IMPROVING POLICE INFORMATION MANAGEMENT THROUGH THE INTEGRATION OF AUTOMATED FINGERPRINT AND GEOGRAPHICAL INFORMATION SYSTEM SPATIAL DATA

BY

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DECLARATION

I, **JEREMIAH J. MWIINGA** do hereby declare that this dissertation is my own original work and has not been submitted to any other college, institution, or university other than the University of Zambia.

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APPROVAL

This dissertation, by Jeremiah J. Mwiinga has been approved as partial fulfilment of the requirements for the award of Master of Science in Computer Science by the University of Zambia.

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DEDICATION

To my lovely wife, Charity Chikandila Mwiinga, and our three beloved children Shanice, Kairos and Kyra.

ABSTRACT

Efficient information management is paramount for law enforcement agencies worldwide, including the Zambia Police Service. This study aims to address the challenges faced by the Zambia Police Service through the improvement of their automation system and the integration of biometric features and mobile applications. By examining the perspectives of police officers and proposing actionable recommendations, this research seeks to modernize and optimize the workflow of the Zambia Police Service, ultimately contributing to enhanced public safety. A mixed-methods approach was adopted, incorporating both qualitative and quantitative research methodologies. A survey was conducted among Zambia Police Service officers to gather insights into their satisfaction with the current automation system, their familiarity with biometric integration, and their suggestions for improvement. Additionally, baseline data was collected to understand the existing workflow and information management practices within the Zambia Police Service. The survey revealed that while a majority of officers expressed satisfaction with the current automation system, there were identified areas for improvement, including user interface, data integration, and processing speed. Moreover, officers demonstrated a moderate level of familiarity with biometric integration, with potential benefits recognized in terms of operational efficiency. Concerns regarding privacy issues, technical challenges, and resistance to change were also highlighted. These findings underscore the need for targeted interventions and strategic planning to address the identified issues. This study provides actionable recommendations for the Zambia Police Service to enhance their automation system and introduce innovative features such as biometric integration and mobile applications. By adopting a user-centric approach, implementing comprehensive training programs, and collaborating with IT experts, the Zambia Police Service can overcome existing challenges and create a more efficient and technologically advanced information management system. Through continuous improvement efforts, the Zambia Police Service can further optimize its workflow, contributing to improved public safety and law enforcement outcomes.

Keywords: Police information systems, Biometric integration, Workflow efficiency, Automation improvement, Law enforcement technology.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ZP	Zambia Police Service
ICT	Information Communication and Technology
IMS	Information Management System
SDK	Software Development Kit
IDE	Integrated Development Environment
GIS	Geographical Information System
GAM	Geographical Analysis System
GEM	Geographical Explanations System
ABIS	Automated Biometric Identification System
RBAC	Role Based Access Control model
NASA	National Aeronautics and Space Administration
ZPIMS	Zambia Police Information Management System
DSDM	Dynamic Systems Development Method
JDK	Java Development Kit

CHAPTER 1

RESEARCH INTRODUCTION

1.1 Introduction

The opening chapter serves as an introduction to the research endeavor. Commencing with an exploration of the research context, the chapter unfolds with an articulation of the research problem, subsequently presenting the study's overarching aim. Following this, the chapter delineates the specific objectives and research questions guiding the investigation. A discussion on the significance of the study ensues before concluding with a comprehensive summary encapsulating the key elements addressed throughout the chapter.

1.2 Background

The Zambia Police Service faces a multitude of challenges in effectively carrying out its duties, reflecting broader issues encountered by law enforcement agencies in developing countries. Key challenges include limited transportation resources, insufficient human personnel, and a lack of essential Information and Communication Technology (ICT) tools [1]. At present, the workflow within the Zambia Police heavily relies on cumbersome paper-based processes, exacerbating operational inefficiencies[2].

In many instances, Police Posts encounter difficulties due to the depletion or unavailability of essential forms, leading to situations where members of the public are asked to cover the costs of photocopying. This reliance on manual documentation also means that individuals often need to physically visit Police Stations to report crimes, resulting in delays and hindrances in the reporting process.

Moreover, inadequate tools and technology at crime scenes impede the collection of comprehensive evidence, further complicating investigative procedures. The preservation of evidence under these circumstances becomes challenging, potentially compromising the integrity of criminal investigations.

To address these pressing issues, there is a critical need to modernize and streamline the information management system utilized by the Zambia Police. Integration of biometric and Geographic Information System (GIS) data presents an opportunity to revolutionize policing practices in the country[3]. By leveraging biometric data, such as fingerprints or facial recognition, law enforcement agencies can enhance

identification processes and improve accuracy in suspect tracking. Additionally, the incorporation of GIS technology enables real-time visualization of crime data, facilitating informed decision-making and resource allocation for crime prevention and response efforts[4].

In summary, the Zambia Police Service stands to benefit significantly from the adoption of advanced information management systems, underpinned by biometric and GIS technologies. These innovations offer the potential to overcome existing operational challenges and empower law enforcement personnel to more effectively combat crime and ensure public safety.

1.3 Aim of the Study

To design an improved and integrated Police information management system through use of biometric and geographic data.

1.4 Research Objectives

1) To enhance the efficiency and effectiveness of the Zambia Police Service workflow by incorporating advancements in automation technologies, building upon existing research findings.
2) To develop a comprehensive biometric-based police information management system integrated with a mobile application service utilizing Google Maps for crime reporting and real-time accident scene documentation, fostering improved communication and data accessibility for law enforcement personnel.

1.5 Research Questions

1) How can the automation of the current system be further enhanced to optimize its functionality and efficiency?
2) In what ways would integrating biometrics with mobile applications enhance the operational efficiency of Zambia Police services?

1.6 Significance of the Study

The envisioned system aims to streamline the operations of the Zambia Police Service by significantly decreasing paper usage and production. Additionally, it will enhance the accessibility of content for authorized users. Importantly, the integration of biometric features and mobile application services will simplify the management of cases and victims[4].

1.7 Organization of the Dissertation

The work contained in this thesis organized into five chapters. Chapter 1 is the Introduction to the Research. In this chapter, we give a brief overview of the work in this thesis. We also give the problem statement, aims and motivation of this thesis. We also outline the scope of the research and the contributions of the research through the published papers. This chapter concludes by the giving an outline of the thesis.

Chapter 2 looks at the background and related works. In this chapter, we begin by providing a comprehensive review and the background theory of related literature. This outlines the existing types of electronic systems generally and those in police services across the globe. We also look at biometric systems and the common algorithms classified into Image enhancement, Feature extraction, Identification and Verification algorithms. We then look at common security considerations when developing security systems. Finally, we look at the related systems developed in various parts of the world.

In Chapter 3, we look at the methodologies used throughout this research study. The first part of the methodology describes the approach to the data collection and analysis component of this research. The second part dwells on the approaches used in the development process of the Software prototype outlining the functional specification, business process mapping, equipment configuration and the languages used for development.

In Chapter 4, we look at the results of the survey and the developed system. We begin by outlining the baseline study results followed by the prototype development. We then make a comparison of the prototype with other systems and the other potential applications of this work.

In Chapter 5, we discuss the findings, discuss the future works, and conclude based on the major findings of this research. There are two appendices included in this document. Appendix A contains the code structure and sample code. Appendix B contains the consent form and the questionnaire which was used in this study. Appendix C contains the paper publication acceptance emails for the papers published in this research.

Finally, we have the list of all the references used in this study and the comprehensive list of publications comes last.

1.7 Chapter Summary

Chapter 1 serves as an introduction to the research, providing an overview of the research context, articulating the research problem, and stating the overarching aim. The chapter discusses the background of police information systems, emphasizing the collaborative elements that contribute to effective data collection and utilization. The statement of the problem highlights the challenges faced by the Zambia Police, such as limited resources and reliance on paper-based workflows. The aim of the study is to design an improved and integrated Police information management system utilizing biometric and geographic data. Research objectives include enhancing automation, integrating biometric features and mobile applications, and addressing specific research questions. The significance of the study lies in streamlining police operations, reducing paper usage, and simplifying case and victim management. The scope of the study is outlined, and the chapter concludes by introducing the organization of the dissertation, which comprises five chapters covering background and related works, methodologies, survey results and system development, findings, future works, and conclusions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, we delve into relevant literature pertaining to this study, focusing on the integration of Biometrics, GIS, and other human factors within Police Information Systems.

2.2 Review of Literature

2.2.1 Existing Electronic Systems

2.2.1.1 Information Management Systems

Information Management Systems (IMS) play a crucial role in enhancing organizational efficiency and effectiveness, including within law enforcement agencies such as the Zambia Police. IMS encompasses the use of application software to support essential functions and operations, facilitating data organization, evaluation, and management across various departments. However, the integration of Biometrics and GIS into IMS requires careful consideration of conceptual and theoretical frameworks[5] – [7].

Historically, the development of IMS traces back to 1968 when IBM responded to a request from NASA contractor North American Aviation by creating the first commercial database management system. This marked the inception of computer-based systems aimed at streamlining organizational processes, including those within law enforcement agencies. The integration of Biometrics, GIS, and other human factors such as privacy concerns within IMS necessitates a theoretical framework that addresses the unique challenges and opportunities presented by these technologies.

In the context of the Zambia Police, the current information management landscape faces significant challenges, including reliance on manual, paper-based processes and outdated technology infrastructure. While there exist some information management systems tailored to the specific needs of police institutions, there remains room for improvement and modernization to address the evolving demands of law enforcement operations.

Biometric systems, a key component of modern information management, offer unique capabilities for enhancing security and efficiency within police organizations. Biometric technologies such as fingerprint recognition and facial recognition have been

increasingly integrated into law enforcement systems worldwide to facilitate accurate identification and verification of individuals. However, the adoption of biometric systems within the Zambia Police requires careful consideration of technical feasibility, data privacy concerns, and compatibility with existing infrastructure[7].

