

Table 3.8: Data Dictionary for Notice table

NOTICE (stores notices)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idNotice	String	Primary Key, Unique	For the mapping the record
idOffice	String	Not Null	Url for mapping officer
idComplainant	String	Not Null	Url for mapping complainant
createdAt	Date	Not Null	Date it was created

Table 3.8 above is the data dictionary for the notice table, it depicts the attributes of the notice table, it further shows idNotice as the primary key for the table. The table generally stores information of all notifications.

Table 3.9 below shows the data dictionary for occurrence table;

Table 3.9: Data Dictionary for Occurrence table

OCCURRENCE (store information about crime occurrences/reports)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idOccurence	Long	Primary Key, Unique	For the mapping the record
idComplainant	String	Not Null	Url for mapping complainant
idAccused	String	Null	Url for mapping accused
refNumber	Sting	Not Null	Occurrence reference number
obNumber	String	Not Null	Status of approval level
subject	String	Not Null	Type of offence
occurence	String	Not Null	Narration of what occurrence
latitude	Decimal	Not Null	Latitude of where the crime occurred
longitude	Decimal	Not Null	Longitude of where the crime occurred
timeOfOcurrence	TimeStamp	Not Null	Time when the crime occurred
timeStamp	String	Not Null	Time when crime was captured

Table 3.9 depicts the attributes of the occurrence table, it further shows idOccurence as the primary key for the table. The table generally stores information about crime occurrences and crime reports.

Table 3.10 below shows the data dictionary for complainant table;

Table 3.10: Data Dictionary for Complainant table

COMPLAINANT (stores information about a complainant)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idUser	String	Primary Key, Unique	For the mapping the record
firstName	String	Not Null	First name of the citizen
lastName	String	Not Null	Last name of citizen
nrc	String	Not Null	NRC of citizen
phoneNumber	String	Not Null	Phone number of citizen
residentialName	String	Not Null	Residential name of citizen
latitude	String	Not Null	Latitude of residential
longitude	String	Not Null	Longitude of residential

The data dictionary in table 3.10 depicts the attributes of the complainant table, it further shows idUser as the primary key for the table. The table generally stores information about the complainant.

Table 3.11 below shows the data dictionary for Accused table;

Table 3.11: Data Dictionary for Accused table

ACCUSED (stores information about the accused person or suspect)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idUser	String	Primary Key, Unique	For the mapping the record
firstName	String	Not Null	First name of the citizen
lastName	String	Not Null	Last name of citizen
nrc	String	Null	NRC of citizen
phoneNumber	String	Null	Phone number of citizen
residentialName	String	Null	Residential name of citizen
latitude	String	Null	Latitude of residential
longitude	String	Null	Longitude of residential

Table 3.11 above is the data dictionary for the accused table, it depicts the attributes of the accused table, it further shows idUser as the primary key for the table. The table generally stores information about the accused also known as suspects.

Table 3.12 below shows the data dictionary for Crimes table;

Table 3.12: Data Dictionary for Crimes table

CRIMES (Stores detailed information about a crime)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idOccurence	Long	Primary Key, Unique	For the mapping the record
idComplainant	String	Not Null	Url for mapping complainant
idAccused	String	Not Null	Url for mapping accused
refNumber	Sting	Not Null	Occurrence reference number
obNumber	String	Not Null	Status of approval level
subject	String	Not Null	Type of offence
particularsOfOffence	String	Not Null	Narration of what occurrence
timeStamp	String	Not Null	Time it was captured
dateOfResult	String	Not Null	Date when the trial results
status	String	Not Null	Status of case

Table 3.12 above is the data dictionary for the crimes table, it depicts the attributes of the crimes table, it further shows idOccurence as the primary key for the table. The table generally stores information about crimes.

Table 3.13 below shows the data dictionary for RecoveredItems table;

Table 3.13: Data Dictionary for RecoveredItems table

RECOVEREDITEMS (stores information about the recovered items)			
Field Name	**Data Type & Length**	**Constraints**	**Description**
idOccurence	Long	Primary Key, Unique	For mapping the record
idComplainant	String	Not Null	Url for mapping complainant
idAccused	String	Null	Url for mapping accused
idOccurence	Long	Not Null	For mapping the records
Description	String	Not Null	Description of item
item	String	Not Null	Name of item

Table 3.13 above is the data dictionary for the RecoveredItems table, it depicts the attributes of the RecoveredItems table, it further shows idAccused as the primary key for the table. The table generally stores information about the recovered items.

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. Purposive and convenient sampling techniques were used in the selection of the sample size for the baseline study and an Object-Oriented System Development Methodology was used in the system design and implementation. In addition, different System models were presented to provide the means by which the Crime mapping model could be implemented, the system models included use cases, sequence diagrams, entity relationship diagrams and data dictionaries.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter firstly presents the results that were derived from the baseline study. The main purpose of conducting the baseline study was to identify the challenges in the current crime mapping system used by the Zambia Police Service. The baseline study was conducted through interviews and issuance of structured questionnaires. The chapter also present results of the implementation of the system prototype using screenshots of the system application. The developed system prototype was designed through mapping of business processes derived from the results of the baseline study.

4.2 Baseline Study

The data that was collected from the baseline study was analyzed using descriptive statistics and the results were presented in form of tables, bar charts and pie charts.

4.2.1 Demographic Characteristics

The main instrument used for the collection of data in this study was a questionnaire, which was distributed to 100 individual police officers that were selected from nine (9) different police stations across Lusaka District. However, 88 questionnaires were successfully responded to and given back, representing a response rate of 88%.

4.2.2 Gender of Respondents

Among the respondents that participated in the study, 61.4% of them were male police officers while 38.6% were female Police officers. Though the gender distribution was skewed towards male, this did not affect the findings of the study. Figure 4.1 below shows gender distribution.

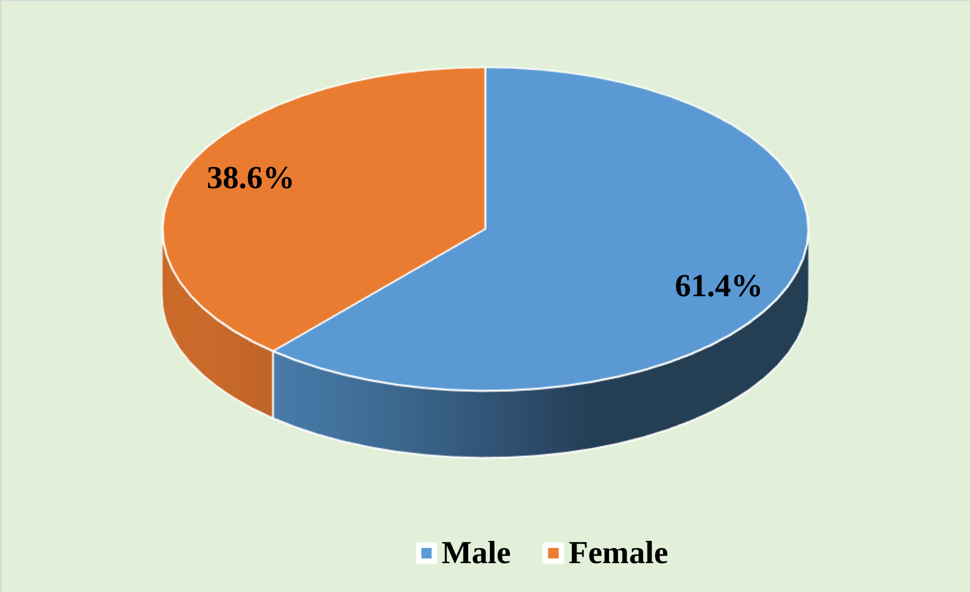


Figure 4.1: Gender Distribution

4.2.3 Age Distribution

The age distribution of the respondents demonstrated a normal distribution with majority respondents in excess of 64.8% falling in the age category 30-45 years, followed by the age category 18-29 years and 46-55 years with 19.3% and 15.9% respectively. The information on age was an important aspect because it helped the researcher understand the levels of maturity and understanding among the respondents and how easily respondents would be able to learn on how to use the computerized crime mapping system. Figure 4.2 below shows a detailed illustration of the results;

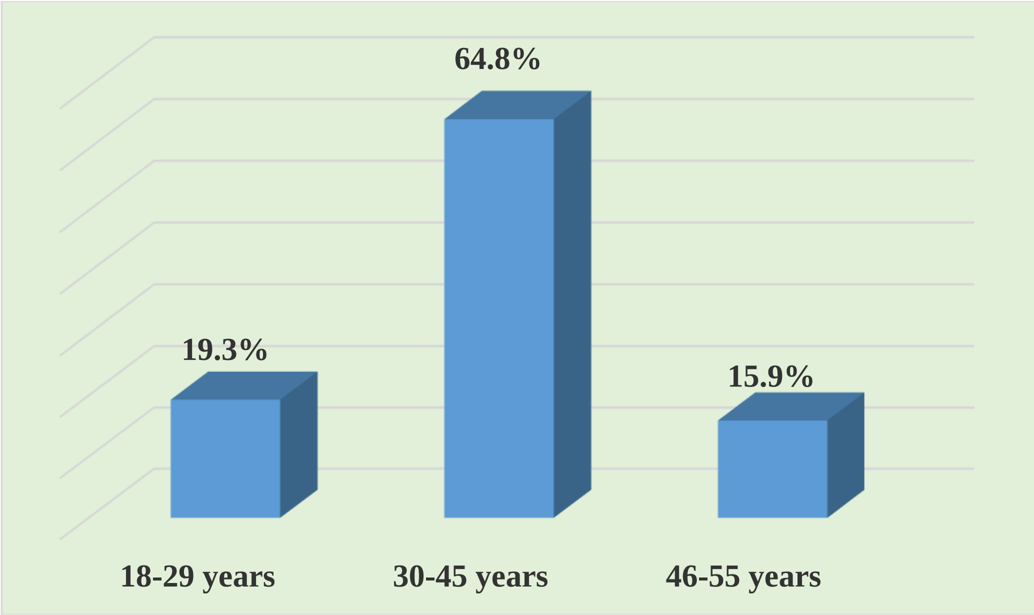


Figure 4.2: Age Distribution

4.2.4 **Target Population/Departments**

Data was collected from the officers domiciled in nine (9) different police stations across Lusaka. The study further targeted those police officers dealing with issues of receiving and recording crime reports from the public, as well as crime mapping. Police stations interviewed include Lusaka Central, Woodlands, Kabwata, Chawama, Emmasdale, Chelstone, Matero, Chilenje and Kanyama Police Station. Among these stations, the study particularly focused on the activities of the Criminal Investigations Department and the Victim Support Unit. Among the respondents, 62.5% were from the Criminal Investigations Department while 37.5% were from the Victim Support Unit. Figure 4.3 shows the illustration.

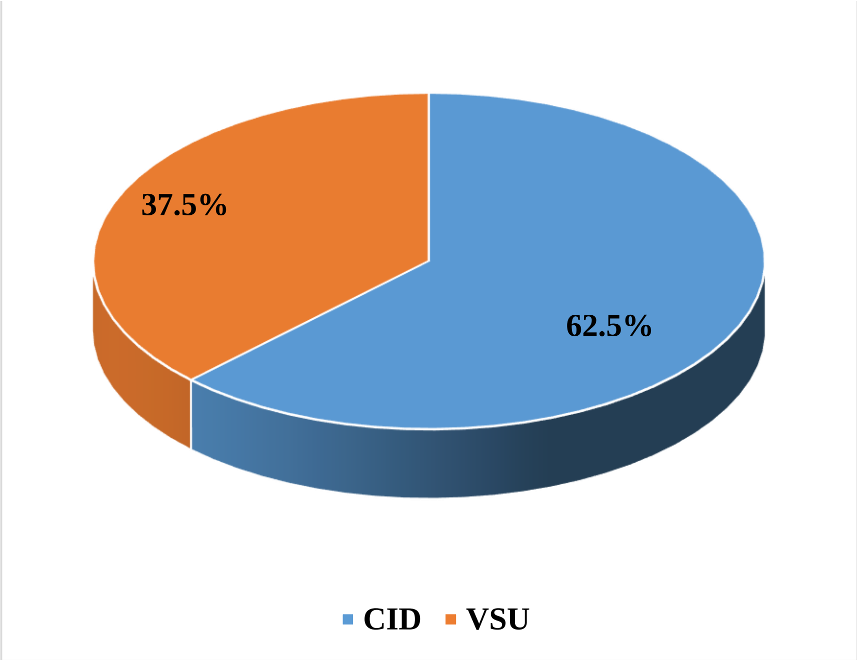


Figure 4.3: Police Department

4.2.5 **Work Experience**

The study was conducted to find out the work experience of the police officers in the target departments who participated in the study. Figure 4.4 shows the results.

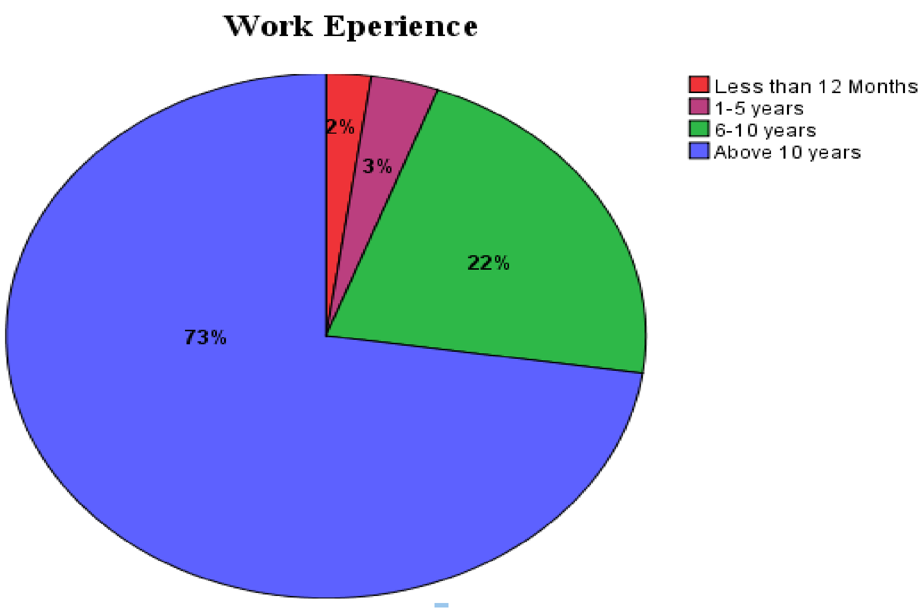


Figure 4.4 Work Experience:

The results in figure 4.4 shown indicate that majority of officers in excess of 73% served more than 10 years of experience in the police service while 22% of the respondents indicated that they served for more than 5 years but less than 10 years in service. The results also show that 3% of the respondents served for more than a year but less than 5 years, further the results review that 2% of the respondents had served for less than a year in the Police Service.

4.2.6 **Level of Education**

The study was conducted to find out the levels of education among the police officers, the results are shown in figure.

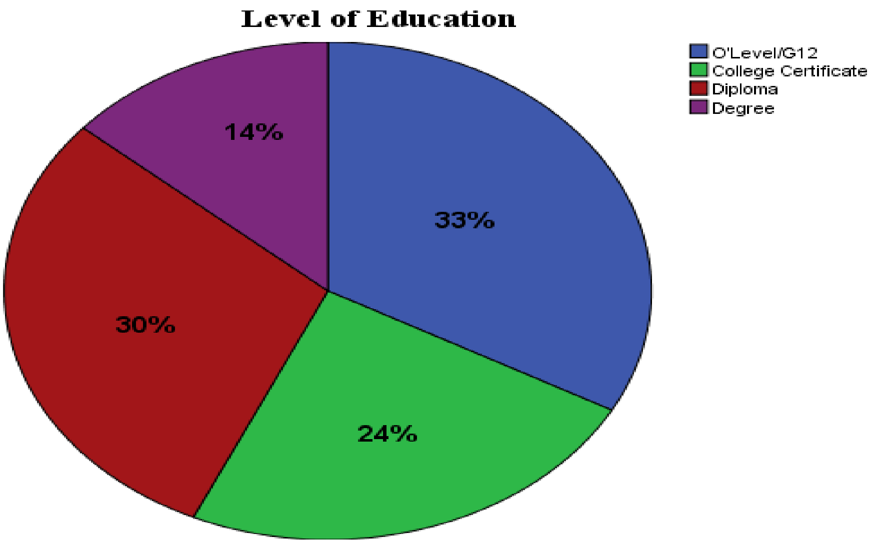


Figure 4.5: Level of Education

As shown in figure 4.5 above, 14% of the respondents obtained degrees, while 30% had diplomas, further 24% the respondents obtained college certificates and 33% only obtained grade 12 certificates.

4.2.7 **Computer Knowledge**

A study was conducted to find out the levels of knowledge in computers among the officers in the Zambia Police, the results are shown in figure 4.6.

Figure 4.6: Computer Knowledge.

The results in figure 4.6 show that 48% officers interviewed indicated they had at least some basic knowledge of computers,43% of the respondents indicated that they had good knowledge in computers and only 8% of them indicted that they had excellent knowledge in computers.

4.2.8 **Availability of Computers**

The study was conducted to find out the availability of computers or how equipped the police stations are with computers, the results are shown in figure 4.7.

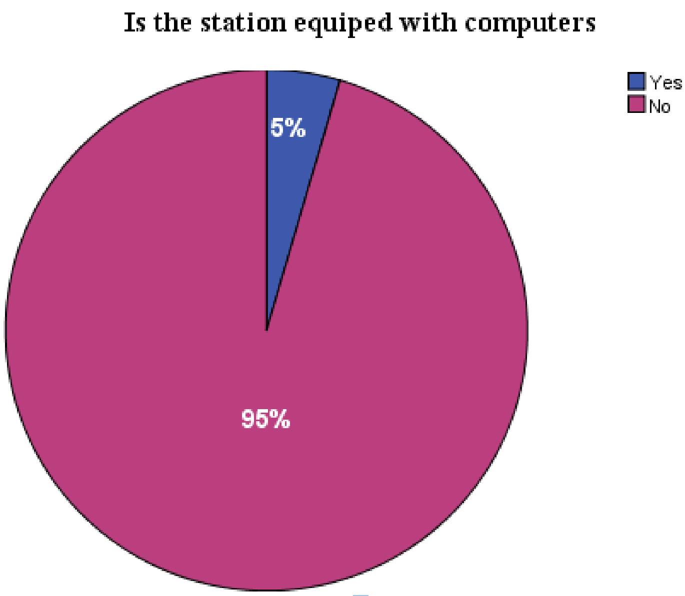


Figure 4.7: Availability of Computers

The results shown in figure 4.7 indicate that 95% of the respondents from different police stations indicated that there are no adequate computers in the police stations, then 5% of the respondents indicated that few computers were available at their stations but only for those in management positions (High Command Level).

In addition, the study was also conducted to find out how many officers who participated in the survey owned personal computers, the results are shown in figure 4.8;

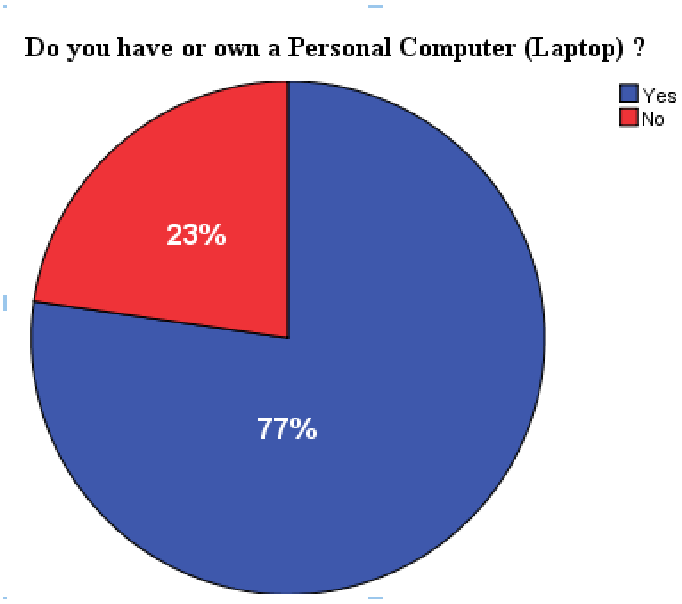


Figure 4.8: Personal Computers

The results shown in 4.8 indicate that 77% of the respondents had or owned personal computers for personal use and only 23% did not own personal computers.

4.2.9 **Crime Mapping Technique**

A study was conducted to find out on the usage of crime mapping technique in police stations, the results are shown in figure 4.9 below.

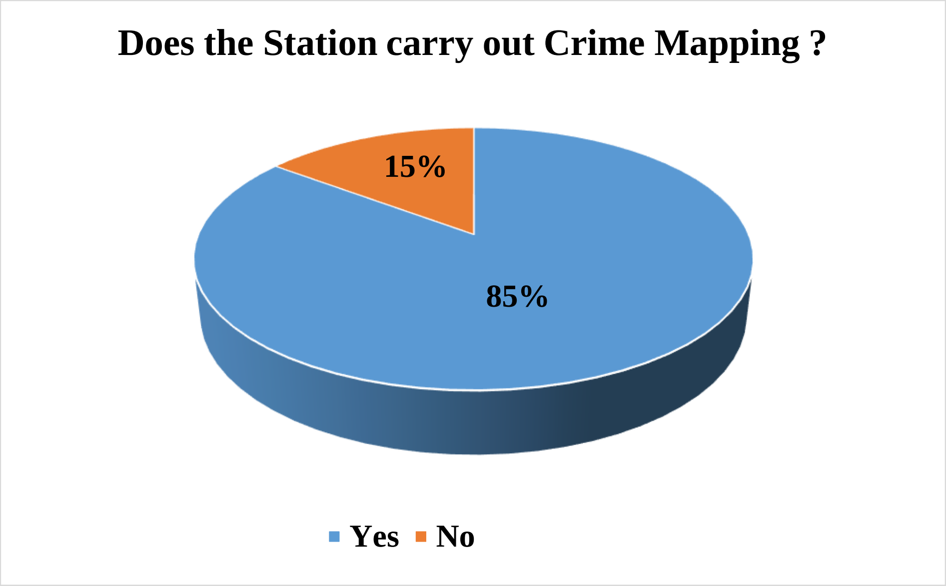


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Figure 4.9: Crime mapping usage

The results in figure 4.9 above show that 85.2% of the stations conduct crime mapping using manual or physical geographical maps and pins placed on the map while 14.8% indicated that they don't use any form of crime mapping technique.

4.2.10 **Challenges of Current System**

The study was conducted to find out some challenges of the current manual system of crime mapping being used by the Zambia Police. The results revealed that one of the challenges of the current manual system is non-instant availability of statistics or data on areas prone to crimes as indicated by 95% of respondents shown in figure 4.10.

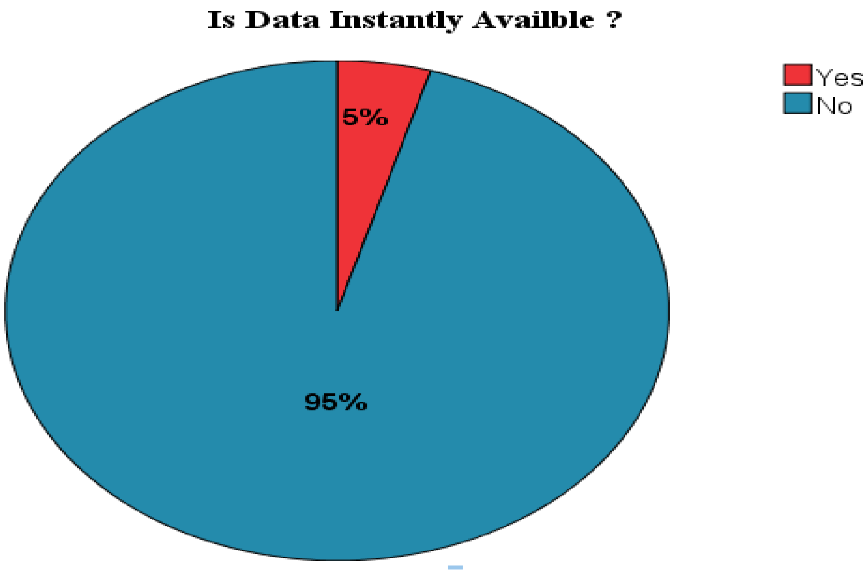

Figure 4.10: Non instant availability of data

As shown in figure 4.10, one of the major cause of non-instant availability of crime data is the manual storage of data that requires physical counting. The manual data does not support data querying hence data is subjected to be counted one by one to establish the desired statistics, a process which is known to be time consuming.

A total of 91% of respondents further indicated of having challenges in analyzing & managing crime data with manual maps as shown in figure 4.11 below.

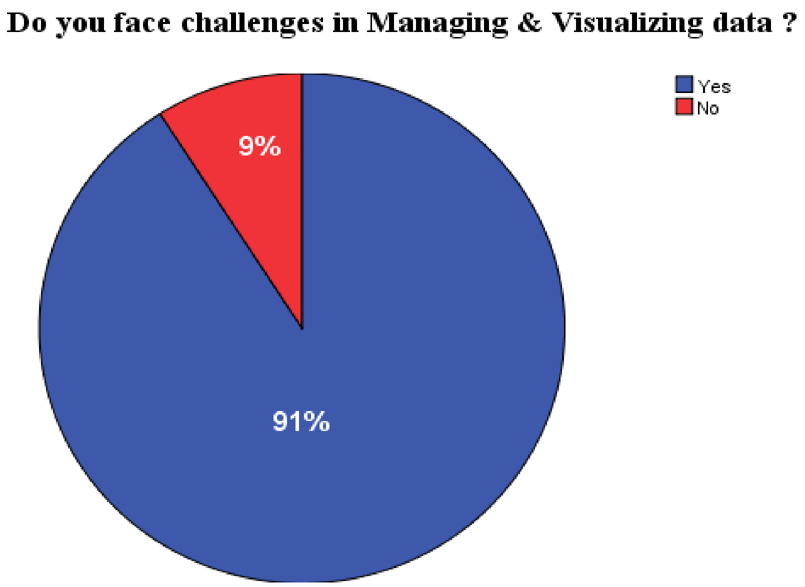

Figure 4.11: Data Management & Visualization

As shown in figure 4.11, the major weakness of physical crime map is that it does not only support querying techniques but also can only accommodate one particular crime data at time.

4.2.11 **Crime Reporting Methods**

The study looked at how crimes are reported by the general public and how the police capture and record crime data, table 4.1 shows the crime reporting methods.

Table 4.1: Crime reporting methods

How does the public report crimes ?			
	Responses		
	Frequency	Percent	Cumulative frequency
Does the public walk in to the police station when making crime reports?	88	75.9%	100.0%
Does the public make a call to the police when making crime reports?	28	24.1%	31.8%
Total	116	100.0%	131.8%

The results shown in table 4.1 indicate that 75.9% of people walk to the station to report crimes. Only 24.9% make phone calls. In addition, all crime cases and statistics are manually captured, recorded, processed and stored in books & papers.

4.2.12 **Mobile Devices**

Data input is critical for the accurate of digital maps, in order for digital crime maps to be automated, there is need to consider digitalizing the stage of reporting, capturing and recording of crime data by introducing a mobile application platform to be used by the general public to report crime cases. In order to understand the type and nature of mobile devices used by the general public, questionnaires were distributed to citizens who were visiting the police stations for various reasons across Lusaka city. The results are shown in figure 4.12 below

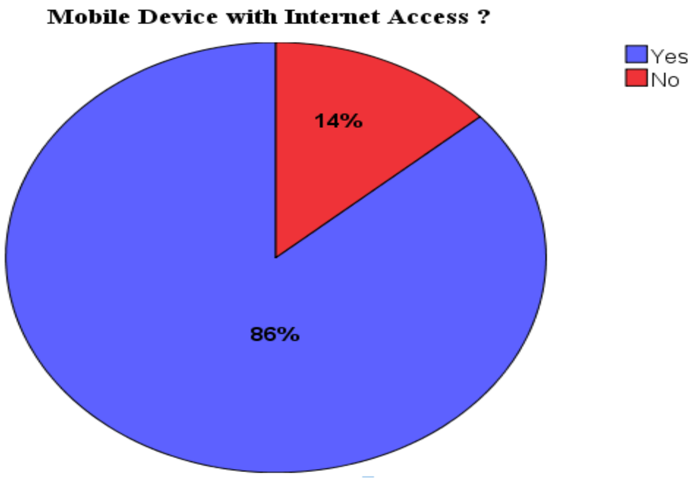

Figure 4.12: Mobile Devices

The results in figure 4.12 show that 86% of the general public or respondents own Phones or other Mobile devices that have access to internet and only 14% of the respondents had mobile devices that did not have access to internet.

The study further wished to know and uncover the type of the mobile operating systems of the mobile devices considered in the survey, the results are shown in figure 4.13.