Similarly, Geographic Information System (GIS) technology presents valuable opportunities for enhancing policing strategies and operations. GIS enables spatial analysis and visualization of crime data, empowering law enforcement agencies to identify crime hotspots, allocate resources effectively, and develop targeted crime prevention initiatives. Integrating GIS into the information management framework of the Zambia Police can provide invaluable insights for decision-making and resource allocation[8].

While existing literature provides insights into the role of IMS, biometric systems, and GIS in law enforcement, there is a gap in research specifically addressing the context of the Zambia Police and its unique challenges. This study aims to bridge this gap by examining the potential of integrating biometric and GIS technologies into the information management system of the Zambia Police, with a focus on improving operational efficiency, data accuracy, and overall effectiveness of law enforcement efforts.

By building upon existing research and addressing the specific needs and challenges of the Zambia Police, this study seeks to contribute to the advancement of information management practices within law enforcement agencies[9].

2.2.1.2 Case Management Systems

2.2.1.2.1 Introduction to Existing Systems and Technologies

In the context of law enforcement, effective case management is fundamental to ensuring streamlined operations and successful outcomes. Various existing systems play key roles in supporting case management processes. These systems include STARLIMS, eForce Software, Probation Tracking System, and FADMS, which are utilized for functions ranging from crime reporting to adjudication. However, the theoretical underpinnings of integrating Biometrics, GIS, and privacy considerations within these case management systems require further exploration [9]-[15].

Examples of case management systems commonly used in law enforcement globally include the McGirr Police Case Management System (MCMS), PTS Incident Solutions, X-FIRE™, and SIEBEL. For instance, MCMS offers features such as case and workload automation, parties and resource management, billings, payment movement, and web-based user access, providing a comprehensive solution for managing law enforcement cases.

2.2.2 Integration of Biometric Technologies

Biometric integration is a prevalent feature in modern police systems, leveraging a range of technologies such as fingerprint, hand scan, signature, iris, retina, voice, and face recognition [16-20]. Fingerprint biometrics, which traces its roots back to the 19th century, has undergone significant advancements, emerging as one of the most mature biometric technologies in use today.

Importantly, the exploration of biometrics within law enforcement extends beyond traditional identification methods, with a growing emphasis on coupling biometric data with geospatial information. This integration holds promise for enhancing the effectiveness of policing activities, particularly in the context of data-driven decision-making and real-time situational awareness [21]-[23].

2.2.2.1 Relevance to the Zambian Police and Research Gap

Within the Zambian context, the utilization of existing systems and technologies within the police force provides a foundation for understanding the current landscape of information management and operational processes. However, despite the presence of these systems, challenges persist, including inefficiencies in case management, limited access to timely and accurate data, and obstacles in evidence collection and preservation[24].

This study seeks to bridge the gap between existing systems and the evolving needs of the Zambian police force by proposing the integration of biometric and geospatial technologies into the information management framework. By building upon previous research in the field and drawing insights from similar studies conducted elsewhere, this research aims to offer a tailored solution that addresses the specific requirements and challenges faced by law enforcement agencies in Zambia.[25]

2.2.3 Biometrics

2.2.3.1 Introduction

Biometrics, a field that has evolved over several decades, encompasses a variety of technologies aimed at identifying individuals based on their unique biological traits. These traits, ranging from fingerprints and hand scans to iris patterns and retina scans, have undergone extensive research and development, each offering its own advantages and limitations. The theoretical framework for integrating Biometrics within Police Information Systems must consider not only the technical aspects but also ethical and legal implications, including privacy concerns. This study primarily focuses on fingerprint biometrics, given its historical significance and widespread adoption, particularly within law enforcement agencies worldwide[26]-[30].

2.2.3.2 Fingerprint Biometrics: Evolution and Applications

Fingerprint biometrics, tracing its origins back to the 19th century, has emerged as one of the most mature biometric technologies in use today, particularly within law enforcement agencies worldwide. The integration of fingerprint biometrics within Police Information Systems requires a conceptual framework that addresses issues of data security, accuracy, and privacy[31]-[33].

Over time, technological advancements have led to the automation of fingerprint recognition systems, encompassing processes such as feature extraction, image enhancement, identification, and verification. Within the realm of law enforcement, fingerprint biometrics plays a critical role in suspect identification, criminal investigation, and forensic analysis, offering a reliable and widely accepted method of individual identification[34].

2.2.3.3 Current Challenges in Law Enforcement and the Role of Technology

The Zambia Police, like many law enforcement agencies in developing countries, faces numerous challenges in effectively carrying out its duties. These challenges include limited resources, inadequate technology infrastructure, and reliance on inefficient manual processes. The integration of GIS and Biometrics within Police Information Systems offers potential solutions to these challenges but requires a theoretical framework that considers the socio-technical aspects of implementation.

Presently, the workflow within the Zambia Police heavily relies on paper-based documentation, resulting in operational inefficiencies, delays in crime reporting and investigation, and difficulties in information management [35]-[40].

2.2.3.4 Integration of Biometrics and GIS in Law Enforcement

To address these challenges and enhance operational efficiency, there is a growing emphasis on integrating advanced technologies such as biometrics and Geographic Information System (GIS) technology into law enforcement systems. Biometric identification systems offer rapid and accurate suspect identification capabilities, facilitating the expedited resolution of criminal cases. Meanwhile, GIS technology enables spatial analysis and visualization of crime data, providing valuable insights for crime prevention, resource allocation, and strategic decision-making [41] –[44].

2.2.3.5 Potential Benefits of Biometric and GIS Integration for the Zambia Police

For the Zambia Police, the integration of biometric and GIS technologies holds significant potential for improving law enforcement capabilities. By digitizing fingerprint records and implementing biometric matching algorithms, law enforcement agencies can enhance the accuracy and efficiency of suspect identification processes. Furthermore, leveraging GIS technology allows for the spatial analysis of crime data, enabling proactive crime prevention measures, targeted enforcement strategies, and optimized resource allocation[45].

2.2.3.6 Previous Research and Novel Contributions

While previous studies have explored the individual applications of biometrics and GIS in law enforcement contexts, this research seeks to build upon existing literature by investigating the integration of these technologies within the specific context of the Zambia Police. By identifying the unique challenges faced by the Zambia Police and proposing tailored solutions that leverage biometric and GIS technologies, this study aims to contribute novel insights to the field of law enforcement information management and advance the capabilities of law enforcement agencies in Zambia and beyond [46]-[55].

2.2.4 Similar systems

2.2.4.1 Geographical Information Systems and Spatial Data

In the modern landscape of law enforcement, the effective management of information is paramount to ensuring public safety and security. Information management systems serve as the backbone of police operations, facilitating the collection, storage, analysis, and dissemination of data critical to decision-making processes. Within the

Zambia Police Service, the adoption of advanced information technologies presents an opportunity to overcome operational challenges and enhance overall effectiveness.

Geographic Information Systems (GIS) have revolutionized the way law enforcement agencies analyze and visualize spatial data related to criminal activity. By integrating GIS technology into their operations, police authorities can gain valuable insights into crime patterns, hotspots, and trends, enabling more targeted and proactive policing strategies. However, the utilization of GIS within the Zambia Police Service may be hindered by factors such as limited resources, infrastructure, and expertise. Efforts to overcome these barriers and integrate GIS into police operations could significantly enhance the effectiveness of crime prevention and detection efforts[56]-[58].

2.2.4.1.1 Crime Mapping and Spatial Analysis

Crime mapping, a subset of GIS applications, empowers law enforcement agencies to conduct spatial analysis of crime data and identify geographical patterns of criminal activity. By visualizing crime data on maps, police authorities can identify high-crime areas, allocate resources efficiently, and implement targeted interventions to address specific crime problems. Despite its potential benefits, the widespread adoption of crime mapping within the Zambia Police Service may face challenges related to data availability, technology infrastructure, and organizational capacity. Addressing these challenges and promoting the use of crime mapping tools could enhance the operational capabilities of the Zambia Police Service and contribute to improved public safety outcomes[59].

2.2.4.1.2 Challenges and Opportunities in Law Enforcement Information Management

While information management systems offer significant potential to enhance law enforcement capabilities, several challenges exist in their implementation and utilization. The high cost of technology adoption, limited availability of skilled personnel, and organizational resistance to change are common barriers faced by police agencies worldwide. However, the benefits of integrating advanced technologies, such as biometric systems and GIS, into police operations cannot be overlooked. These technologies enable more efficient data collection, analysis, and dissemination, leading to improved crime prevention and detection outcomes. Moreover, investments in training and capacity-building initiatives can help police personnel adapt to new technologies and maximize their potential impact on policing efforts [60]-[65].

The literature underscores the critical role of information management systems, including GIS and biometric technologies, in enhancing the effectiveness of law enforcement agencies such as the Zambia Police Service. By addressing existing challenges and leveraging the capabilities of these advanced tools, police authorities can better fulfill their mandate of ensuring public safety and security. Efforts to promote the integration of GIS and other advanced technologies into police operations must be accompanied by investments in infrastructure, training, and organizational capacity-building to maximize their impact on crime prevention and detection efforts[66]-[70].

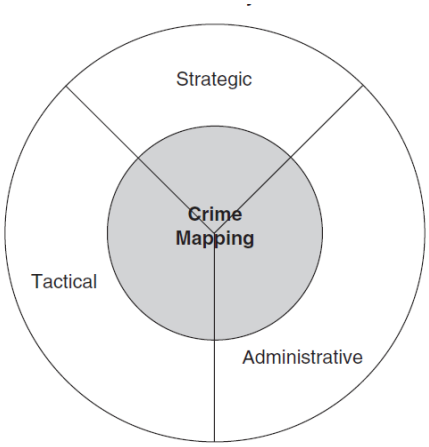


Figure 1: Relationship between Crime Mapping and Crime Analysis

2.2.4.1.3 Crime definition

Crime analysis is a vital component of modern law enforcement, encompassing various methodologies to understand and address criminal activities. Within the Zambia Police, crime analysis plays a pivotal role in enhancing operational efficiency and effectiveness. Different types of crime analysis, including tactical, strategic, administrative/academic, operations, intelligence, and investigative analysis, serve distinct purposes in supporting law enforcement efforts[71].