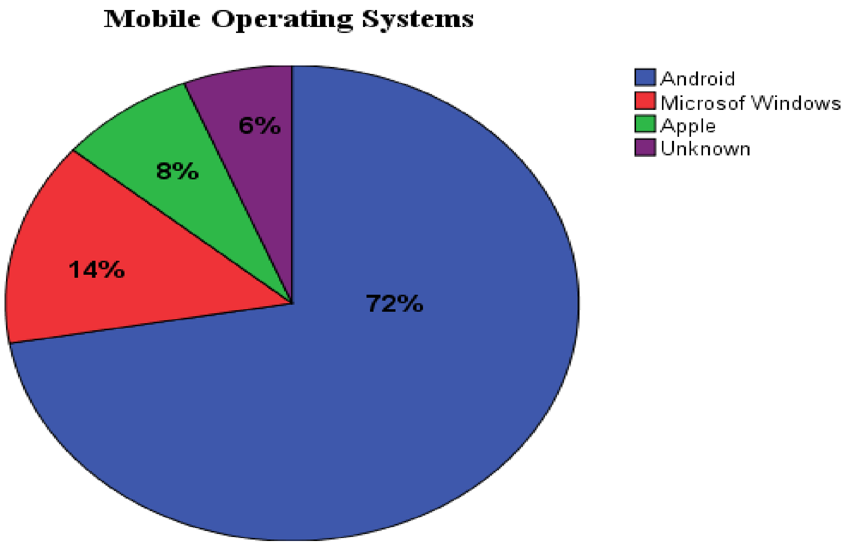

Figure 4.13: Reviewed Mobile Operating Systems

As shown in figure 4.13, for the mobile devices that have internet access carried out in this survey, 72% of those had android operating system,14% had Microsoft windows while only 8% had Apple and 6% had unknown mobile operating systems. With these results it is evident that in order for the system to be accessed by majority citizens it had to be belt on both web and android application platforms.

4.3 System Prototype Implementation

Manual methods of crime mapping and data management can be replaced with automated systems in order eliminate the challenges brought about by manual systems. In order to show how an automated crime mapping will work in Zambia Police, a prototype was developed to show the proof of the concept. As already outlined in chapter 3, the prototype application named crime mapper consists of the web and android mobile platforms. The web application will strictly be used only by the police consisting of front end which is a web browser and a sever backend consisting of firebase web server and cloud firebase database for data storage. The police can use the web application to record crime incidences from the citizens who walks into the police station, generate, view and update crime maps. The android mobile application will be running on the user's mobile device which can be used to report crime incidences. Both the web application and mobile application are connected to one central database in the cloud.

4.3.1 **Mobile Application**

The mobile application will only be used by the general public to report crime incidences, the user is required to download the application and register his or her details into the system as shown in figure 4.14.

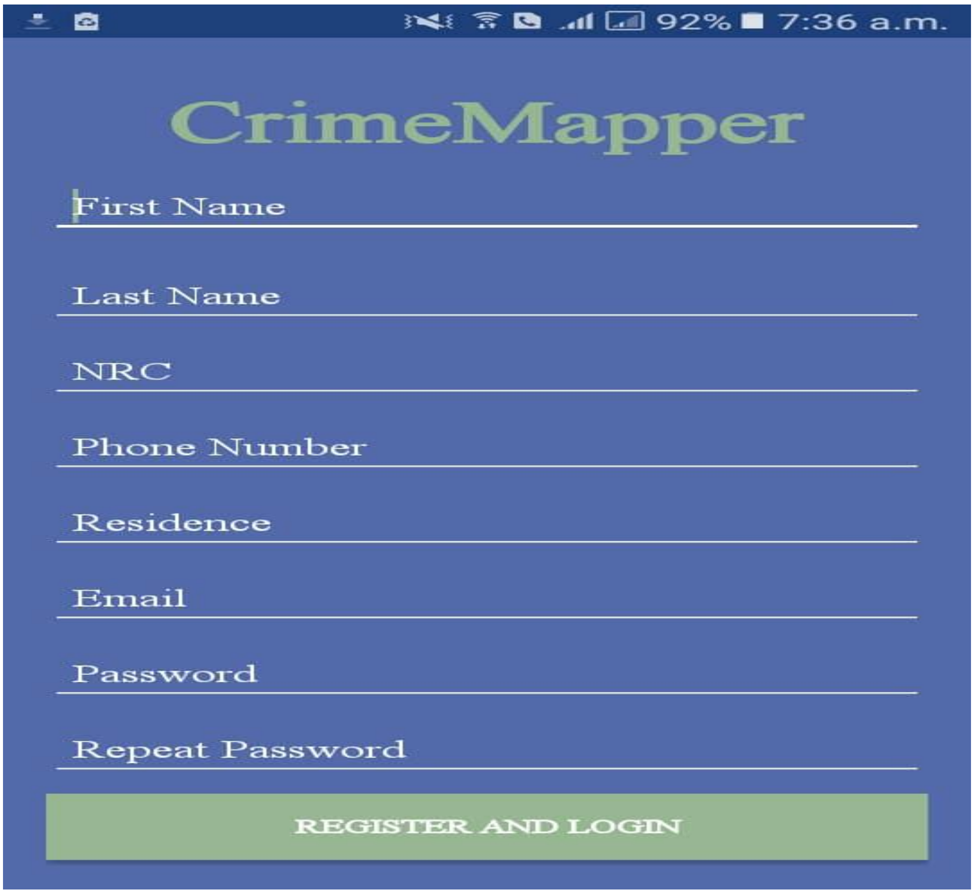

Figure 4.14: User registration – Mobile App

As indicated in figure 4.13 above, the registration details specified by the user will be saved into the database and displayed in the occurrence book at the Police Station. The next time the user wants to use the application, he or she will be prompted to sign in as shown in figure 4.15 ;

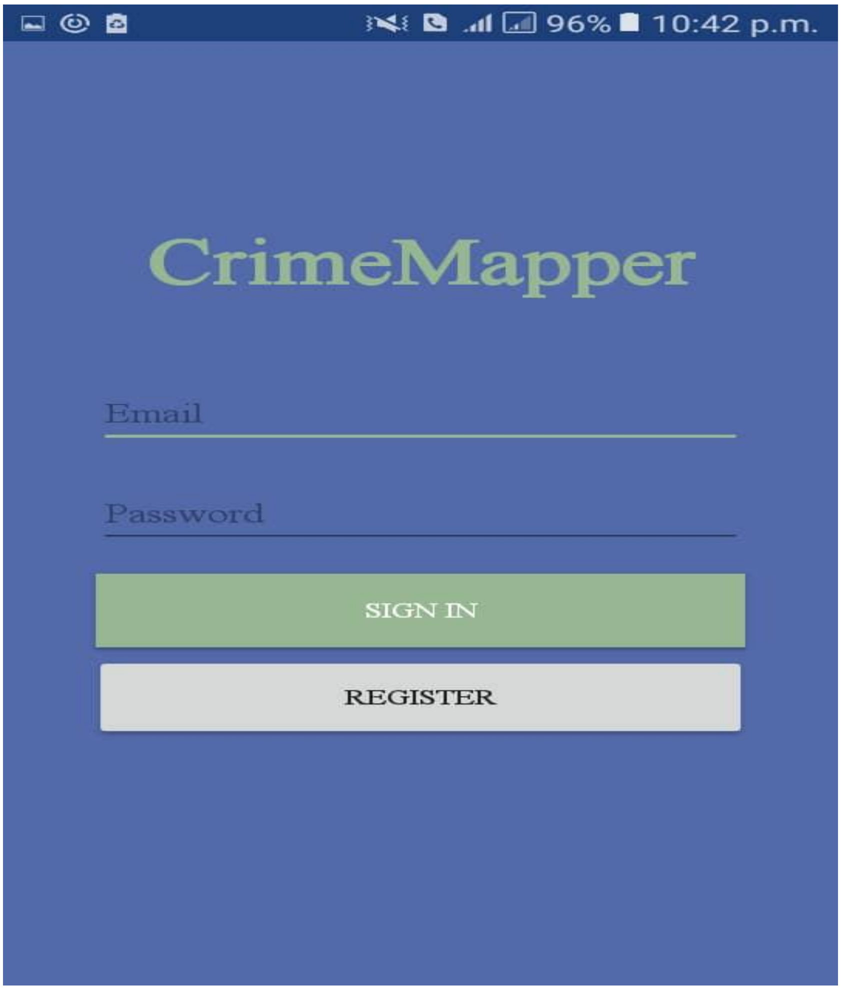

Figure 4.15: Login - Mobile App

Once the user successfully registers or logs into the application, the system will direct the user to the crime incident reporting screen as shown in figure 4.16;

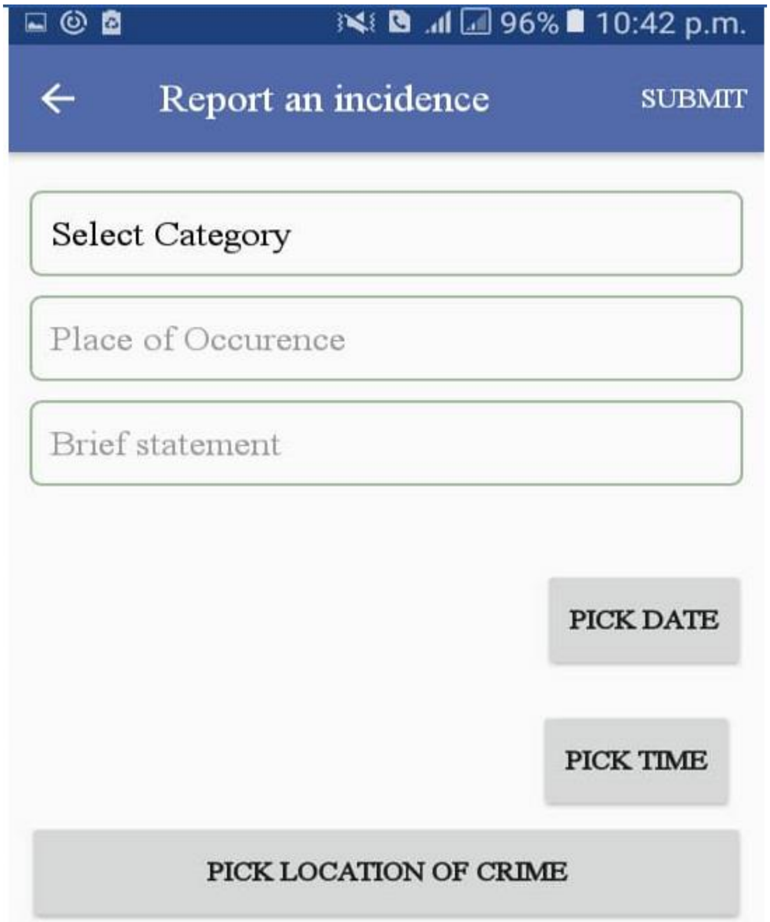

Figure 4.16: Crime reporting – Mobile App

The user who is also a complainant is required to enter details of the case into a mobile app, that includes a category of a case from a drop down menu when he/she clicks on "select category" button. The categories of the cases are already predefined and preconfigured in the system. Examples of categories of crimes include rape, murder, theft and many others. In addition, the user is required to specify the date, time and location of crime incident. The location of crime is selected from the google map using a location navigator as shown in figure 4.17 below;

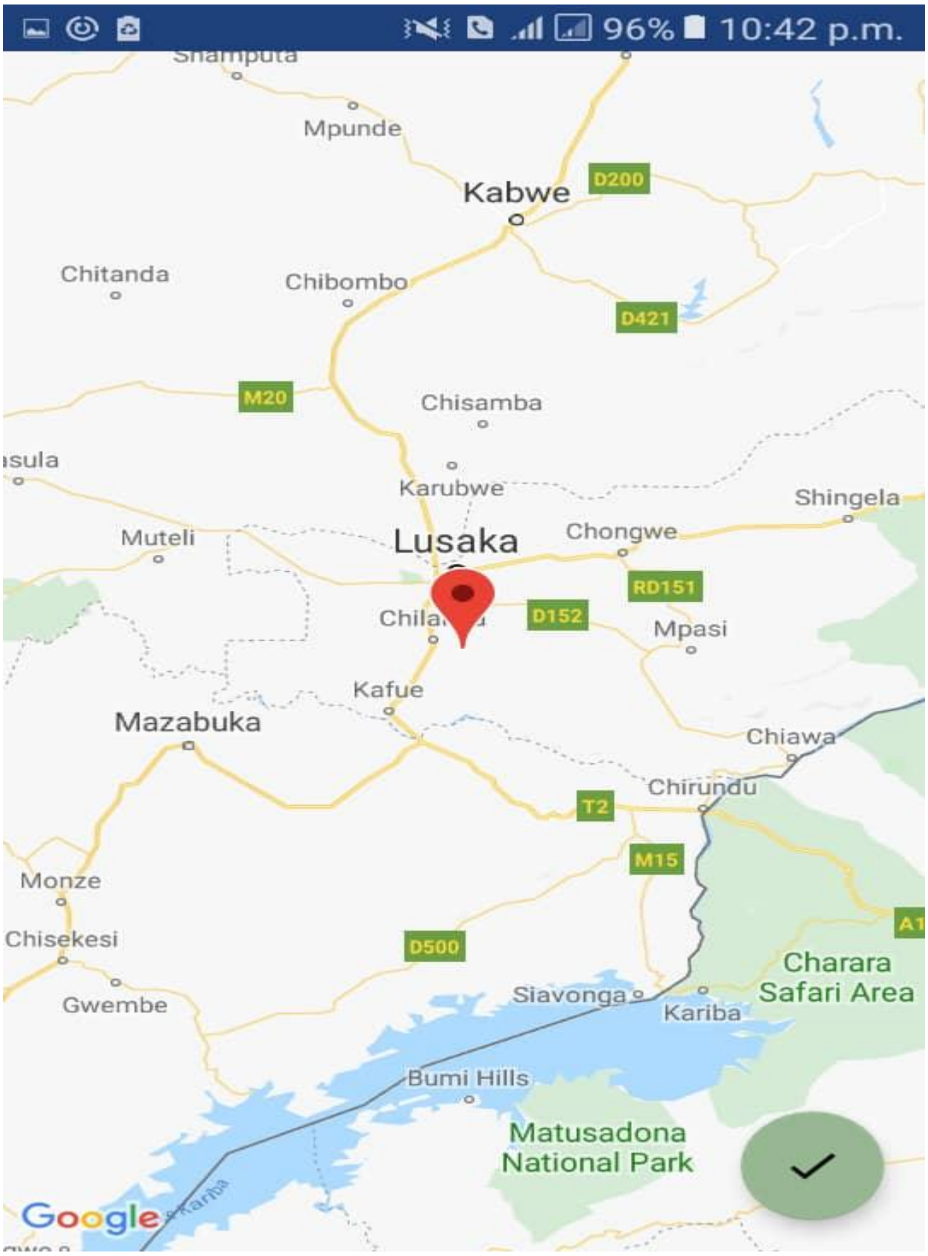

Figure 4.17: Crime location navigator – Mobile App

The user navigates to the actual location of crime on the map using a location or navigation picker, the crime location coordinates together with other crime details are saved into the occurrence book and crime register designed in the cloud database which can only be accessed by the police using the web application. Based on the crime location coordinates, the crime incident report is directed to a nearby police station and the user will be notified were the case has been submitted as shown in figure 4.18.