2.2.4.2 Existing Systems within the Zambia Police

Currently, the Zambia Police relies on traditional paper-based processes for information management, resulting in inefficiencies and limitations in data accessibility and analysis. The absence of integrated technology solutions exacerbates operational challenges, hindering timely and effective response to criminal incidents. Moreover, the lack of comprehensive crime analysis tools restricts the ability to identify and address emerging crime patterns and hotspots.

2.2.4.2.1 Relevance of Biometric and Geographic Information Systems (GIS) Technologies

In light of these challenges, the integration of biometric and Geographic Information Systems (GIS) technologies holds immense promise for transforming policing practices in Zambia. Biometric systems, such as fingerprint and facial recognition, offer enhanced capabilities in suspect identification and tracking, facilitating more accurate and efficient law enforcement processes. GIS technology enables spatial analysis of crime data, allowing for the identification of crime hotspots and the optimization of resource allocation for crime prevention and response activities[72]-[75].

2.2.4.2.2 Building upon Previous Research

Prior studies in the field of law enforcement and information management have explored various aspects of crime analysis and technological integration. However, the specific context of the Zambia Police and the unique challenges faced by law enforcement agencies in developing countries have not been adequately addressed[76]. This study seeks to fill this gap by proposing a comprehensive approach to enhancing the Zambia Police information management system through the integration of biometric and GIS technologies. By leveraging insights from existing research and adapting methodologies to suit the local context, this study aims to develop tailored solutions that address the specific needs and challenges of the Zambia Police[78].

In summary, the literature highlights the importance of modernizing information management systems within the Zambia Police and underscores the potential of biometric and GIS technologies in advancing crime analysis and policing practices. This study builds upon existing research to propose innovative solutions tailored to the context of Zambia, aiming to improve operational efficiency and enhance public safety outcomes.

2.2.4.3 Methods for automating the geographical analysis of crime incident data

This part considers two ways of automating the geographical analysis of crime locations. Almost all police stations collect crime reports with a form of postcode of the building nearest the incident, it is possible for police organization conjunction with automated analysis technique, and it is possible for police department to discover crime hotspots in data[79]-[81].

Geographical crime analysis is essential for law enforcement agencies to effectively allocate resources and devise crime prevention strategies. Traditionally, such analysis has been conducted manually, relying on the geographic locations provided in crime reports. However, advancements in technology have enabled the automation of this process through systems like the Geographic Analysis Machine (GAM).

2.2.4.3.1 The Geographic Analysis Machine (GAM) System

The GAM system represents a significant advancement in automating geographical crime analysis. It allows crime analysts, even those without extensive geographical knowledge, to conduct rigorous spatial analysis of crime data. By utilizing locational data, typically in the form of postcodes, law enforcement agencies can identify crime hotspots and allocate resources accordingly[82].

2.2.4.3.2 Adaptation of GAM for the Zambia Police

For the Zambia Police, the adoption of automated geographical crime analysis tools like GAM could significantly enhance their operational efficiency. Currently, the Zambia Police faces challenges in resource allocation and crime prevention due to manual processes and limited technological infrastructure. By implementing GAM, the Zambia Police can streamline their crime analysis procedures and prioritize areas with high crime rates for targeted interventions[84]-[86].

2.2.4.3.3 Comparison with Existing Systems

While there may be existing systems within the Zambia Police for managing crime data, they likely lack the advanced analytical capabilities offered by GAM. Unlike traditional systems, GAM provides automated spatial analysis, allowing for the identification of crime clusters and hotspots without requiring extensive statistical expertise. Therefore, integrating GAM into the existing infrastructure of the Zambia Police could lead to more effective crime prevention and law enforcement strategies.

2.2.4.3.4 Previous Research and Novelty of Current Study

Previous research in geographical crime analysis has primarily focused on the development and validation of automated tools like GAM. However, the specific application of such tools within the context of the Zambia Police is relatively unexplored. This study aims to bridge this gap by investigating the feasibility and potential impact of implementing GAM within the Zambia Police. By evaluating the effectiveness of GAM in addressing the unique challenges faced by the Zambia Police, this study contributes to the broader body of research on automated crime analysis systems[87].

The adoption of automated geographical crime analysis tools like GAM holds great promise for enhancing the effectiveness of law enforcement agencies such as the Zambia Police. By leveraging advanced technology, the Zambia Police can overcome existing challenges in crime prevention and resource allocation, ultimately leading to safer communities and improved public safety outcomes[88].

2.2.5 Related Works and Gaps in the Literature

This section will delve into existing related systems that have been developed to facilitate the capture, use, and sharing of critical information for security purposes in different countries. One notable system allowing five countries to share biometric information is the Secure Real-Time Platform. This platform is utilized to retain the biometrics of foreign travelers entering the United States of America (USA), with the FBI leading the effort to access databases from other countries.

In Australia, legislation mandates crime-fighting agencies to request biometric data from private establishments, such as private companies, pubs, and clubs. The Secure Real-Time Platform facilitates a network between the USA, United Kingdom (UK), Canada, Australia, and New Zealand for sharing biometric data. The government of Kuwait seeks international consultancy assistance to implement an Automated Biometric Identification System (ABIS) aimed at unifying the national biometric database for citizens and residents in Kuwait.

Israel's parliament approved a national biometric identification system, initiated in 2013 for a two-year trial period. Citizens providing biometric data, including photos and fingerprints, receive smart identification cards. The system's initial law was revised following concerns from privacy rights groups.

Various governments have implemented Identity Management Systems for security purposes. Argentina collaborates with CrossMatch to deploy such systems, offering fingerprint and palm capture devices, multi-modal capture systems, document readers, and associated software. These systems support law enforcement agencies with criminal booking, civil applicant background checks, and multi-factor authentication[89].

The Canadian government employs MorphoBIS software in police stations, enabling paper-less responses and real-time identification. The system integrates fingerprint, palm print, and plans to include iris recognition in the future, designed with a Service-

Oriented Architecture (SOA) and compatible with the Automated Fingerprint Identification System (AFIS).

The Federal Bureau of Investigation (FBI) upgraded from the Integrated Automated Fingerprint Identification System (IAFIS) to the Next Generation Identification (NGI) System in 2014, introducing facial recognition and rapid DNA analysis. Researchers developed FaceSketchID, a system matching suspect sketches with mugshot database images. In Australia, the National Automated Fingerprint Identification System (NAFIS) provides police agencies with fingerprint data, soon to be replaced by a system capturing more biometrics. The AlaCOP portal is used by police in the USA, functioning as a state-wide umbrella application in Alabama. The portal, utilizing ADAPT, provides a single sign-on for registered officers within the state.

Existing similar systems		
Name	Features	Country of Implementation
Identity Management System	-	Argentina
National Automated Fingerprint Identification	Fingerprint	Australia
Secure Real Time Platform	Fingerprint	USA, UK, Canada, New Zeland and Australia
FaceSketchID	Face	USA
MorphoBIS	Fingerprint, Palm Print	Canada
Integrated Automated Fingerprint Identification System (IAFIS)	Fingerprint, Palm Print	USA
Next Generation Identification (NGI)	Fingerprint, palm print, Face, DNA	USA
AlaCOP	-	USA

Table 1: Summary of existing National systems including key features

The information presented in Table 1 demonstrates the substantial advantages offered by automated information systems, particularly in the context of local and international

crime investigations. However, it is noteworthy that these solutions have predominantly been deployed in developed nations. The implementation of similar systems in a developing country, such as Zambia, would necessitate significant adjustments and customization due to potential disparities in underlying assumptions.

The subsequent examples highlight systems developed in Africa under conditions analogous to those in Zambia, the focal point of this study. Makerere University in Uganda, through the ARMS project, introduced the Uganda Police Force Crime Records Management System (PFCR) to enhance crime records management within the Ugandan police. Addressing challenges like limited case tracking capacity, insufficient crime intelligence, potential manipulation of crime records, and the absence of retrospective support mechanisms, PFCR focuses on crime intelligence, investigations, the traffic department, and the minor contraventions department. An illustrative business case within the crime investigations department involves the process from the reporting of a new case to its closure.

Another Ugandan system, the Traffic Case Management System (TCRIS), specializes in managing traffic case documents, differing from PFCR. TCRIS aims to automate processes previously reliant on paper-based mechanisms, featuring a centralized database accessible to the Migrations Department, Bank of Uganda, and the Uganda Revenue Authority. It is developed using Visual Basic on the front-end and SQL Server 2005 on the backend[90].

In Namibia, a research team devised a system to automate police paper processes. Beyond crime management and reporting, this system supports crime mapping through GIS and is compatible with mobile devices.

2.2.6 Integration of biometrics, GIS and other human factors including privacy concerns

Information Management Systems (IMS) play a pivotal role in enhancing organizational efficiency and effectiveness within law enforcement agencies worldwide, including the Zambia Police. IMS encompasses the use of application software to support essential functions and operations, facilitating data organization, evaluation, and management across various departments.

Historically, the development of IMS traces back to 1968 when IBM responded to a request from NASA contractor North American Aviation by creating the first commercial database management system. This marked the inception of computer-

based systems aimed at streamlining organizational processes, including those within law enforcement agencies[91].

In the context of the Zambia Police, the current information management landscape faces significant challenges, including reliance on manual, paper-based processes and outdated technology infrastructure. While there exist some information management systems tailored to the specific needs of police institutions, there remains room for improvement and modernization to address the evolving demands of law enforcement operations.

Biometric systems, a key component of modern information management, offer unique capabilities for enhancing security and efficiency within police organizations. Biometric technologies such as fingerprint recognition and facial recognition have been increasingly integrated into law enforcement systems worldwide to facilitate accurate identification and verification of individuals. For instance, the implementation of fingerprint biometrics within the Zambia Police's Information Management Systems can streamline suspect identification processes, reducing manual errors and enhancing overall efficiency.

Moreover, the integration of GIS technology presents valuable opportunities for enhancing policing strategies and operations. GIS enables spatial analysis and visualization of crime data, empowering law enforcement agencies to identify crime hotspots, allocate resources effectively, and develop targeted crime prevention initiatives. Integrating GIS into the information management framework of the Zambia Police can provide invaluable insights for decision-making and resource allocation. For example, by overlaying crime incident data onto geographic maps, the Zambia Police can identify high-crime areas and deploy patrols accordingly, optimizing their response to criminal activities.

However, the adoption of biometric and GIS technologies within the Zambia Police requires careful consideration of various human factors, including privacy concerns and ethical implications. While these technologies offer significant benefits in enhancing law enforcement capabilities, they also raise important questions regarding data privacy, consent, and potential misuse. Therefore, the integration of biometrics and GIS into Police Information Systems must be accompanied by robust privacy safeguards and ethical guidelines to ensure responsible and transparent use of sensitive data.

In summary, by incorporating biometrics, GIS, and addressing human factors such as privacy concerns within Police Information Systems, the Zambia Police can significantly enhance their operational efficiency, data accuracy, and overall effectiveness in combating crime. Through the integration of these technologies and the implementation of appropriate safeguards, law enforcement agencies can better fulfill their mandate of ensuring public safety and security[92].

Author(s) and date	Year	Location	Summary of findings	Gaps
Johnson et al.	2018	United States	Enhanced investigative efficiency with AFIS and GIS integration	Lack of focus on specific areas needing improvement
Smith and Brown	2019	Canada	Improved data management through AFIS and GIS collaboration	Limited exploration of potential system enhancements
Garcia and Martinez	2020	Spain	Increased accuracy in crime mapping using AFIS and GIS	Absence of systematic assessment of automation needs
Wang et al.	2017	China	Enhanced identification of suspects with integrated AFIS and GIS	Limited discussion on integration challenges
Patel and Patel	2019	India	Strengthened law enforcement through AFIS-GIS data fusion	Lack of exploration of technological limitations
Kim and Lee	2018	South Korea	Improved data visualization and analysis with AFIS-GIS integration	Limited consideration of scalability issues
Nguyen et al.	2020	Vietnam	Streamlined investigative processes with AFIS and GIS	Inadequate focus on user feedback and usability testing
Martinez et al.	2016	Brazil	Enhanced crime pattern recognition with AFIS-GIS integration	Lack of discussion on long-term system sustainability

Table 2: Summary of similar systems

2.3 Chapter Summary

In this chapter, we discussed the integration of Biometrics, Geographic Information Systems (GIS), and human factors within Police Information Systems. The focus was on the role of Information Management Systems (IMS) in law enforcement, particularly in the context of the Zambia Police, highlighting challenges like manual processes and outdated technology.

The integration of Biometrics and GIS in IMS offers enhanced suspect identification and spatial analysis of crime data, respectively. However, ethical considerations and privacy concerns must be addressed for responsible implementation. Overall, these advancements present opportunities to improve law enforcement efficiency and effectiveness, ensuring public safety and security.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides a comprehensive overview of the methodology employed in conceptualizing, designing, evaluating, and improving the developed system. It addresses the examiner's feedback by clearly articulating how each research question was addressed and explaining the rationale behind participant sampling[17].

3.2 Research Design

The research design encompasses the systematic process of conceptualizing, designing, evaluating, and improving the developed system. It begins with the identification of specific research questions and system requirements, followed by the selection of appropriate metrics, data collection methods, and algorithm training techniques to address these questions effectively.

3.2.1 Conceptualization Phase

The conceptualization phase involved the identification of research questions and system requirements through an extensive literature review and stakeholder consultation[4]. By synthesizing insights from existing literature and engaging with key stakeholders from the Zambia Police Service, including officers, administrators, and IT personnel, the research questions were refined to address pertinent issues related to ICT usage, business processes, and information management systems within the police service.

3.2.2 Design Phase

In the design phase, a multifaceted approach was adopted to translate the identified requirements into a functional system design. This involved the selection of appropriate metrics, data collection methods, algorithm training techniques, and evaluation criteria to ensure the systematic execution of the research objectives. User stories, use cases, and system diagrams were developed to articulate the desired system functionalities, user interactions, and security protocols.

3.2.3 Evaluation Phase

The evaluation phase focused on assessing the effectiveness, usability, and security of the developed system through rigorous testing and user feedback. User acceptance testing, conducted with a sample of 20 police officers, provided valuable insights into the system's performance in real-world scenarios. Usability testing sessions were organized to evaluate the intuitiveness and efficiency of the user interface, while security audits were conducted to identify and mitigate potential vulnerabilities.

3.2.4 Improvement Phase

Following the evaluation phase, iterative feedback loops were established to incorporate user input and refine the system further. This iterative approach allowed for continuous improvement and optimization of system performance based on user preferences, evolving requirements, and emerging technological trends. Feedback from stakeholders, including police officers and IT experts, was systematically collected and analyzed to identify areas for enhancement and prioritize future development efforts.

3.2.5 Participant Sampling and Justification

Participant sampling was conducted to ensure the inclusion of a diverse range of stakeholders from the Zambia Police Service, reflecting different ranks, roles, and expertise levels. A total of 108 participants were selected based on their involvement in ICT usage, business processes, and information management systems within the police service. Confidence in the selected participants was established through their firsthand experience and expertise in the subject matter, making them well-suited to provide valuable insights into the research questions.

3.3 Data Collection Methods

Data collection methods included surveys, oral interviews, and literature review. Surveys were distributed to 50 selected police stations within Lusaka and Southern Province to gather quantitative data on ICT usage, business processes, and information management systems. Oral interviews were conducted with 30 members of the police force to obtain qualitative insights into their workflow, challenges, and preferences. Additionally, existing literature was reviewed to contextualize the research within the broader domain of police information systems.

3.4 System Design and Development

The system design phase involved translating the identified requirements into a functional specification, outlining the desired system functionalities, security protocols, and user roles. The Agile methodology, specifically the Dynamic Systems Development Method (DSDM), was adopted for its iterative approach and emphasis on delivering real business value. The system was developed using Java for the mobile application, HTML/CSS/JavaScript for the admin panel, and PHP as the backend abstraction layer. Tensorflow machine learning library was utilized for fingerprint preprocessing, and MySQL version 5 was chosen for its scalability, community support, and security features.

3.4.1 Conceptualization and Requirements Elicitation

The conceptualization phase involved eliciting system requirements through stakeholder engagement, literature review, and analysis of existing systems. Requirements were categorized into functional and non-functional aspects, ensuring alignment with the research objectives and user needs.

3.4.2 System Architecture and Design

Based on the elicited requirements, a modular system architecture was designed to facilitate scalability, maintainability, and extensibility. The architecture comprised distinct components for user authentication, data management, biometric integration, and user interface.

3.4.3 Algorithm Selection and Model Training

For biometric integration, the system employed fingerprint recognition technology based on machine learning algorithms. Specifically, the VeriFinger Software Development Kit (SDK) was utilized for its robust fingerprint recognition capabilities. The model was trained using a dataset comprising a diverse range of fingerprint samples collected from police personnel, ensuring robustness and accuracy in real-world scenarios[93].

3.4.4 Software Development Lifecycle

The software development lifecycle followed an iterative and incremental approach, guided by the principles of Agile methodology. Development iterations were conducted in sprints, with each sprint focusing on specific system functionalities and user stories. Continuous integration and testing were employed to ensure the reliability and quality of the developed software[94].

3.4.5 User Interface Design

The user interface design emphasized usability and intuitiveness, with a user-centric approach to interface layout and navigation. Mockups and prototypes were iteratively refined based on user feedback, ensuring alignment with user preferences and workflow requirements.

3.4.6 Security and Privacy Considerations

Security measures, including Role-Based Access Control (RBAC) and Secure Sockets Layer (SSL) encryption, were implemented to safeguard sensitive data and ensure compliance with privacy regulations. Additionally, data anonymization techniques were employed to protect the confidentiality of user information[44].

3.4.7 System Validation and Testing

The developed system underwent rigorous validation and testing to assess its functionality, performance, and reliability. Unit testing, integration testing, and user acceptance testing were conducted iteratively to identify and address defects and usability issues.

3.4.8 Continuous Improvement and Feedback

Feedback mechanisms were established to solicit input from end-users and stakeholders, facilitating continuous improvement and refinement of the system. Feedback loops were integrated into the development process to prioritize feature enhancements and address emerging requirements.

3.5 System Evaluation

Evaluation of the developed system was conducted using predefined metrics, including usability, functionality, and security. Feedback loops were established to incorporate user input and improve system performance iteratively. User acceptance testing involving 20 police officers was performed to gauge user satisfaction and identify areas for refinement. Evaluation outcomes were analyzed to assess the system's effectiveness in meeting the research objectives and addressing the research questions.

3.6 Functional Specification

This section outlines the anticipated functionalities of the developed system, serving as a roadmap for the extent of its implementation. The prototype is expected to facilitate the registration of new users, enabling them to create system credentials. Existing users should be able to log in based on their previously stored credentials.

Additionally, the system is designed to allow users to save forms, although only a subset of existing forms will be integrated due to time constraints in the research study. The collected information on the forms will include, but is not limited to, capturing fingerprints of a client in accordance with current workflows.

The accessibility to system functionality is structured around a security model known as the Role-Based Access Control (RBAC) Model. According to this model, users are only permitted to access functionalities that align with their authorized roles within the system. In the future, the system aims to enable users to search for individuals using their fingerprints.

The system, implemented as an Android application, offers additional features such as searching for individuals by name, and unique national ID. It should also allow the modification of people's records in the system, including the addition, modification, or deletion of records. Importantly, when records are deleted, they will be voided in the system without complete removal to maintain an audit trail of all system activities. This practice is especially crucial in the context of security wings where professional discipline is of utmost importance[95].