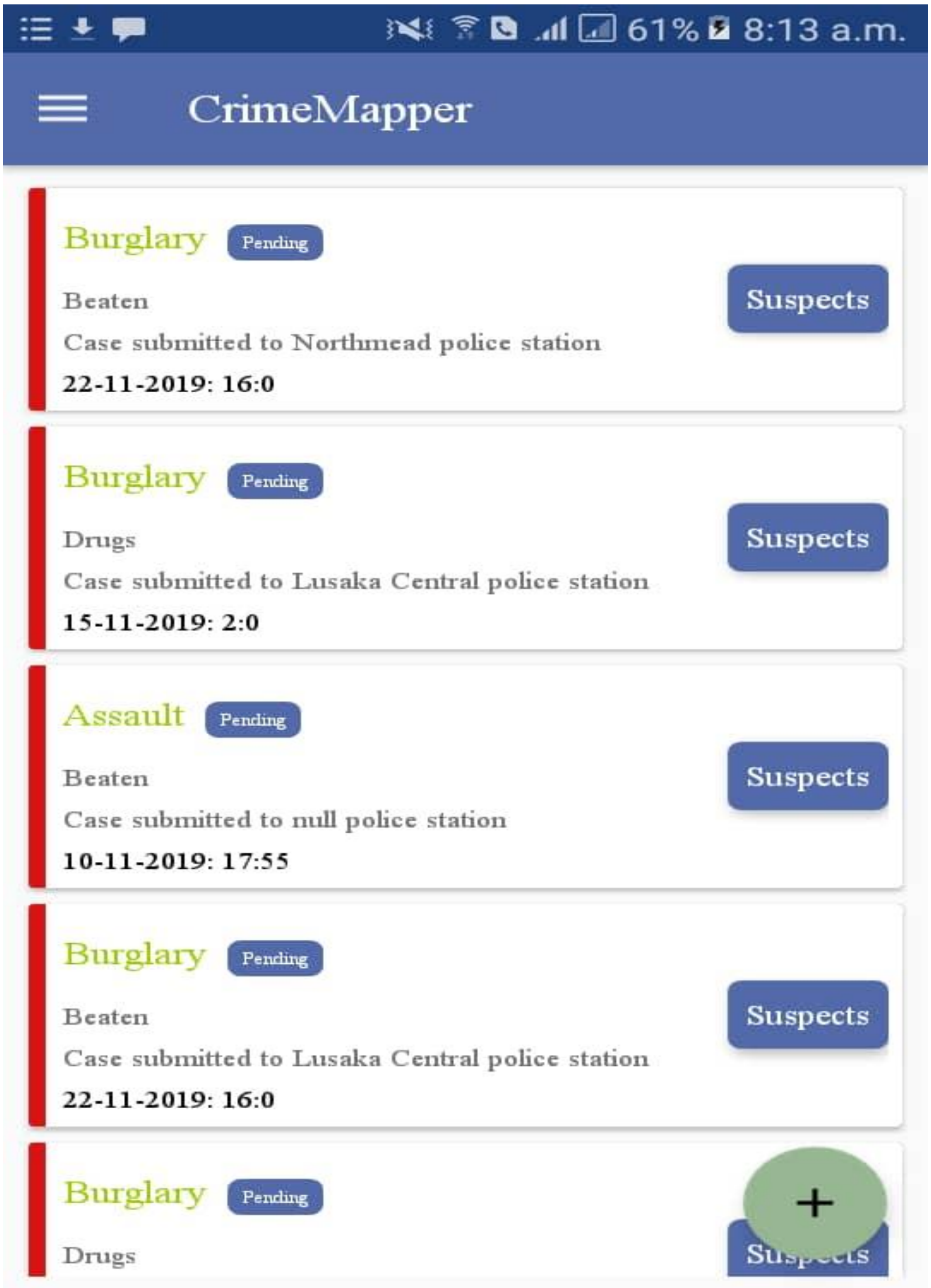

Figure 4.18: Crime status – Mobile App

The mobile user does not only view the Police station where the crime report was directed and submitted to but also he/she is able to monitor the status of the case.

4.3.2 **Web Application**

The web application will only be used by the police to record crime incidences from the general public that walks or physically visits the police station. The application will be used to view and generate crime maps and statistical reports. The users who are the Police Officers and have system administrative privileges are required to register user details of police officers into the system as shown in figure 4.18 below;

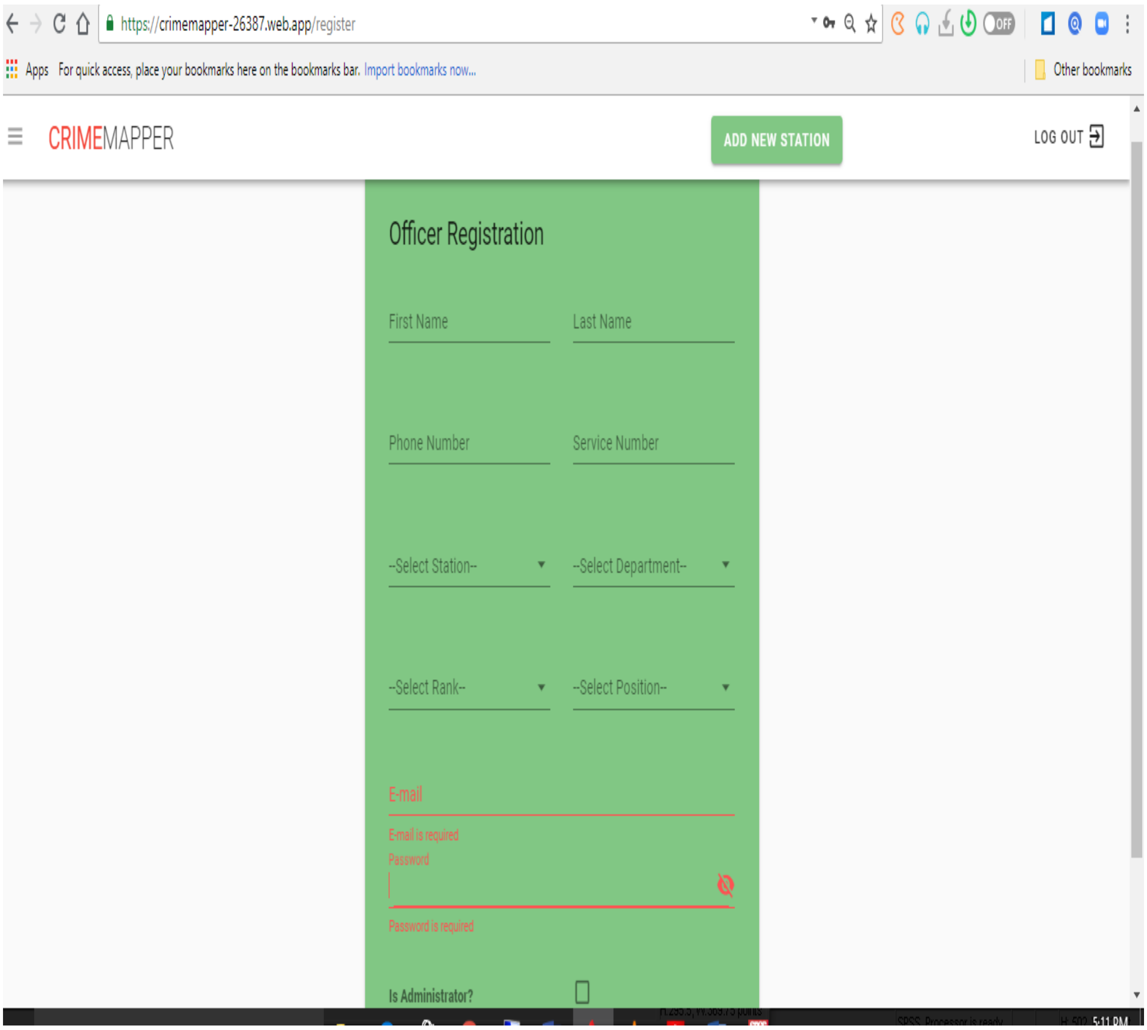

Figure 4.19: User Registration – Web App

If the details of the user are already captured into the application, the system prompts him or her to login as shown in figure 4.20 below;

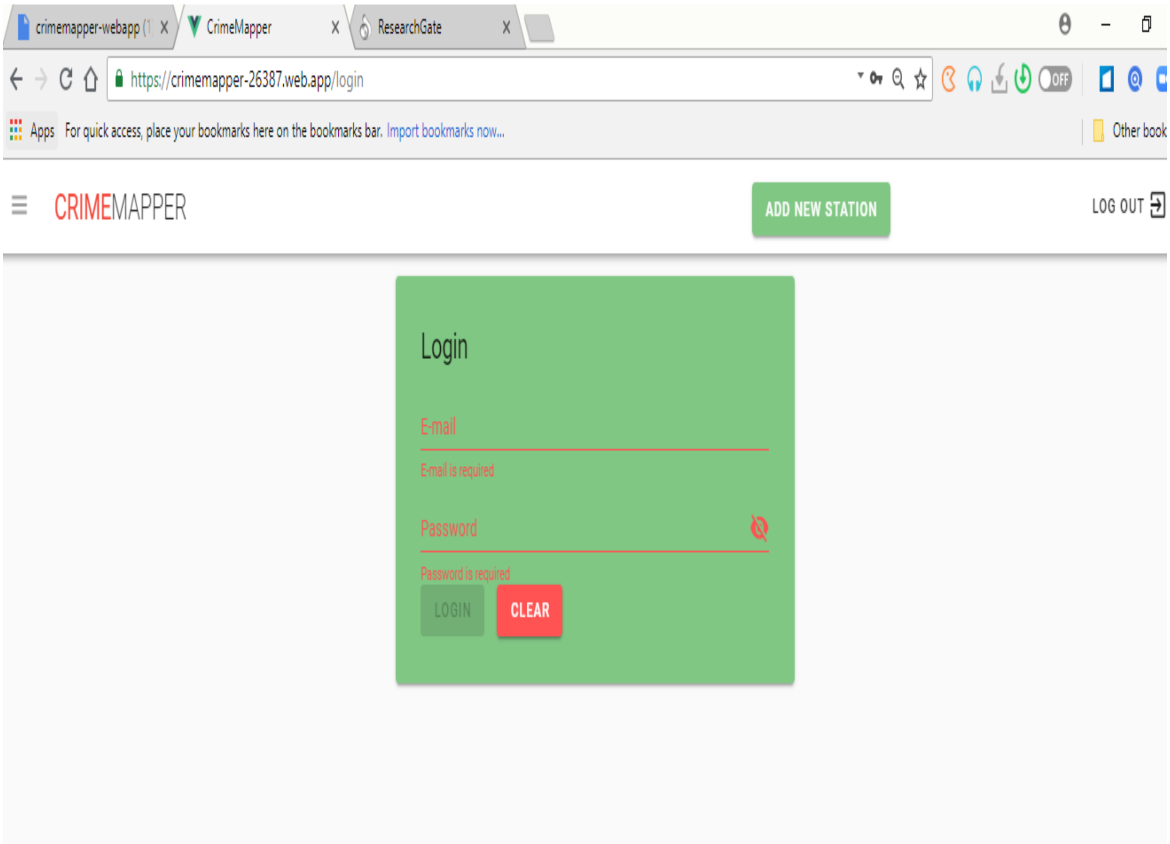

Figure 4.20: Login – Web app

When the user successfully logs into the application, the system directs him/her to the window where crime reports are listed as shown in figure 4.21.

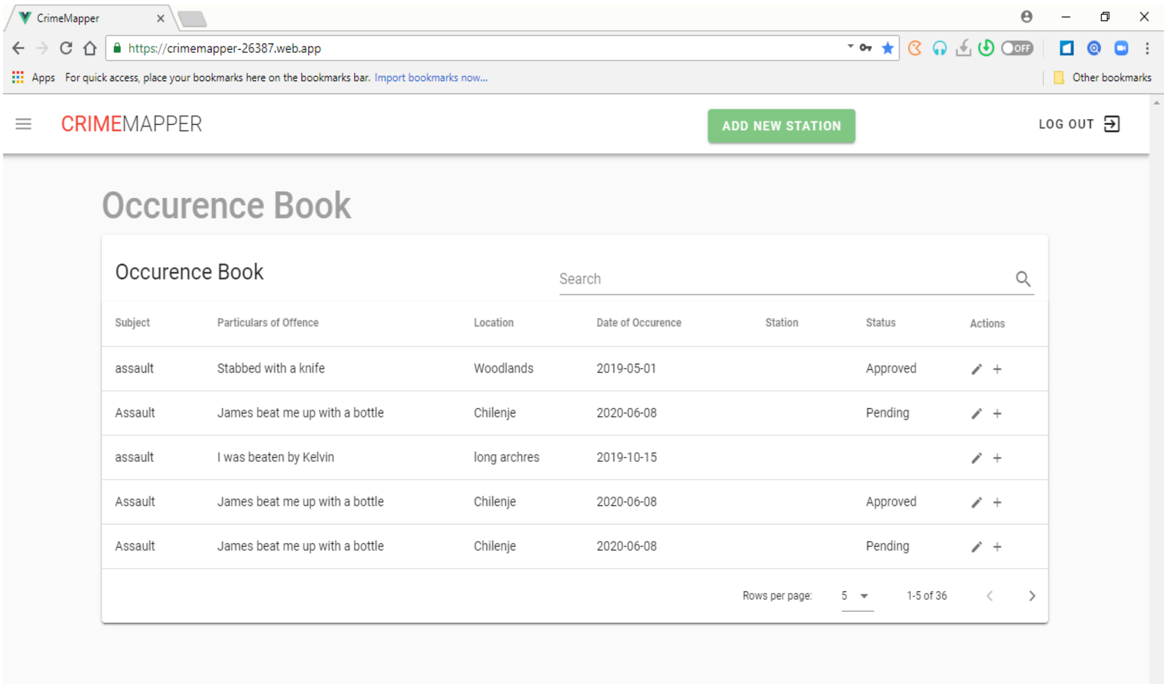

Figure 4.21: Crime reports list – Web App

As shown in figure 4.21, the window shows the occurrence book which was directly depicted from the manual book, this is where all reported crimes are recorded.

The user can record a new case by clicking on "add new case" button and a new window will be opened as shown in figure 4.22.