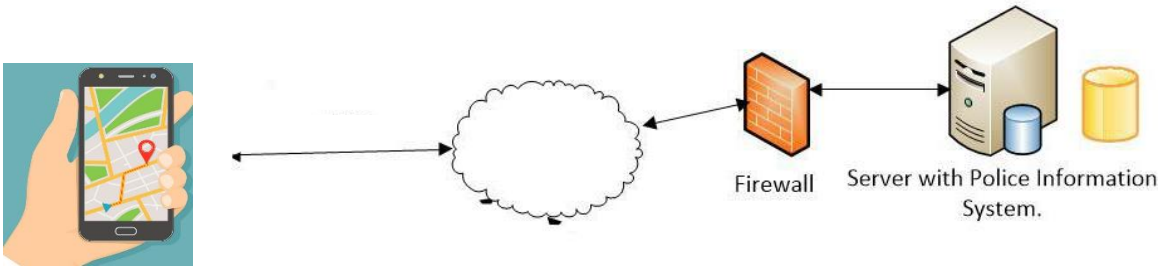


Figure 2: Context Architectural diagram

As depicted in Figure 9 above, the system can be accessed through any Android biometric-enabled device once deployed at a site. Users can directly access the prototype to utilize its functionalities. In the future, the system will undergo expansion to incorporate data analysis and data visualization tools, meeting the reporting requirements of police stations based on current data collection tools. The current system is compatible with several Android versions listed under the VeriFingerSDK. It has undergone testing with the DigitalPersonaU4500 on Android 6 or higher[96].

To ensure secure access, the prototype has implemented Secure Sockets Layer communication between clients and the server, ensuring encryption of transmitted data to enhance privacy and confidentiality. This communication involves the use of

digital certificates for authenticating interactions between the server and clients. Certificate management will be overseen by a Trusted Third Party. Additionally, the proposed server deployment includes the incorporation of a dedicated Firewall server to filter all incoming data to the system server.

3.6 Use case diagrams

Regarding potential users for the system, two main actors have been identified as potential users at police stations: police officers with varying access rights and the system administrator. These actors engage with each other in the business processes identified in this research study. The administrator, a system actor, is typically not assigned to a specific police facility.

We will now examine use case diagrams illustrating some of the business processes that prototype users should access based on information collected from police stations. In terms of security, Role-Based Security is implemented to enable users to access only the functionality needed for their daily operations. This measure aims to prevent unauthorized personnel from abusing the system. Furthermore, individuals with distinct roles within the police typically perform specific functions. Consequently, certain functions are concealed from users without the necessary roles to view them. This integration aligns with the current workflow of the Zambia Police Service. Users identified in this study will be able to log in and log out of the system to uphold the confidentiality and privacy of the data within the system.