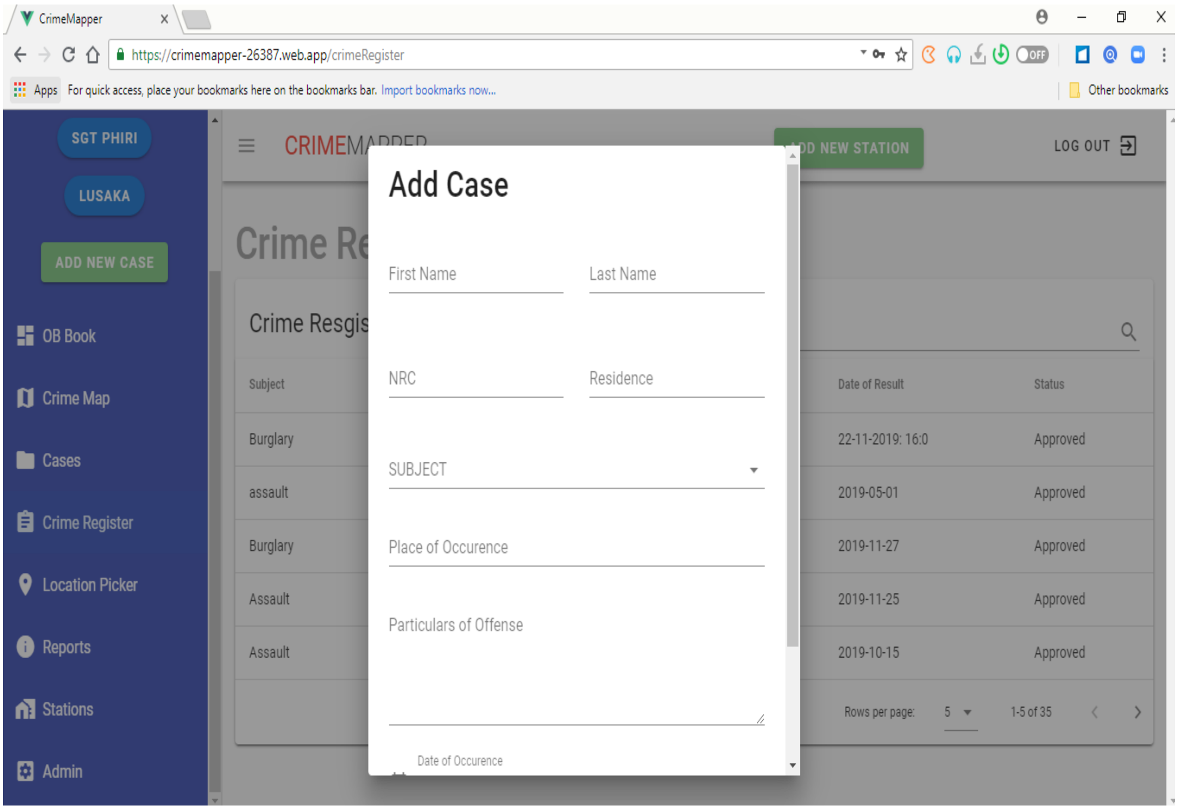

Figure 4.22: Adding a crime report –Web App

As shown in figure 4.22, the user is able to enter details of a complainant like names, NRC, residence and others.

In addition, the user can specify the location of the crime by navigating on the google map as shown in figure 4.23 below.

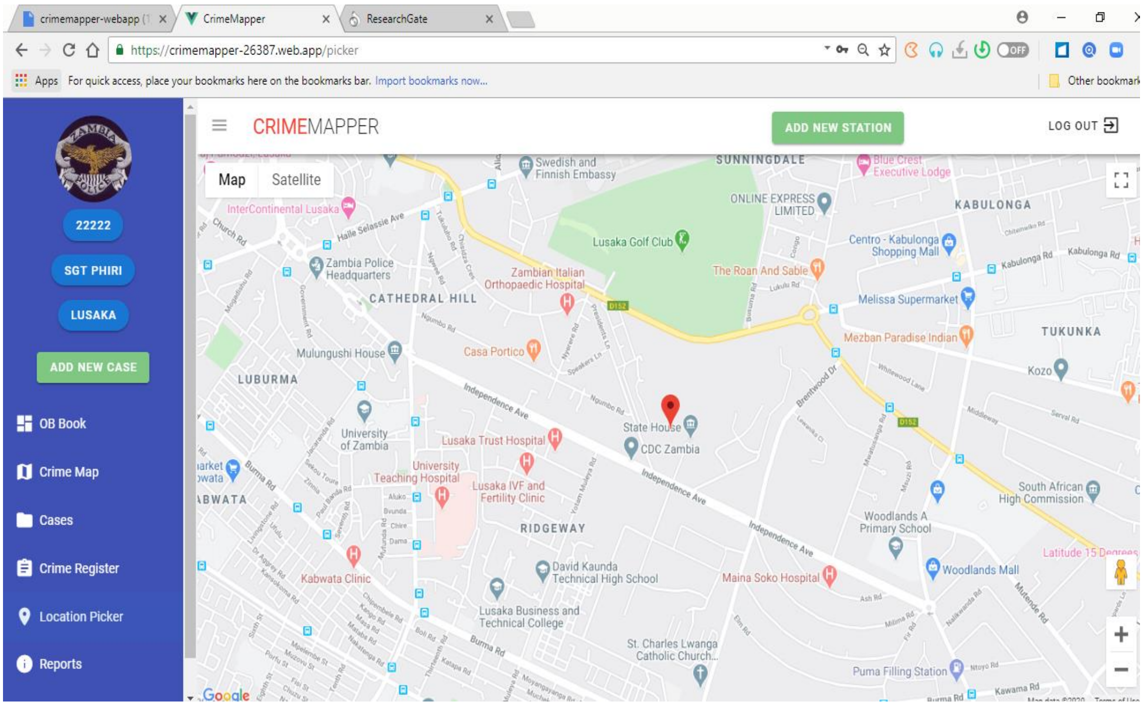

Figure 4.23: Crime location navigator – Web App

As shown in figure 4.23, the location navigator enables the user to select the exactly location of a crime from a google map. The location coordinates are saved into the central cloud database.

The screenshot window in Figure 4.24 shows the filtering of the map based on the name of crime.

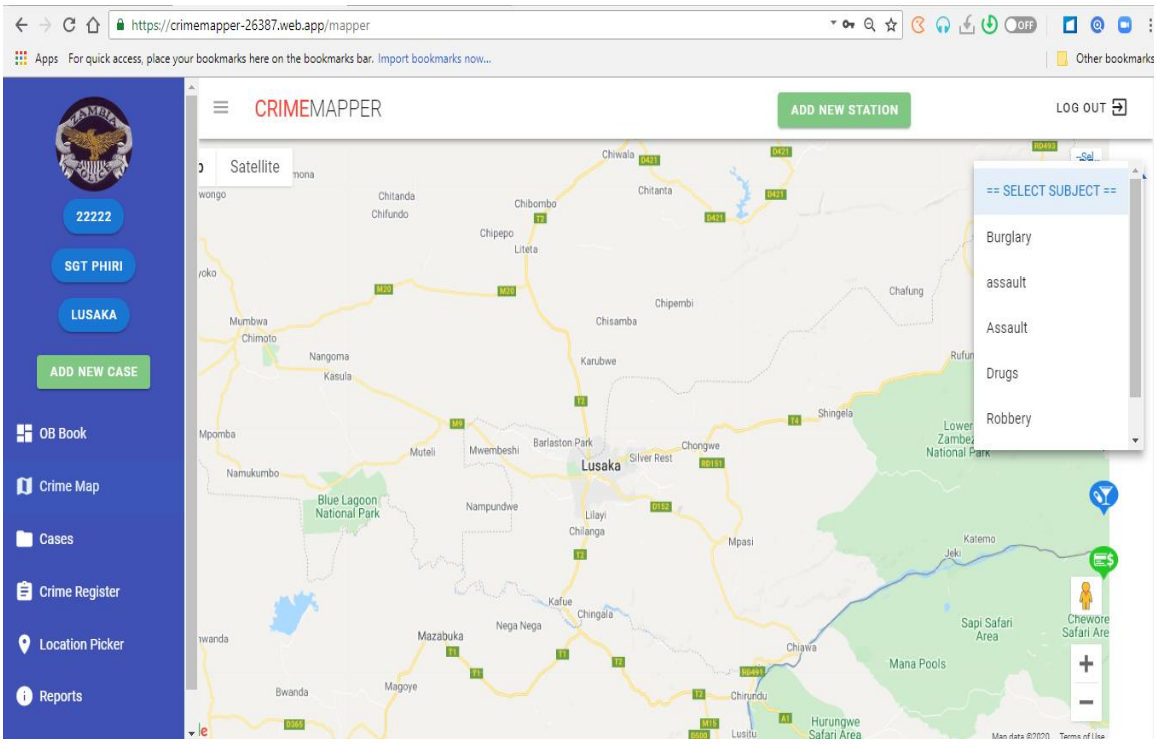

Figure 4.24: Filtering Map – Web Map

As shown in figure 4.24, the crime map can be filtered using the name of a crime like murder, rape, theft and others types of crime. This means that a user can choose specific spatial spots to be displayed on the crime map.

Figure 4.25 shows a screen shot window displaying sample spatial location of crime spots, the crime map is displayed when a user has clicked in a “crime map “button.

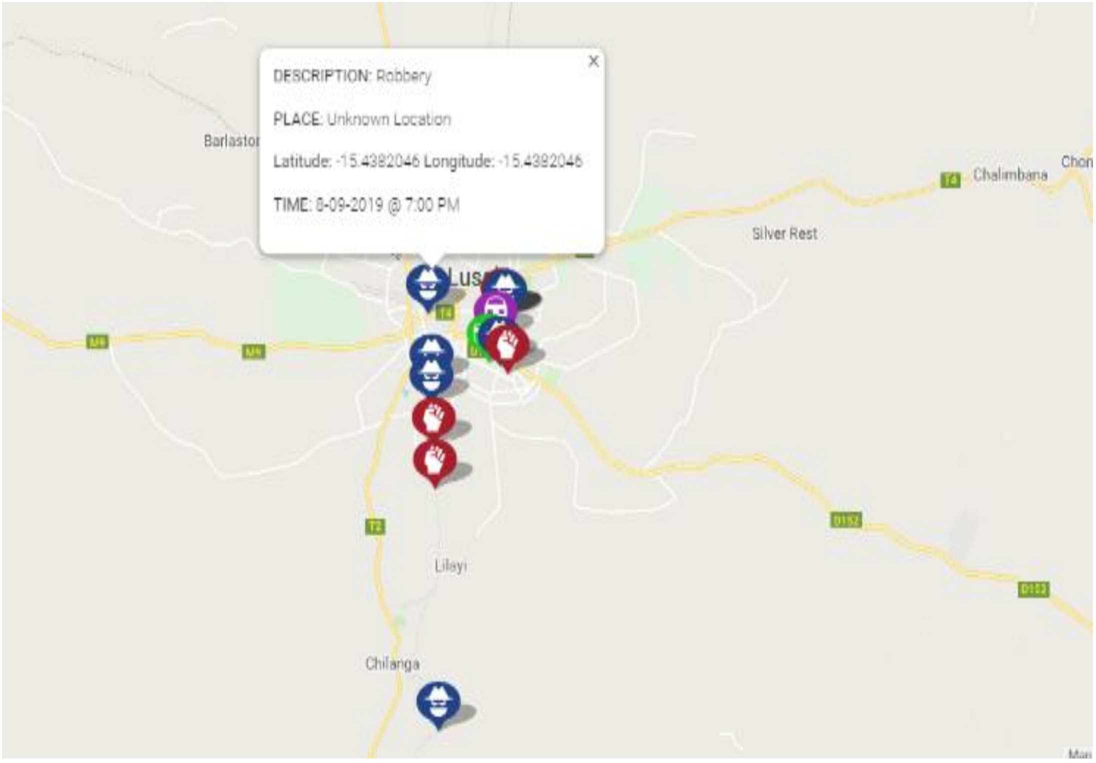

Figure 4.25: Spatial crime spots – Web App

As shown in figure.25, the system is able to display spatial crime spots as they are being reported by the general public. Whenever a crime is reported and recorded into the system through either mobile application or web application, a pin is placed on the map representing a crime incident. Each crime sport shows name, location and its coordinates, date and time the crime was reported.

Figure 4.26 shows the key symbols of crime pins in the map.

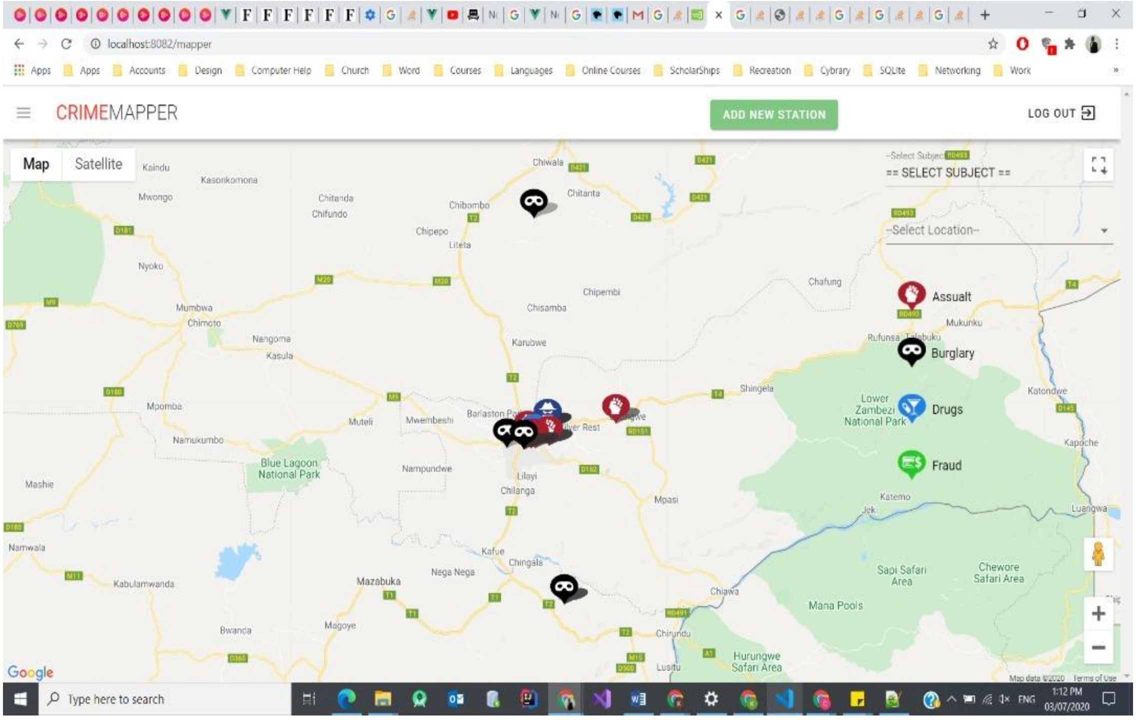

Figure 4.26 Crime Key Symbols – Web App

As shown in figure 4.26, the user is well guided with the key symbols of crime pins or dots on various kinds of crimes they represent.

4.4 Summary

The researcher established that Zambia Police Service currently experiences challenges in data management, data visualization of crimes and non-instant availability of crime data for crime prone areas. Also, all crime data and reports are manually captured and stored in books and papers. Under system implementation, the designs from the survey conducted were derived and illustrated, and the proposed designs for automation of the current manual processes were presented. Finally, the screenshots for the automated crime mapping model prototype implementation were presented.

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 Introduction

This chapter presents the discussion of the research findings that were shown in chapter four. Firstly, the results of the baseline study are discussed in this chapter, followed by the discussion of system prototype development. Then later conclusion, recommendations and future works will be discussed and lastly the summary of the chapter.