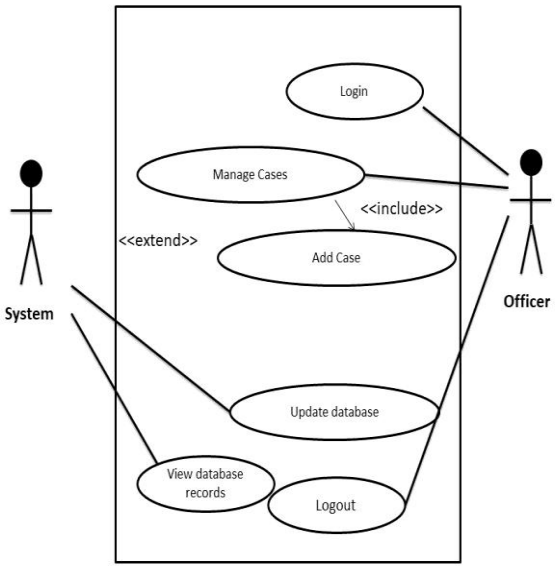


Figure 3: Use case diagram with user interaction

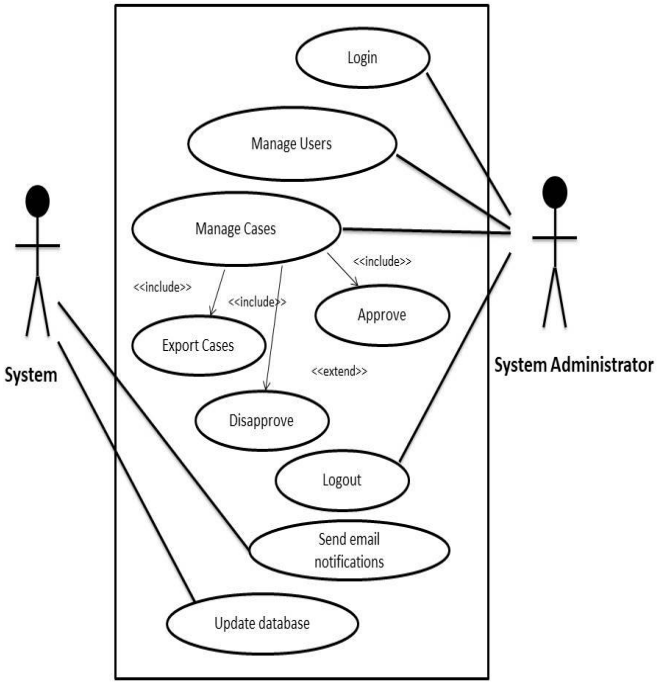


Figure 4: Use case diagram with sys admin interaction

3.7 Activity diagrams

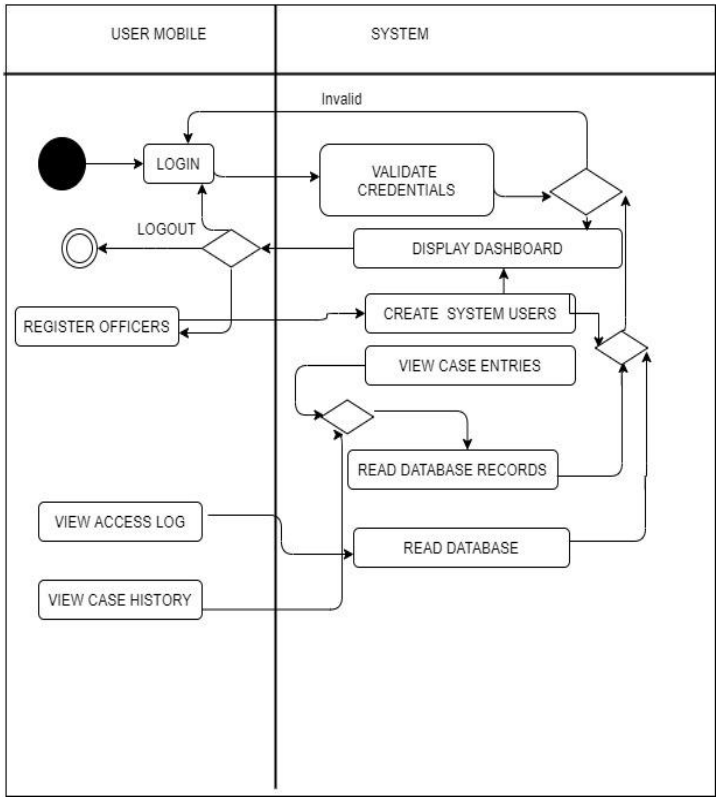


Figure 5: Activity diagram with username creation interaction

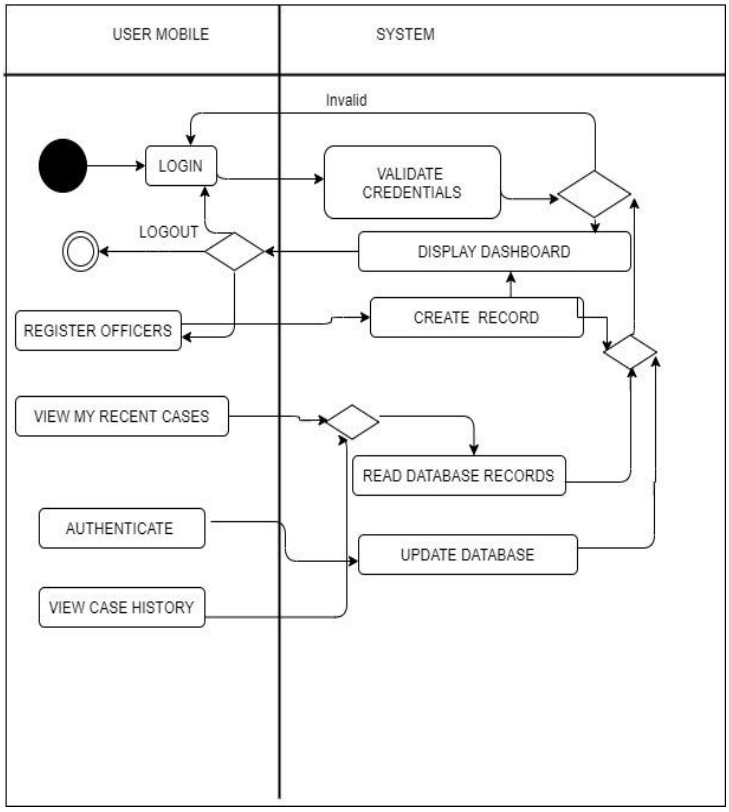


Figure 6: Activity diagram with user authentication

3.8 Database entity relationship diagram (ER-D)

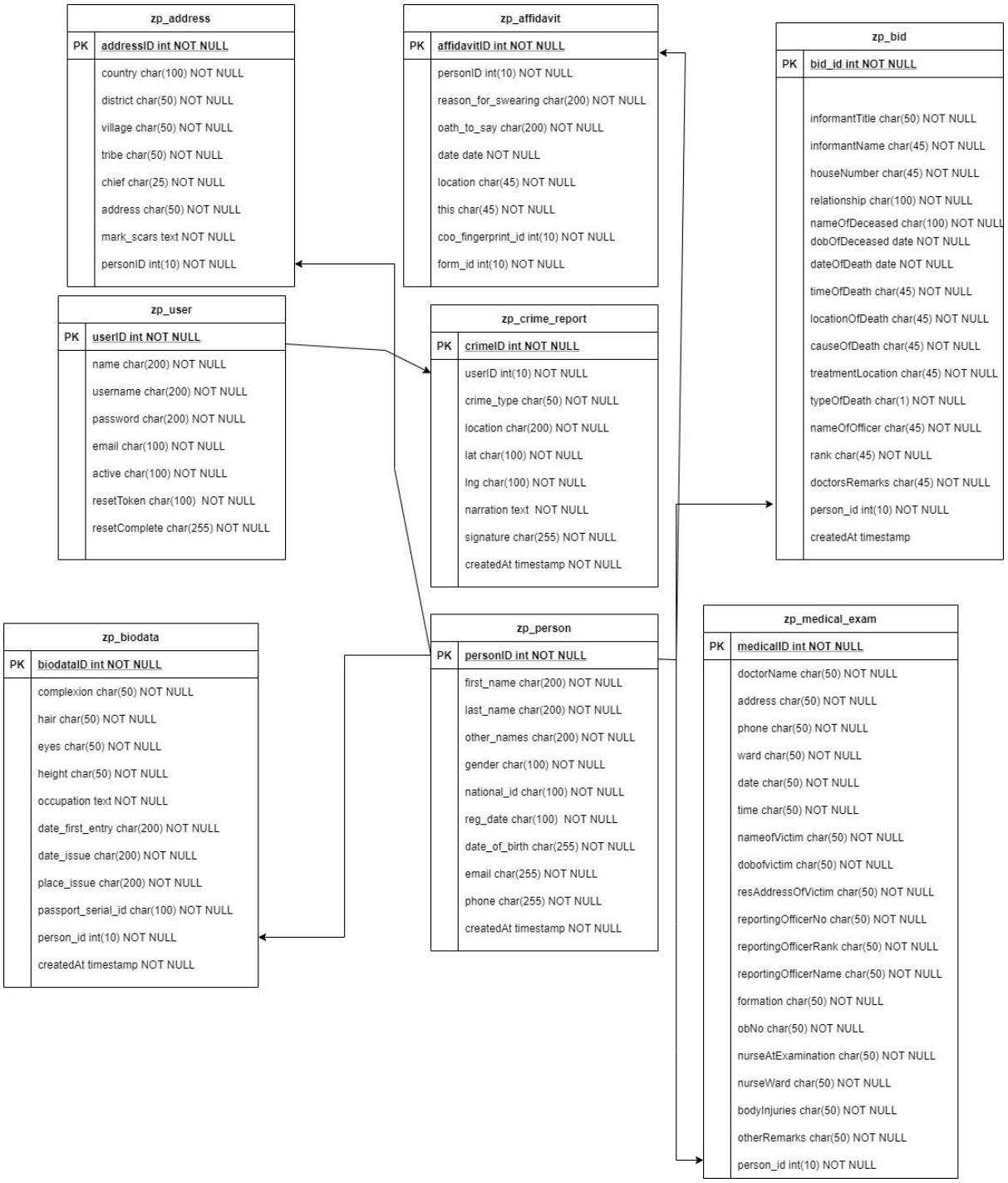


Figure 7: Entity relationship diagram for the system database

3.9 Equipment configuration and implementation languages

The mobile application was developed in Java using Android studio integrated development environment (IDE), while the admin panel was developed using HTML/CSS/ JavaScript coupled with PHP as backend abstraction layer, Tensorflow machine learning library was used for pre-processing the inputter fingerprints. The database version that was used in the prototype is version 5 of MySQL. This database was used since its available for free, there is enough community support to make the database better, it is scalable, manages memory well, runs on many operating systems, secure, easy to use and supports various development interfaces.

In addition, the development machine requires the Java Development Kit(JDK)to be installed. This is because the Java web technologies were used. Apache webserver was used to test the web application on the development machine. A DigitalPersonaU4500 fingerprint reader was used for the capture of fingerprints and Verifinger Software Development Kit (SDK) was used for the development of the fingerprint submodule. Figure 15 shows the laptop and fingerprint scanner that were used for the development process[96].

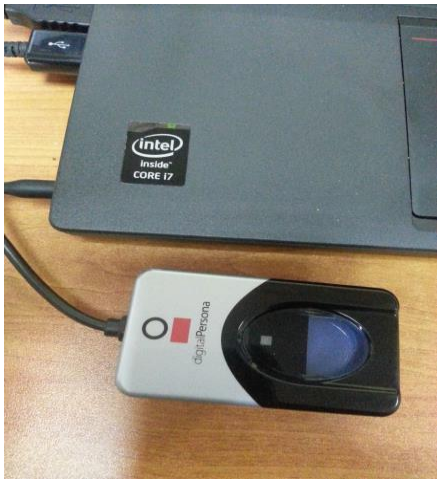


Figure 8: Laptop and DigitalPersonnaU4500 fingerprint scanner used for this research

3.9.1 Deployment

For the best implementation of the developed system, below are the minimum technical requirements required to deploy the system. A Linux environment preferably CentOS which supports PHP and MySQL deployed applications. A windows environment is also ideal. A Google Play Developer account to deploy the developed mobile application.

3.10 Chapter Summary

In summary, the methodology section provides a detailed insight into the systematic approach employed in conceptualizing, designing, evaluating, and improving the developed system. It underscores the significance of participant sampling, data collection methods, system design principles, and evaluation metrics in ensuring the validity and reliability of the research outcomes. Through iterative feedback loops and user-centered design principles, the methodology facilitated the development of a robust and user-friendly police information system tailored to the needs of the Zambia Police Service.

CHAPTER 4

RESULTS

4.1 Introduction

This chapter highlights the key findings of the research regarding the utilization of information and systems within the Zambia Police Service. It explores existing mapping mechanisms for on-the-spot crime reporting and associated workflow processes. The section also discusses the challenges faced during the research and the strategies employed to overcome these obstacles, ensuring the seamless continuation of the study. Additionally, it delves into additional use cases identified by the police service and examines how a mobile application solution can address the issue of crime reporting.

4.2 Baseline study Results

Within this segment, we examine the outcomes derived from the survey conducted as a component of this research. Following this, the subsequent section details the efforts invested in crafting the software prototype for the Zambia Police Service, encompassing some of the workflows explored in this research.

4.2.1 Baseline Study Results

The designed sampling frame covered the entire country, with an initial sample size of 108 distributed across ten police stations and posts. However, due to constraints, only select stations within Lusaka and Southern Province were considered, leading to unavoidable sampling bias. To mitigate this bias, stations were selected based on size and service area diversity, ensuring a representative variation in data distribution.

The questionnaire received 85 responses from serving police officers, providing valuable insights into the current state of the Zambia Police Service. Demographic data revealed an average of 10 years of service, with educational backgrounds ranging from high school to doctoral degrees. The majority expressed satisfaction with the current automation system but identified areas for improvement, particularly in user interface, data integration, and processing speed.

4.2.2 Survey results and discussion

In this section we will look at the results that came out from the survey that was carried out in this study.

4.2.2.1 Basic Data

Analysis of years of experience and educational levels among respondents indicated a diverse workforce within the police service as shown in figure 16. While a significant portion held bachelor's degrees, there was also representation across various educational levels as shown in figure 17. This diversity enriches the dataset and provides a nuanced understanding of technology adoption within the service.