5.2 Discussion

This section discusses the results of the baseline study and system prototype.

5.2.1 **Baseline Study**

The study was aimed at identifying and establishing challenges of the current crime mapping system used by the Zambia Police service and also design a computerized crime mapping model for reporting and mapping of crimes. From the baseline study conducted, it was discovered that 85.2% of the stations considered in the study conduct crime mapping using manual or physical geographical maps and pins placed on the map while 14.8% indicated that they don't use any form of crime mapping technique. The study revealed that one of the challenges of the current manual system is non-instant availability of statistics or data on areas prone to crimes as indicated by 95% of respondents, the major attribute to this challenge is the manual storage of data that requires physical counting. The manual data does not support data querying hence data is subjected to be counted one by one to establish the desired statistics, a process which is known to be time consuming. The study further showed that total of 91% of respondents further indicated of having challenges in analyzing & managing crime data with manual maps, some of the weakness of physical crime map include not support querying techniques and also can only accommodate one particular crime data at time. The study also looked at how crimes are reported by the general public and how the police capture and record crime data, results indicated that 75.9% of people walk to the station to report crimes. Only 24.9% make phone calls. In addition, all crime cases and statistics are manually captured, recorded, processed and stored in books & papers. In the same process of planning to develop an automated system, the researcher carried out a study to understand and find out the levels of knowledge in computers among the officers in the Zambia Police, in the results, all the officers interviewed indicated that they had at least some basic knowledge of computers, with more than 50% of the respondents indicating that their level of knowledge in computers was either good or excellent. In addition, the research wished to appreciate the availability of ICT infrastructure in the police station, in view of this a study was conducted to find out the availability of computers in the police stations. The results of the study showed that 95% of the respondents indicated that there are inadequate computers in the police stations, then only 5% of the respondents indicated that there is availability of computers in their respective police stations for only those in management positions (High Command Level). Further, the study was conducted to find out how many officers owned personal computers, the results showed that 77% of the respondents had or owned personal computers for personal use and only 23% did not own personal computers. With these results the researcher was able to conclude that it would be very easy for Zambia Police Officers to adopt to the usage of any ICT innovation as the proposed automated crime mapping system could even be accessed using personal computers while waiting for the supply of institutional computers. For digital crime maps to be automated there is need consider digitalizing the stage of reporting, capturing and recording of crime data by introducing a mobile application platform. The study introduced mobile and web application platforms to be used to capture crime reports. The crime data captured from both the web application and Mobile application should be stored in one central cloud database.

In order to understand the type and nature of mobile devices used by the general public, questionnaires were distributed to citizens who were visiting the police stations for various reasons across Lusaka city. The results show that 86% of the general public own phones or other mobile devices that have access to internet. The study further wished to know and uncover the type of the mobile operating systems of the mobile devices considered in the survey, the results indicated that 72% of those had android operating system,14% had Microsoft windows while only 8% have Apple and 6% had unknown mobile operating systems. With these results it is evident that in order for the system to be accessed by majority citizens it had to be belt on both web and android application platforms.

5.2.2 **System Prototype Implementation**

The problems that are brought about by manual and paper crime mapping such as inefficiency, inaccuracies, poor management and non-instant availability of crime data can be mitigated through automating processes involved in mapping crime in the Zambia Police Service. The current business processes were mapped as indicated in fig.3.1 and a model based on cloud architecture and spatial data was designed as indicated in fig.3.2 and fig.3.3 in chapter 3 (methodology) from which the system requirements were derived. While all the business processes and models necessary for automation were mapped, the scope of the prototype implementation was limited to developing firmware which is the initial software to be loaded when the system starts up, in this case a cloud database server. A firebase cloud database which is an open source and runs on both free and premium versions was used to implement the cloud computing module of the system. Basic functionalities including adding new crime cases, editing, deleting and viewing crime records stored in the cloud database and generation of crime maps were implemented based on the Use Cases and data models that were presented in Chapter 3. The prototype was developed using Hipper Text Markup Language (HTML), cascading style sheet (CSS) and Vue-Js programming languages for front end, while Java Server Pages(JSP) was used for the back end. The prototype was successfully developed and it shows how spatial data and cloud computing can be used to enhance crime mapping in Zambia Police, it comprises of web application and android mobile application platforms respectively all connected to a central firebase cloud database. The prototype demonstrates how crime data reports can be centrally managed and received in real time as they come from either mobile or web application platforms and stored into one central cloud database (cloud firebase). The web application will only be used by the Police to not only generate and view crime maps but also capture and record crime reports from the general public. The mobile application will only be used by the general Public to report crime cases to the police. Spatial crime spots are added to the map in real time as crime cases are reported. The test results of the prototype showed improved data capture of crime cases and also improved crime data visualization through generated crime maps the model also proved that it is more efficient and effective than the current system. Crime maps can be filtered based on the name of crime like murder, theft, rape and other type of crimes. For an institution like Zambia Police that is still depending on papers and books for its daily operations, implementing the automated crime mapping system would be a good starting point towards utilization and usage of ICT in Zambia Police Service. The model also demonstrated that cloud technologies are a better way to manage information from multiple sources, the information can readily be accessed anytime and anywhere by authorized users, it is also ideal for storage of spatial data.

5.3 Conclusion

The baseline study was conducted and a number of challenges were identified in the current manual system such as manual capturing and recording of crime reports, non-instant availability of crime data of areas with high crimes, poor crime data management, poor data visualization and many others. The study proposed a computerized crime mapping model based on cloud and spatial data to address the challenges in the current system used by the Zambia Police. The current business processes were mapped and a crime mapping model was designed and developed in order to address the challenges that were discovered in the baseline study. The proposed model is based on the Cloud Architecture, Android Mobile Application, Web Application, Google Map API and Java programming language. Test results of the proposed system shows improved spatial data visualization and reporting of crime data with reduced dependency on manual transactions, it also proved to be more effective and efficient than the current system.

5.4 Recommendation and Future Works

5.4.1 Recommendation

The study has revealed that the automated crime mapping system is desirable and effective. With the police personnel that exhibited high levels of knowledge in computers including a general population that is drifting towards the use of ICT, we recommend the adoption of the proposed model as it will improve the work efficiency within the Police Service. The model will enable members of general public to report crime cases using mobile devices hence reducing unnecessary logistical costs of physically visiting police stations.

5.4.2 Future Works

Further development of the system prototype to a full-fledged crime mapping system will be carried out. The current prototype is but a simple system showing proof of the concept of crime mapping automation using spatial data and cloud computing. Some future works that can be done on this system include;

i. The crime dataset generated through crime reporting platforms in this system can be integrated with machine and deep learning techniques to predict future crime occurrences.

ii. Introducing case docket management would add value to the system. A case docket contains information like address and date of crime, statements, reports from experts, witnesses, details of complainants and suspects. The public prosecutor makes use of the all the information in the case docket to present a case in the court of law.

5.5 Summary

In this chapter, the results presented in Chapter four are presented. In section 5.2.1, the results obtained from the baseline study were discussed. In section 5.2.2, the system implementation was discussed. Lastly, the conclusion of the study, the recommendations and the future works were presented.

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APPENDICES

APENDIX A: Questionnaire for Zambia Police

UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

CRIME MAPPING MODEL BASED ON CLOUD AND SPATIAL DATA - A CASE OF ZAMBIA POLICE SERVICE.

QUESTIONNAIRE

Dear Respondent,

My name is **JONATHAN PHIRI (0964801091)** and I am a student at the University of Zambia pursuing a Master of Engineering degree in Information and Communication Technology Security (ICT-SEC). I am carrying out a baseline study to profile crime-recording practices by Zambia police officers. The research is aimed at designing a computerized crime reporting & mapping system in a bid to introduce electronic geographical crime maps for crime pattern analysis. In order to accomplish this study, I need input from the **Police Service** on the experiences and knowledge about crime reporting and crime maps to assist with information on the research subject.

Kindly help by providing answers to the questions below and provide attachments where possible. Your responses will be treated with the highest level of confidentiality and will strictly be used for academic purposes.

Thank you in anticipation

Research Supervisor: Dr. Phiri Jackson- Email – Jackson.phiri@cs.unza

Assistant Dean-Postgraduate: Dr. C. Kahanji Email Charles.kahanji@unza.zm

INSTRUCTIONS:

Please tick or cross on the applicable choices provided, or write where indicated.

SECTION A – BACKGROUND INFORMATION

1. What is your gender?

☐ Male ☐ Female

2. What is your age (number of years)?

18 – 29	30 – 45	46 – 55	Above 55

3. Which Department do you work under?

☐ CID ☐ VSU

Other specify ……………………………………………………………

4. Work experience in the service

☐ Less than 12 months ☐ 1– 5 years ☐ 10years ☐ Above 10 years

5. Education Level

☐ O' Level/Grade 12 ☐ College Certificate ☐ Diploma

☐ Degree ☐ Masters Degree ☐ Doctorate/PhD

6. What is your level of knowledge in computers?

☐ Basic ☐ Good ☐ Excellent

7. Do you have a laptop, phone or any other device that can access internet services?

☐ Yes ☐ No

8. What is the mobile operating system of your phone/device?

☐ Android ☐ Apple ☐ Windows

Other Specify ……………………………………………………………………..

SECTION B – CRIME MAPPING AND RECORDING PRACTICES

9. Briefly list the order of steps or procedures of recording a reported crime
   i. ………………………………………………………..
   ii. ……………………………………………………….
   iii. ……………………………………………………….
   iv. ………………………………………………………
   v. ………………………………………………………
   vi. ………………………………………………………..

10. Indicate the common ways through which crimes are reported by the general public

☐ Walk to Police Station ☐ Make a Call ☐ Email

Other specify
……………………………………………………………………………………

11. How are crime reports recorded at your station?

☐ Books/papers ☐ Electronic

Other specify……………………………………………………………………………

12. How are the crime records stored?

☐ Books/papers ☐ Electronic

13. Does the station make use of crime mapping technique (Analyzing crime patterns of particular areas using maps)?

☐ Yes ☐ No

14. Does the station have a computerized system to help calculate specific crime statistics of particular areas?

. ☐ Yes ☐ No

15. If the response to Q16 is no, what are the reasons for not migrating to the computerized system?

☐ Luck of skills ☐ Inadequate computers ☐ No Confidence

Other specify……………………………………………………………………………

16. Is the Station equipped with Computers?

☐ Yes ☐ No

17. Do you have or own a personal Computer?

☐ Yes ☐ No

18. Is crime data instantly available when needed?

☐ Yes ☐ No

19. Do you face challenges in managing and visualizing crime data?

☐ Yes ☐ No

END

THANK YOU FOR YOUR PARTICIPATION

APENDIX B: Questionnaire for General Public

UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

CRIME MAPPING MODEL BASED ON CLOUD AND SPATIAL DATA - A CASE OF ZAMBIA POLICE SERVICE

Dear Respondent,

My name is **JONATHAN PHIRI (0964801091)** and I am a student at the University of Zambia pursuing a Master of Engineering degree in Information and Communication Technology Security (ICT-SEC). Conduct a baseline study to ascertain the extent of challenges faced by Zambia police in crime mapping. This research is aimed at designing a computerized crime mapping system in a bid to introduce electronic geographical crime maps.

I need input from the general Public to assist with information on the research subject.

Kindly help add quality to this research work by providing answers to the questions below and provide attachments where possible. Your responses will be treated with the highest level of confidentiality and will strictly be used for academic purposes.

Thank you in anticipation

For any information about this survey, you may wish to contact the following;

Research Supervisor: Dr. Phiri Jackson- Email – Jackson.phiri@cs.unza

Assistant Dean-Postgraduate: Dr. C. Kahanji Email Charles.kahanji@unza.zm

INSTRUCTIONS:

Please tick or cross on the applicable choices provided, or write where indicated.

SECTION A – BACKGROUND INFORMATION

20. What is your residential area/town? ……………………………………………………….. ………………………………………………………………………………… …………..

21. What is your gender?

☐ **Male** ☐ **Female**

1. What is your age (number of years)?

18 – 29	30 – 45	46 – 55	Above 55

22. Work experience in the service

☐ 0 – 12 months ☐ 2 – 19 years ☐ 20 years and above

23. Education background

☐ O' Level/Grade 12 ☐ College Certificate ☐ Diploma

☐ Degree ☐ Masters degree ☐ Doctorate/PhD

24. Which of the following best describes your occupation?

☐ Student ☐ PrivateSectorEmployee

☐ GovernmentEmployee ☐ Unemployed

☐ Self-employed

SECTION B – CRIME REPORTING

25. Do you have a phone or any other handset that is able to access internet?

☐ Yes ☐ No

26. What is the mobile operating system of your phone/mobile Handset?

☐ Android ☐ Apple ☐ Microsoft

Other Specify ……………………………………………………………………

27. Have you ever reported a crime to the Police Station?

☐ Yes ☐ No

28. If the answer to question 8 is yes, what method did you use?

☐ Went to Police Station ☐ Made a Call ☐ Wrote SMS

Other specify ……………………………………………………………………

END

THANK YOU FOR YOUR PARTICIPATION

APENDIX C: Complete System Prototype Code

LOGIN

```
<template>
 <v-card max-width="500" color="green lighten-2" class="mx-auto mt-4 pa-4">
   <v-card-title>Login</v-card-title>
    <v-card-text>
      <v-form  ref="form" v-model="valid" lazy-validation>
         <v-text-field v-model="email" :rules="emailRules" label="E-mail"
required></v-text-field>
         <v-text-field v-model="passWord"
         :rules="passWordRules"
          :append-icon="showPassword ? 'mdi-eye' : 'mdi-eye-off'"
          :type="showPassword ? 'text' : 'passWord'"
          label="Password" required
          @click:append="showPassword = !showPassword"></v-text-field>
        <p class="red-text center" v-if="feedback">{{feedback}}</p>
        <v-btn :disabled="!valid" color="success" class="mr-4"
@click="validate">Login</v-btn>
        <v-btn color="error" class="mr-4" @click="reset">Clear</v-btn>
      </v-form>
      </v-card-text>
  </v-card>

</template>

<script>
import firebase from 'firebase';
require('firebase/auth')
export default {
  data: () => ({
    showPassword: false,
```

```
    valid: true,
    passWord: null,
    feedback: null,
    passWordRules: [
      v => !!v || "Password is required"
    ],
    email: "",
    emailRules: [
      v => !!v || "E-mail is required",
      v => /.+@.+\..+/.test(v) || "E-mail must be valid"
    ]
  }),

  methods: {
    validate() {
      if (this.$refs.form.validate()) {
          firebase.auth().signInWithEmailAndPassword(this.email, this.passWord)
          .then(cred =>{
             this.$router.push({name: 'Dashboard'})
          }).catch(err => {
              this.feedback = err.message;
            });
      } else {
        //console.log("Pass")
      }
    },
    reset() {
      this.$refs.form.reset();
    },
  }
};
</script>
```