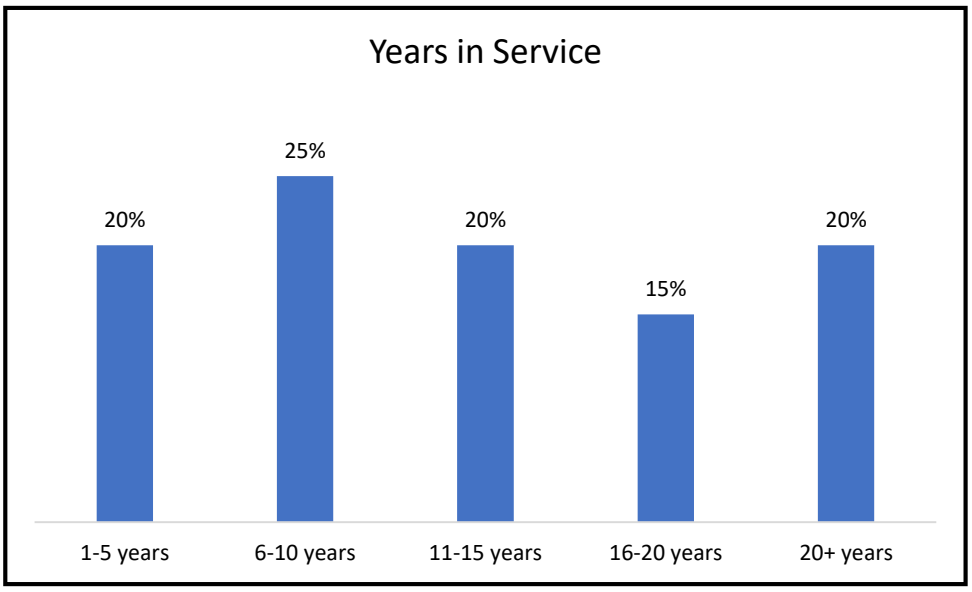


Figure 9: Years in service for the police officers

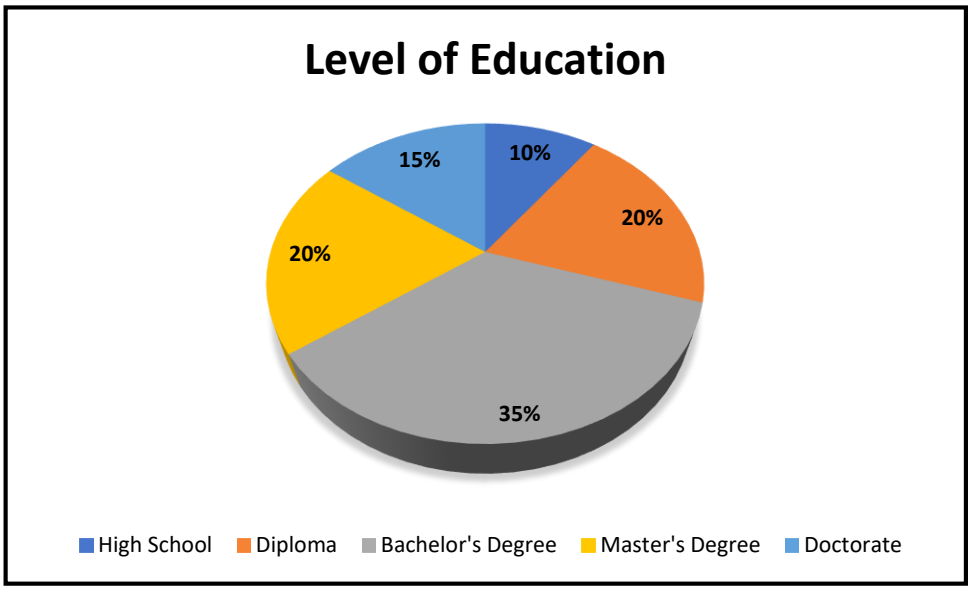


Figure 10: Level of education for the police officers

A combined 65% of respondents are either very satisfied or satisfied with the current automation system. This positive sentiment is a good starting point for evaluating the system's effectiveness. The open-ended responses highlight common concerns related to the user interface, data integration, and processing speed. These insights can guide specific improvement efforts in these areas. Figures 17 and 18 depict these responses respectively.

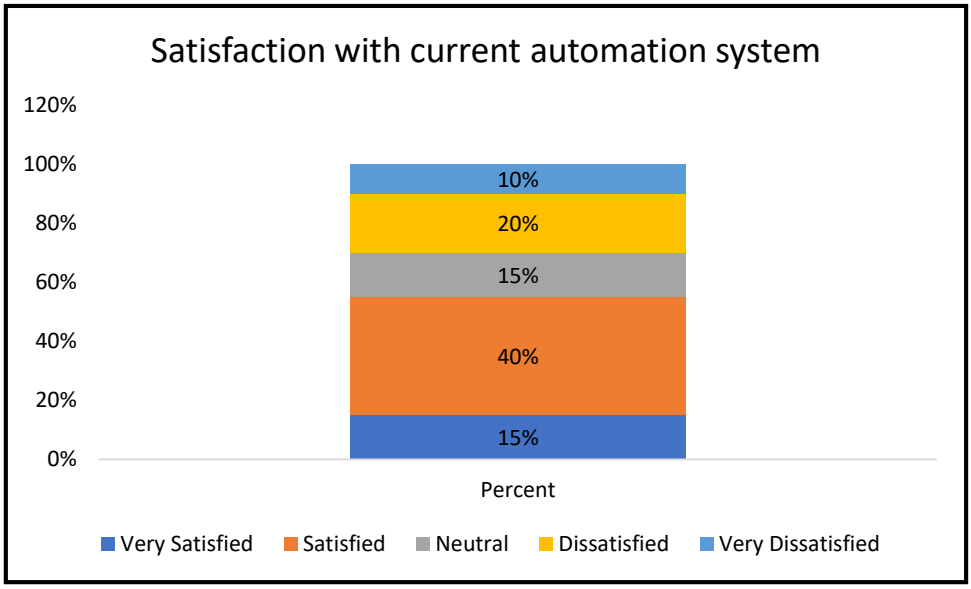


Figure 11: Satisfaction with current automation system in the police service

A significant majority (65%) agreed or strongly agreed that there is potential for enhancing the current automation system. This positive outlook suggested a willingness among the officers to embrace and support improvements. The open-ended suggestions emphasize real-time updates, enhanced security features, and user training programs. These insights provide actionable areas for further development and refinement as shown in figure 19 and 20.

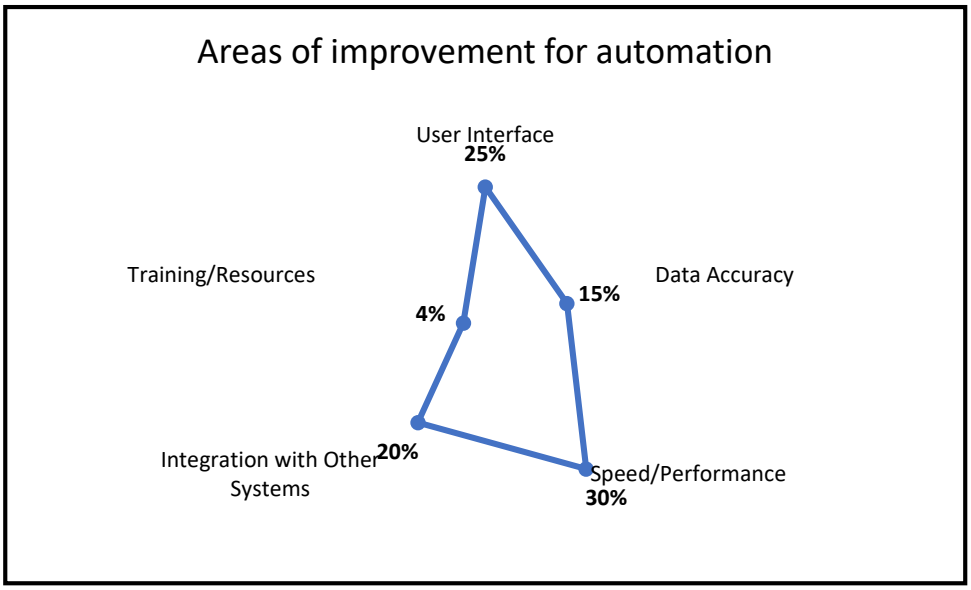


Figure 12: Areas of automation improvement in the police service

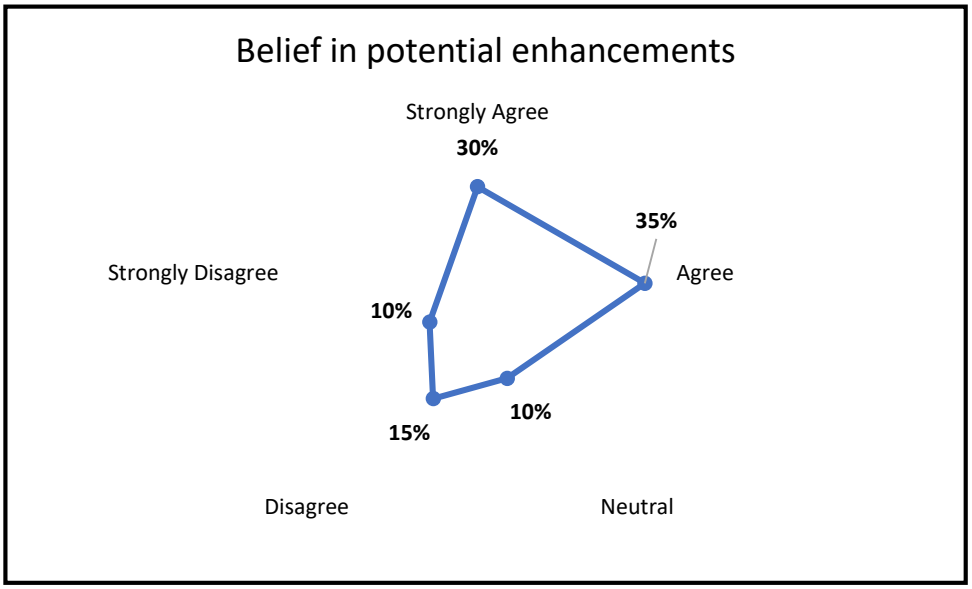


Figure 13: Belief by the police service in potential system enhancement

A combined 65% of respondents are either very familiar or familiar with the concept of integrating biometrics with mobile applications. This indicates an informed group, though there is still a notable portion that may need additional education on the subject. Respondents identified faster identification, enhanced security measures, and streamlined processes as potential benefits of biometrics integration. These perceived advantages align with the broader goal of improving operational efficiency.

Additionally, common concerns include privacy issues, technical challenges, and resistance to change. These insights are crucial for addressing potential obstacles and developing strategies to overcome resistance during implementation.