REGISTRATION

```
<template>
  <v-card max-width="520" color="green lighten-2" class="mx-auto mt-4 mb-4 pa-
4">
    <v-card-title>Officer Registration</v-card-title>
     <v-card-text>
       <v-form  ref="form" v-model="valid" lazy-validation>
         <v-row>
           <v-col cols="12" sm="6" md="6">
             <v-text-field v-model="firstName" :rules="nameRules" label="First Name"
required></v-text-field>
           </v-col>
           <v-col cols="12" sm="6" md="6">
           <v-col cols="12" sm="6" md="6">
             <v-text-field     v-model="serviceNumber"     :rules="serviceNumberRules"
label="Service Number" required></v-text-field>
           </v-col>
         </v-row>

          <v-row>
           <v-col cols="12" sm="6" md="6">
              <v-select
                v-model="station"
                :items="stations"
                 item-text="text"
                 item-value="value"
                :rules="[v => !!v || 'Stations is required']"
                label="--Select Station--"
                required></v-select>
            </v-col>

           <v-col cols="12" sm="6" md="6">
              <v-select
                v-model="department"
                :items="departments"
```

```
        :rules="[v => !!v || 'Departments is required']"
        label="--Select Department--"
        required></v-select>
   </v-col>
</v-row>

<v-row>
  <v-col cols="12" sm="6" md="6">
    <v-select
      v-model="rank"
      :items="ranks"
      :rules="[v => !!v || 'Ranks is required']"
      label="--Select Rank--"
      required></v-select>
  </v-col>
  <v-col cols="12" sm="6" md="6">
    <v-select
      v-model="position"
      :items="positions"
      :rules="[v => !!v || 'Position is required']"

      @click:append="showPassword = !showPassword"></v-text-field>



<v-row>
  <v-col cols="12" sm="6" md="6">
    <p class="mt-6 font-weight-black">Is Administrator?</p>
  </v-col>
  <v-col cols="12" sm="6" md="6">
    <v-checkbox v-model="isAdmin"></v-checkbox>
   </v-col>
</v-row>
```

```
        <p class="red-text center" v-if="feedback">{{feedback}}</p>
         <v-btn          :disabled="!valid"          color="success"          class="mr-4"
@click="signup">Register</v-btn>
         <v-btn color="error" class="mr-4" @click="reset">Clear</v-btn>
          <v-btn text>
           <span class="mr-2">OR</span>
         </v-btn>
         <v-btn @click="redirectToLogin()">
           <span class="mr-2">Login</span>
         </v-btn>
      </v-form>
      </v-card-text>
    </v-card>
  </template>

  <script>
  import db from "@/firebase/fb";
  import firebase from 'firebase';
  require('firebase/auth')
  export default {
    data: () => ({
      showPassword: false,
      valid: true,
      serviceNumber: null,
      passWord: null,
      firstName: null,
      lastName: null,
      phoneNumber: null,
      district: "Lusaka",
      division: "Lusaka",
      position: null,
      department: null,
      station: null,
      rank: null,
```

```
feedback: null,
isAdmin: false,
stations: [],
phoneNumberRules: [
  v => !!v || "Phobe Number is required",
  v => (v && v.trim().length > 10) || "Name must be atleast 10 character long"
],

passWordRules: [
  v => !!v || "Password is required",
  v => (v && v.trim().length > 8) || "Name must be atleast 8 characters long"
],
serviceNumberRules: [
  v => !!v || "Service Number is required",
  v => (v && v.trim().length > 4) || "Name must be atleast 5 characters long"
],
nameRules: [
  v => !!v || "Name is required",
  v => (v && v.trim().length > 1) || "Name must be atleast 1 character long"
],
email: "",
emailRules: [
  v => !!v || "E-mail is required",
  v => /.+@.+\..+/.test(v) || "E-mail must be valid"
],

// stations: ["Chawama", "Chelstone", "Chilenje", "Emmasdale", "Kabwata" , "Kanyama", "Lusaka Central", "Matero", "Woodlands"],

departments: ["Criminal Investigations", "General Duties", "Traffic"],

ranks: ["IG", "DIG-1", "DIG-2", "COMPOL", "SACP" , "ACP", "S/SUPT", "SUPT", "C/INSP", "INSP", "SGT", "CONST"],
```

```
  positions: ["CIO", "Investigator", "Records Officer", "Secretary"],
}),

created() {
  db.collection("stations")
    .get()
    .then(crimes => {
      crimes.docs.forEach(doc => {
        let elem = doc.data();
        var infowindow;
        var lastWindow = null;
        this.stations.push({
          value: elem.station,
          text: elem.station
        });
      });
  });
},
```

```
          db.collection("officers").doc(cred.user.uid).set({
            firstName: this.firstName.trim(),
            lastName: this.lastName.trim(),
            serviceNumber: this.serviceNumber.trim(),
            division: this.division.trim(),
            district: this.district.trim(),
            department: this.department.trim(),
            position: this.position,
            rank: this.rank.trim(),
            isAdmin: this.isAdmin,
            userId: cred.user.uid
          })
        }).then(() =>{
```

```
                this.$router.push({name: 'Login'})
               }).catch(err => {
                  this.feedback = err.message;
               });
            } else{
                this.feedback ="Officer already registered with this service number";
            }
       });
     }//End validate
    },
    reset() {
      this.$refs.form.reset();
    },

    redirectToLogin(){
       this.$router.push({name: 'Login'})
    },
  }
};
</script>
```

ADDING A CASE

```
<template>
  <div class="text-center">
    <v-dialog v-model="dialog" width="500">
      <template v-slot:activator="{ on }">
        <v-btn color="green lighten-2" dark v-on="on">Add new case</v-btn>
      </template>
      <v-card>
        <v-card-title>
          <h2
-text>
          <v-form ref="form">
            <v-row>
```

```
                <v-col cols="12" sm="6" md="6">
                  <v-text-field v-model="firstName" :rules="nameRules" label="First Name" required></v-text-field>
                </v-col>
                <v-col cols="12" sm="6" md="6">
                  <v-text-field v-model="lastName" :rules="nameRules" label="Last Name" required></v-text-field>
                </v-col>
              </v-row>
              <v-row>
                <v-col cols="12" sm="6" md="6">
                  <v-text-field v-model="nrc" :rules="nameRules" label="NRC" required></v-text-field>
                </
              <v-select
                v-model="subject"
                :items="items"
                :rules="[v => !!v || 'Subject is required']"
                label="SUBJECT"
                required></v-select>
              <v-text-field v-model="place" label="Place of Occurence" required></v-text-field>
              <v-textarea label="Particulars of Offense" v-model="particularOfOffence"></v-textarea>
              <v-menu
                  v-model="menu2"
                  :close-on-content-click="false"
                  :nudge-right="40"
                  transition="scale-transition"
                  offset-y
                  full-width
                  min-width="290px">
                  <template v-slot:activator="{ on }">
                      <v-text-field
```

```
                    v-model="date"

-field>
              </template>
              <v-date-picker v-model="date" @input="menu2 = false"></v-date-
picker>
            </v-menu>
            <p class="red-text center" v-if="feedback">{{feedback}}</p>

          </v-form>
        </v-card-text>
        <v-card-actions>
          <div class="flex-grow-1"></div>
       <!--    <v-btn right class="success mx-0 mt-3 mr-4" @click="dialog =
false">Add Case</v-btn>
          <v-btn class="danger mx-0 mt-3 mr-3" @click="dialog = false">Cancel</v-
btn>-->
            <v-btn right class="success mx-0 mt-3 mr-4" @click="validate">Add
Case</v-btn>

            <v-btn color="error" class="mr-4" @click="reset">Clear</v-btn>
        </v-card-actions>
      </v-card>
    </v-dialog>
  </div>
</template>

<script>
import db from "@/firebase/fb";
import firebase from 'firebase';
require('firebase/auth')
  export default {
    name: 'Addcase',
  data: () => ({
```

```
            date: new Date().toISOString().substr(0, 10),
            menu2: false,
            feedback: null,
            dialog: false,
            firstName: "",
            lastName: "",
            nameRules: [
              v => !!v || "Name is required",
             // v => (v && v.length < 1) || "Name must be less than 1 character long"
            ],
            nrc: "",
            residence: "",
            subject: "",
            occurence: "",
            particularOfOffence: "",
            place: "",
            items: ["== SELECT SUBJECT ==","Assault", "Burglary", "Drugs",
"Robbery"],
          }),
          methods: {
            validate() {
              var currentWindow = this;
              if (this.$refs.form.validate()) {
                  currentWindow.$router.push({name: 'Dashboard'})
                // db.collection("occurences").add({
                //    subject: this.subject,
                //    icon: this.subject,
                //    place: this.place,
                //    date: this.date,
                //    latitude: window.lat,
                //    longitude: window.lng,
                //    particularOfOffence: this.particularOfOffence,
                //    status:"Pending",
                // })
```

```
            // .then(function(docRef) {
            //          db.collection("occurences").doc(docRef.id).update({occurenceId:
docRef.id})
            //    //currentWindow.$router.push({name: 'Dashboard'})
            // })
            // .catch(function(error) {
            //    console.error("Error adding document: ", error);
            // });
          } else {
            this.feedback = "This service number can not be empty";
          }
        },
        reset() {
          this.$refs.form.reset();
        },
      }
    }
</script>
```

CREATING A BAR CHART

```
<script>
import { Bar } from "vue-chartjs";
import db from "@/firebase/fb";

export default {
  extends: Bar,



  data: function() {
    return {
      markers: [],
      locations: [{value: "", text: "== SELECT  LOCATION =="}],
      subject: "",
      byLocation: null,
```

```
    subjects: {},
    points:[],
    count: 0
  };
},

 created() {
    db.collection("crimes")
      .get()
      .then(crimes => {
        crimes.docs.forEach(doc => {
          let coord = doc.data();
          if (!this.subjects[coord.place]){
            this.subjects[coord.place] = 1;
          } else {
            this.subjects[coord.place] = ++this.subjects[coord.place];
          }
        });
        /*Object.entries(this.subjects).forEach(([key, value]) =>{
            console.log(key, value)
          })*/
          this.points = Object.values(this.subjects);
          this.points.push(0);
          this.populateGraph();
      }); //End for each
  },

              backgroundColor: "#f87979",
              data: this.points.sort()
            }
          ]
        },
        { responsive: true, maintainAspectRatio: false }
      );
```

```
      }
    }
};
</script>
```

CREATING A LINE GRAPH

```
<script>
import { Line } from "vue-chartjs";
import db from "@/firebase/fb";

export default {
  extends: Line,
  data: function() {
    return {
      crimes: {},
      points:[],
    };
  },

   created() {
      db.collection("crimes")
        .get()
        .then(crimes => {


            for(var i = 1; i < 13; i++){
                if (i < 10){
                  this.crimes["0" + i] = 0;
            tooltips:{
              enabled: false
            },
            /*
            datasets: [
              {
                label: "Crimes By Location",
```

```
          backgroundColor: "#f87979",
          data: Object.values(this.subjects)
        }
      ]*/

      datasets: [
     {
      label: "Crimes Reported Monthly 2019",
      data: this.points,
      backgroundColor: "transparent",
      borderColor: "rgba(1, 116, 188, 0.50)",
      pointBackgroundColor: "rgba(171, 71, 188, 1)"
     }
    ]
     },
     { responsive: true, maintainAspectRatio: false }
    );
   }

  },
};
</script>
```

CASES

```
<template>
  <div class="dashboard">
    <v-container class="my-5 ">
      <h1 class="subheading grey--text">Cases Pending Review</h1>

        <v-card>

          <v-card-title>
          Cases Pending Review
```

```
              <v-spacer></v-spacer>
              <v-text-field
                v-model="search"
                append-icon="search"
                label="Search"
                single-line
                hide-details
              ></v-text-field>
            </v-card-title>
              <v-data-table
                :headers="headers"
                :items="occurences"
                :items-per-page="5"
                :search="search"
                class="elevation-1">
        <template v-slot:top>
        <v-toolbar flat color="white">
            <v-dialog v-model="dialog" max-width="500px">
              <v-card>
                <v-card-title>
                  <span class="headline">{{ formTitle }}</span>
                </v-card-title>
                <v-card-text>
                  <v-container>
                    <v-text-field readonly v-model="editedItem.subject" label="Subject"></v-text-field>
                    <v-text-field readonly v-model="editedItem.particularOfOffence" label="Particular of Offence"></v-text-field>
                    <v-text-field readonly v-model="editedItem.date" label="Date"></v-text-field>
                    <v-select
                      v-model="investigator"
                      :items="investigators"
                      item-text="name"
```

```
                item-value="id"
                :rules="[v => !!v || 'Assign investigator to approve']"
                label="Investigator"
                required></v-select>
            </v-container>
          </v-card-text>

          <v-card-actions>
            <v-spacer></v-spacer>
            <v-btn color="blue darken-1" text @click="close">Cancel</v-btn>
            <v-btn color="blue darken-1" text @click="save">Approve</v-btn>
          </v-card-actions>
        </v-card>
      </v-dialog>
    </v-toolbar>
  </template>

  <template v-slot:item.action="{ item }">
    <v-icon
      small
      class="mr-2"
      @click="editItem(item)">visibility</v-icon>
  </template>

  </v-data-table>
       </v-card>

 </v-container>

</div>
</template>

<script>
  import db from '@/firebase/fb'
```

```
export default {
 data: () => ({
    dialog: false,
    occurences: [],
    investigators: [],
    search: '',
    occurenceId: '',
     headers: [
      { text: 'Subject',
        value: 'subject',
        align: 'left',
        sortable: true,},
      { text: 'Particulars of Offence', value: 'particularOfOffence' },
      { text: 'Date of Occurence', value: 'date' },
      { text: 'Status', value: 'status' },
      { text: 'Action', value: 'action', sortable: false },
    ],
    investigator: "",
    editedIndex: -1,
        this.investigators.push({
          name: change.doc.data().firstName,
          id: change.doc.id
        })
      }
    })
  })
 },


 computed: {
  formTitle () {
    return this.editedIndex === -1 ? 'New Item' : 'Case Details'
   },
```

```
  },
  watch: {
    dialog (val) {
      val || this.close()
    },
  },

methods: {

    editItem (item) {
      this.editedIndex = this.occurences.indexOf(item)
      this.editedItem = Object.assign({}, item)
      this.dialog = true
    },

    close () {
      this.dialog = false
      setTimeout(() => {
        this.editedItem = Object.assign({}, this.defaultItem)
        this.editedIndex = -1
      }, 300)
    },

    save () {
      if (this.editedIndex > -1) {
        Object.assign(this.occurences[this.editedIndex], this.editedItem)
        this.occurenceId = this.editedItem.occurenceId;
          db.collection("crimes").add({
              subject: this.editedItem.subject,
              icon: this.editedItem.subject,
              place: this.editedItem.place,
              date: this.editedItem.date,
              latitude: this.editedItem.latitude,
              longitude: this.editedItem.longitude,
```

```
              investigator: this.investigator,
              status:"Approved",
              particularOfOffence: this.editedItem.particularOfOffence,
              occurenceId: this.editedItem.occurenceId
              //station: this.editedItem.station,
              //userUrl: this.userUrl,
            }).then(function(docRef) {
             db.collection("crimes").doc(docRef.id).update({crimeId: docRef.id})
            }).catch(function(error) {
              console.error("Error adding document: ", error);
            });
        } else {
          this.feedback = "This service number can not be empty";
        }
        this.close()
      },

      updateOb(){
        db.collection("occurences").add({
              status:"Approved",
            }).then(function(docRef) {
              console.log("Document written with ID: ", docRef.id);
            }).catch(function(error) {
              console.error("Error adding document: ", error);
            });
      }
    },

  }
</script>

<style>

</style>
```

CRIME REGISTER

```
<template>
  <div class="dashboard">
    <v-container class="my-5 ">
      <h1 class="subheading grey--text">Crime Resgister</h1>
        <v-card>


          <v-card-title>
          Crime Resgister
          <v-spacer></v-spacer>
          <v-text-field
            v-model="search"
            append-icon="search"
            label="Search"
            single-line
            hide-details
          ></v-text-field>
        </v-card-title>



          <v-data-table
            :headers="headers"
            :items="occurences"
            :items-per-page="5"
            :search="search"
            class="elevation-1">
          </v-data-table>
        </v-card>

    </v-container>

  </div>
</template>
```

```
<script>
  import db from '@/firebase/fb'

  export default {
    data: () => ({
        occurences: [],
        search: '',
         headers: [
          { text: 'Subject',
            value: 'subject',
            align: 'left',
            sortable: true,},
          { text: 'Particulars of Offence', value: 'particularOfOffence' },
          { text: 'Date of Occurence', value: 'date' },
          { text: 'Date of Result', value: 'date' },
          { text: 'Status', value: 'status'},
        ],
    }),

    created() {
      db.collection('crimes').onSnapshot(res => {
        const changes = res.docChanges();
        changes.forEach(change => {
          if (change.type === 'added') {
            this.occurences.push({
              ...change.doc.data(),
              id: change.doc.id
            })
          }
        })
      })
    }
  }
```

```
</script>

<style>

</style>
```

DASH BOARD

```
<template>
  <div class="dashboard">
    <v-container class="my-5 ">
      <h1 class="subheading grey--text">Occurence Book</h1>
        <v-card>
          <v-card-title>
          Occurence Book
          <v-spacer></v-spacer>
          <v-text-field
            v-model="search"
            append-icon="search"
            label="Search"
            single-line
            hide-details
          ></v-text-field>
        </v-card-title>



          <v-data-table
            :headers="headers"
            :items="occurences"
            :items-per-page="5"
            :search="search"
            class="elevation-1">
                         </v-col>
                        </v-row>
                        <v-row>
```

```
<v-col cols="12" sm="6" md="6">
  <v-text-field readonly v-model="nrc" label="NRC"></v-
text-field>
</v-col>
<v-col cols="12" sm="6" md="6">
  <v-text-field readonly v-model="age" label="Age"></v-
text-field>
  </v-col>
</v-row>
<v-text-field readonly v-model="residence"
label="Residential Address"></v-text-field>
</v-col>

<v-col cols="6" sm="4" md="4">
  <v-btn
    color="primary"
    dark
    class="ma-2"
    @click="modalAddSuspect = true">Add Suspect</v-btn>
   <v-subheader>Suspects</v-subheader>
    <v-data-table
     :headers="suspects"
     :items="defendant"
     :items-per-page="5"
     :search="search"
     class="elevation-1"> </v-data-table>
</v-col>

<v-dialog
  v-model="modalAddSuspect"
  max-width="500px">
  <v-card>
    <v-card-title>
          <span class="headline">Add Suspect</span>
```

```
</v
      </v-row>
      <v-row>
        <v-col cols="12" sm="6" md="6">
          <v-text-field   v-model="nrc"   :rules="nrcRules"
label="NRC"></v-text-field>
        </v-col>
        <v-col cols="12" sm="6" md="6">
          <v-text-field   v-model="age"   :rules="ageRules"
label="Age"></v-text-field>
         </v-col>
      </v-row>
        <v-text-field                    v-model="residence"
label="Residential Address"></v-text-field>
    </v-row>
   </v-container>
   <small>*indicates required field</small>
   </v-form>
  </v-card-text>
 <v-card-actions>
   <v-btn  :disabled="!valid"  color="success"  class="mr-4"
@click="saveSuspect">Save</v-btn>
   <v-btn              color="error"              class="mr-4"
@click="reset">Clear</v-btn>
 </v-card-actions>
 </v-card>
</v-dialog
<v-col cols="6" sm="4" md="4">
 <v-btn
  color="primary"
  dark
  class="ma-2"
  @click="modalAddVariable = true">Add Item</v-btn>
 <v-subheader>Recovered Items</v-subheader>
```

```
<v-data-table
  :headers="recovered"
  :items="recovered"
  :items-per-page="5"
  :search="search"
  class="elevation-1"> </v-data-table>
</v-col>
</v-row>
<v-form ref="form" v-model="valid" lazy-validation>
<v-container>
  <v-row>
    <v-text-field  v-model="variable" label="Variable recovered"></v-text-field>
    <v-text-field  v-model="description" label="Description"></v-text-field>
     <v-menu
       v-model="menu2"
       :close-on-content-click="false"
       :nudge-right="40"
       transition="scale-transition"
       offset-y
       full-width
       min-width="290px">
       <template v-slot:activator="{ on }">
         <v-text-field
           v-model="date"
led="!valid" color="success" class="mr-4" @click="saveVariable">Save</v-btn>
<v-btn color="error" class="mr-4" @click="reset">Clear</v-btn>
</v-card-actions>
</v-card>
</v-dialog>
</v-card-text>
<div style="flex: 1 1 auto;"></div>
```

```
            </v-card>
          </v-dialog>
      </template>

    <template v-slot:item.action="{ item }">
      <v-icon
        small
        class="mr-2"
        @click="editItem(item)">edit</v-icon>
      <v-icon
        small
        class="mr-2"
        @click="editItem(item)">add</v-icon>
    </template>
    </v-data-table
```

CRIME MAPPER

```
<template name="Mapper">
  <div id=container" >
    <!--  <v-row
        class="mb-6"
        no-gutters>
          <v-col
            v-for="n in 2"
            :key="n"
            :lg="cols[n - 1]"
            :md="6"
            :sm="cols[n - 1]"> -->
              <div class="google-map" id="mapName">


              </div>
      <!--   </v-col> -->


    <!--      <v-col
```

```
            v-for="n in 3"
            :key="n"
            cols="sm">-->
              <div class="filters" id="filters" style="margin-left: 1095px; margin-right: 10px; padding-top: 8px;">
                <v-select
                  v-model="subject"
                  :items="subjects"
                  item-text="text"
                  item-value="value"
                  label="--Select Subject--"
                  required></v-select
                <v-select
                  v-model="byLocation"
                  :items="locations"
                  item-text="text"
                  item-value="value"
                  label="--Select Location--"
                  required></v-select>
              </div>
        <!--   </v-col>
        </v-row> -->
    </div>
  </template>

  <script>
  import db from "@/firebase/fb";
  export default {
    name: "Mapper",
    props: ["Mapper"],
    data: function() {
      //3.svg - Burglary, 7.svg -  Fraud, 10.svg - Robbery Dru = 5.svg
      return {
        mapName: this.name + "-map",
```

```
    map: null,
    bounds: null,
    markers: [],
    locations: [{value: "", text: "== SELECT  LOCATION =="}],
    subject: "",
    byLocation: null,
    location: "",
    subjects: [{value: "", text: "== SELECT  SUBJECT =="}],
  };
},
mounted: function mounted () {
  this.populateMap("","");
},

 watch: {
   subject: function(){
      this.populateMap(this.subject, this.byLocation);
   },
   byLocation: function(){
      this.populateMap(this.subject, this.byLocation);
   }
},

methods: {
    populateMap(filter, byLocation) {
        this.bounds = new google.maps.LatLngBounds();
  // const element = document.querySelector("#" + this.mapName);
    const element = document.querySelector("#mapName");
    //const element = document.getElementById(this.mapName);
    const lat = new google.maps.LatLng(-15.6026746, 28.3380676);
    const options = {
      center: lat
    };
```

```
this.map = new google.maps.Map(element, options);

db.collection("crimes")
  .get()
  .then(crimes => {
    crimes.docs.forEach(doc => {
      let coord = doc.data();
      var infowindow;
      var lastWindow = null;
      this.subjects.push({
        value: coord.subject,
        text: coord.subject
      });

      this.locations.push({
        value: coord.place,
        text: coord.place
      });
      console.
          );
          const marker = new google.maps.Marker({
              "<strong> <br>Longitude: </strong>" +
              coord.latitude +
              "</p>" +
              "<p><strong>Date: </strong>" +
              coord.date +
              "</p>" +
              "</div>" +
              '<div class="iw-bottom-gradient"></div>' +
              "</div>";
            // A new Info Window is created and set content
            infowindow = new google.maps.InfoWindow({
              content: content,
              // Assign a maximum value for the width of the infowindow allows
```

```
            // greater control over the various content elements
            maxWidth: 320
           });
           if(!!lastWindow){
            lastWindow.close();
           // console.log(lastWindow)
           }
           infowindow.open(this.map, marker);
           lastWindow = infowindow;
          });
          this.markers.push(marker);
          this.map.fitBounds(this.bounds.extend(position));
        } else if (filter == "" && byLocation == "") {
          //const   position   =   new   google.maps.LatLng(coord.location.latitude,
coord.location.longitude);
          const position = new google.maps.LatLng(
           coord.latitude,
           coord.longitude
          );
          const marker = new google.maps.Marker({
           position,
           icon: coord.icon.toLowerCase() + ".svg",
           map: this.map
           // title: " Murder " + '\n\n' +" Chilanga Area " + '\n\n' + " 20/09/2019 "
          });
          marker.addListener("click", function() {
           var
  -title"><strong>PLACE: </strong>' +
            coord.place +
            "</div>" +
            "<br><strong>Latitude: </strong>" +
            coord.latitude +
            "<strong> <br>Longitude: </strong>" +
            coord.latitude +
```

```
            "</p>" +
            "<p><strong>Date: </strong>" +
            coord.date +
            "</p>" +
            "</div>" +
            '<div class="iw-bottom-gradient"></div>' +
            "</div>";
          // A new Info Window is created and set content
           infowindow = new google.maps.InfoWindow({
            content: content,
            // Assign a maximum value for the width of the infowindow allows
            // greater control over the various content elements
            maxWidth: 320
          });
          if(!!lastWindow){
            lastWindow.close();
           // console.log(lastWindow)
          }
          infowindow.open(this.map, marker);
          lastWindow = infowindow;
        });
        this.markers.push(marker);
        this.map.fitBounds(this.bounds.extend(position));
      } else if (coord.place == byLocation && filter == "") {
        //const position = new google.maps.LatLng(coord.location.latitude,
coord.location.longitude);

        marker.addListener("click", function() {
          var content =
            '<div id="iw-container">' +
            '<div class="iw-title"><strong>DESCRIPTION: </strong>' +
            coord.particularOfOffence +
            "</div>" +
            '<div class="iw-content">' +
```

```
          "<p>" +
          '<div class="iw-title"><strong>PLACE: </strong>' +
          coord.place +
          "</div>" +
          "<br><strong>Latitude: </strong>" +
          coord.latitude +
          "<strong> <br>Longitude: </strong>" +
          coord.latitude +

          maxWidth: 320
        });
          if(!!lastWindow){
          lastWindow.close();
         // console.log(lastWindow)
        }
        infowindow.open(this.map, marker);
        lastWindow = infowindow;
      });
      this.markers.push(marker);
      this.map.fitBounds(this.bounds.extend(position));
    } else if (coord.place == byLocation && filter == coord.icon.toLowerCase() ) {
      //const position = new google.maps.LatLng(coord.location.latitude, coord.location.longitude);
      const position = new google.maps.LatLng(
        coord.latitude,
        coord.longitude
      );
      const marker = new google.maps.Marker({
        position,
        icon: coord.icon.toLowerCase() + ".svg",
        map: this.map
        // title: " Murder " + '\n\n' +" Chilanga Area " + '\n\n' + " 20/09/2019 "
      });
```

```
    marker.addListener("click", function() {
      var content =
        '<div id="iw-container">' +
        '<div class="iw-title"><strong>DESCRIPTION: </strong>' +
        coord.particularOfOffence +

        "</div>";
      // A new Info Window is created and set content
      infowindow = new google.maps.InfoWindow({
        content: content,
        // Assign a maximum value for the width of the infowindow allows
        // greater control over the various content elements
        maxWidth: 320
      });
        if(!!lastWindow){
        lastWindow.close();
       // console.log(lastWindow)
      }
      infowindow.open(this.map, marker);
      lastWindow = infowindow;
    });
    this.markers.push(marker);
    this.map.fitBounds(this.bounds.extend(position));
  }

  //var map = new google.maps.Map(document.getElementById("map-canvas"),options);

  // Event that closes the Info Window with a click on the map
 /* google.maps.event.addListener(this.map, "click", function() {
    infowindow.close();
  });*/
```

LOCATION PICKER

```
<template>
      <div class="google-map" id="mapName"></div>
</template>

<script>
  import $ from 'jquery'
  export default {
    name: 'Picker',
   data: function () {
    return {
      map: null,
      bounds: null
     }
   },
  mounted: function () {


      center: lskCorrdinate,
      rotateControl:true,
      mapTypeControl: true,
      zoomControl: true,
     }

{
        const bound1 = new google.maps.LatLng(this.bounds.getNorthEast().lat() +
0.01, this.bounds.getNorthEast().lng() + 0.01);
        const bound2 = new google.maps.LatLng(this.bounds.getNorthEast().lat() -
0.01, this.bounds.getNorthEast().lng() - 0.01);
        this.bounds.extend(bound1);
        this.bounds.extend(bound2)
     }
};
</script
```

PUBLICATIONS

[1] J. Phiri, J. Phiri and C. S. Lubobya, “Crime Mapping Model based on Cloud and Spatial Data: A Case Study of Zambia Police Service” International Journal of Advanced Computer Science and Applications (IJACSA), vol.11, no.1 pp.251-265, 2020. https://dx.doi.org/10.14569/IJACSA.2020.0110132

[2] J. Phiri and J. Phiri, "Crime Mapping Model based on Cloud and Spatial Data: A Case Study of Zambia Police Service," Proceedings of the International Conference in ICT , Lusaka , 2019.

https://www.researchgate.net/publication/337943341_CRIME_MAPPING_MODEL_BASED_ON_CLOUD_AND_SPATIAL_DATA_A_CASE_STUDY_OF_ZAMBIA_POLICE_SERVICE