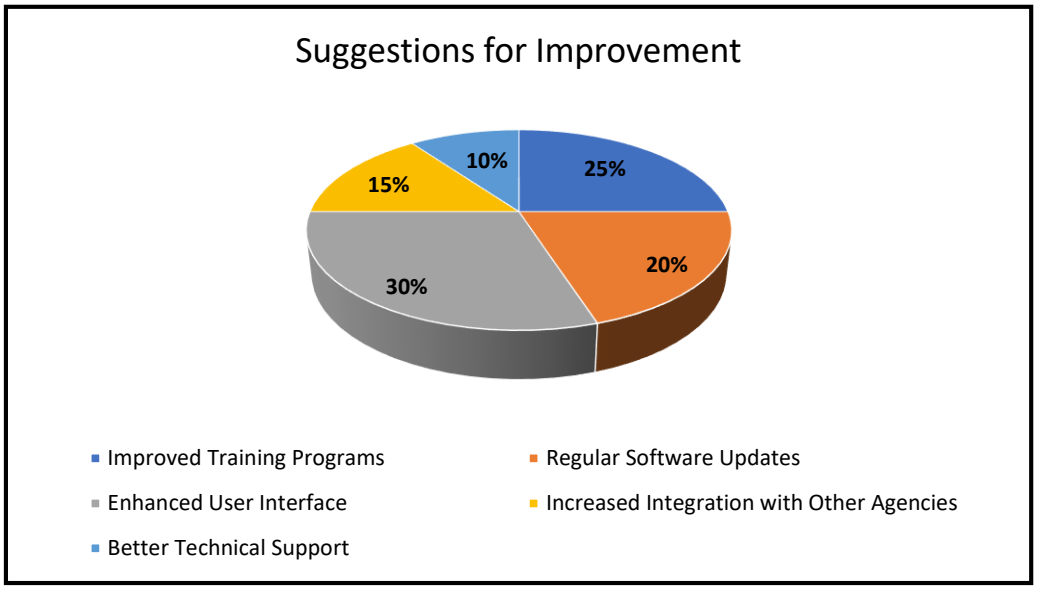


Figure 14: Suggestion for improvements made by the police service

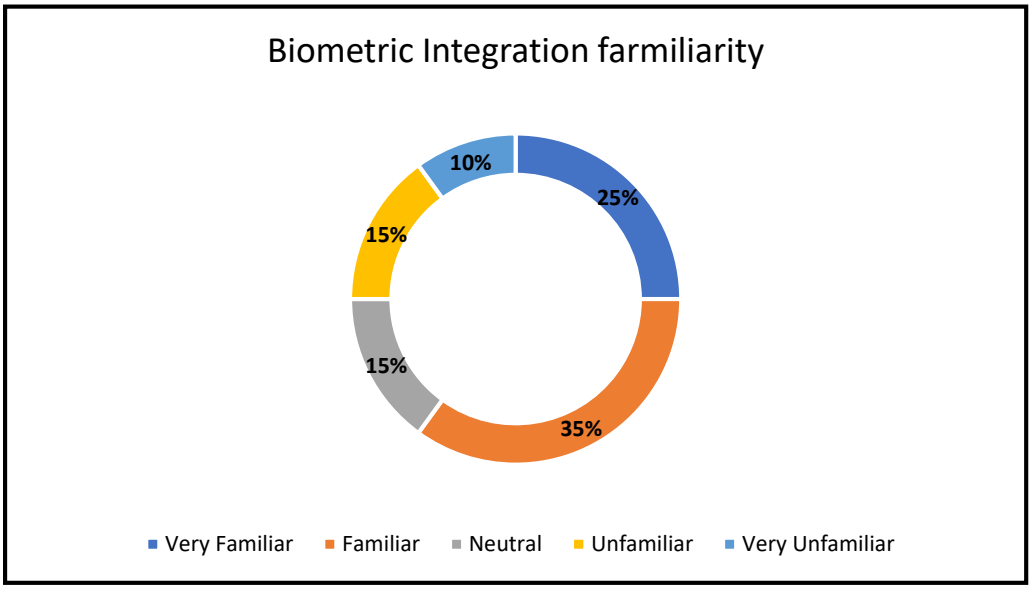


Figure 15: Biometric integration familiarity

4.3 Prototype Development

The developed mobile application, named the Zambia Police Information Management System (ZPIMS), leverages fingerprint biometrics for user authentication. However, the link between fingerprint authentication and police information management needs further clarification. The application interface facilitates seamless crime reporting, with

modules for profile creation, form submission, and real-time updates. The integration of geolocation data enhances the accuracy and efficiency of crime reporting processes. Figures 23 – 38 show various snapshots of the application's UI when a user is logged in.

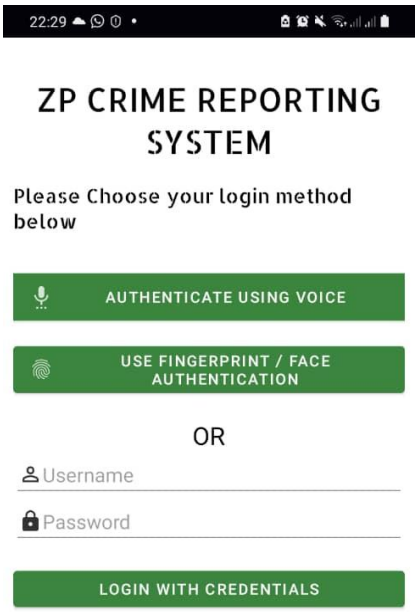


Figure 16: ZPIMS logging screen

Figure 23 shows the main logging in screen of the system where a user is prompted to login. It is worth noting that for this implementation, only finger print was successfully implemented and for the other biometric methods, they can be considered for future expansion of this work.

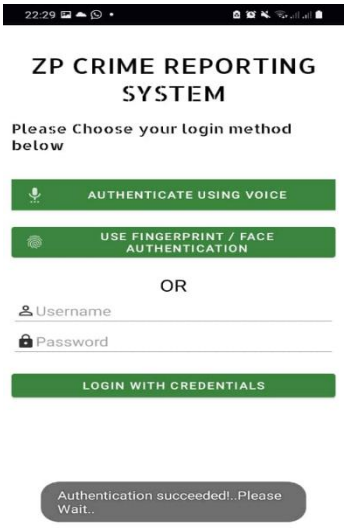


Figure 17: User successfully logging into the system

Figure 24 shows the screen when a user has successfully logged into the system, and they are immediately welcomed to the home screen. Home screen contains a dashboard with the user's names, their designation and duty station. Additionally, the welcome screen contains four modules; add persons , a module that allows the user to create a profile, general forms is the module to locate various forms that the police service uses as indicated in figure 25. The report crime module enables the user to report on the spot crimes. Lastly, the application also has access to the hotline. This feature is meant to be public facing.

Figure 18: System User modules

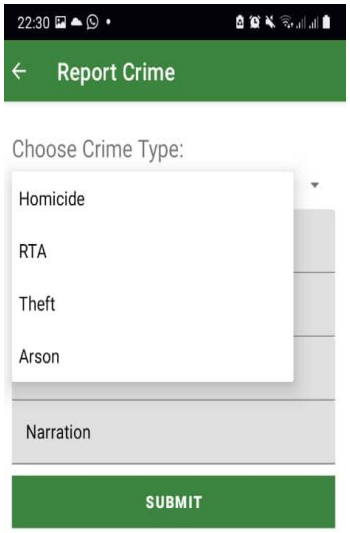


Figure 19: Drop-down menu options when reporting crime

Figure 26 shows the drop-down menu under the report crime module when a user selects it. The user will be able to specify the type of crime they would like to report

whether it is a road traffic accident, homicide, theft, Arson or other and then asks the user to submit the form.

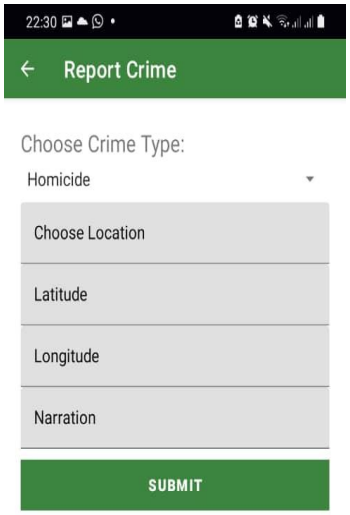


Figure 20: Capturing of geolocation and description of crime

When the user is done selecting the type of crime they are reporting, the system prompts the user to now choose the location where the crime has been reported from or has happened at. Upon completion of this stage, the system automatically populates the longitude and latitude fields based on the location chosen. The user is required to include a brief description or narrative of the crime being reported. These scenarios are depicted in figures 27 and 28.

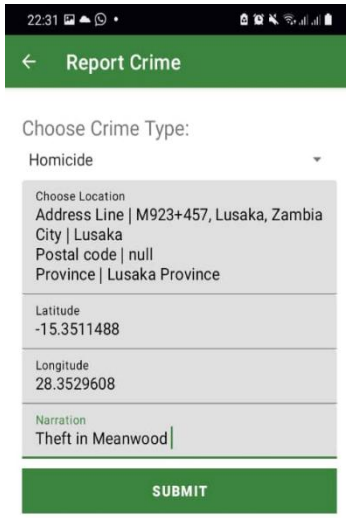


Figure 21: Geospatial data captured and form ready to submit

4.4 Comparison with other similar works

While the current prototype focuses on fingerprint biometrics, global trends indicate a broader shift towards rapid DNA analysis and face recognition systems in law enforcement. Future iterations of ZPIMS could explore these technologies to enhance its functionality and effectiveness. Additionally, acknowledgment is given to fellow researchers for their contributions to similar endeavors in the field of law enforcement software development.

4.5 Application

Beyond addressing the information management needs of the Zambia Police Service, ZPIMS has broader applications across other security and investigative entities in Zambia. Customizations could extend its utility to agencies such as the Drug Enforcement Commission, Zambia Army, and Zambia Airforce. Furthermore, its modular design allows for potential adaptation to non-security agencies, including the Electoral Commission of Zambia and the Immigration Department.

4.6 Chapter Summary

In summary, this chapter presents the development and findings of the ZPIMS application, highlighting its role in enhancing crime reporting and information management within the Zambia Police Service. While acknowledging the positive feedback from respondents, further clarification is needed to establish the direct link between fingerprint authentication and improved police information management.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Introduction

In this chapter, we synthesize the findings of the research, presenting discussions, conclusions, and recommendations derived from the results. Additionally, we explore potential avenues for future research enhancements, encompassing a comprehensive examination of both the baseline study and the developed prototype.

5.2 Improving automation of Zambia Police service workflow

The survey indicates that 65% of police officers express satisfaction with the current automation system, providing a positive foundation for improvement initiatives. This satisfaction suggests that the existing system is meeting some needs but also leaves room for enhancement. Specific areas for improvement, including user interface, data integration, and processing speed, were identified through open-ended responses. Addressing these concerns can lead to a more user-friendly and efficient system, ultimately improving the overall workflow of the Zambia Police Service[97].

Furthermore, the majority of respondents agree that there is potential for enhancing the current automation system, suggesting a receptive environment for change. The suggestions for improvement, such as real-time updates and enhanced security features, provide actionable insights for refining the system. These findings directly inform the development of the prototyped system, guiding the design and functionality to address the identified areas for enhancement based on user feedback. By actively involving end-users in the improvement process, the developed system aims to better align with the specific needs and requirements of the Zambia Police Service.

5.3 Integrating Biometric features and mobile application service

The survey results reveal moderate familiarity with integrating biometrics with mobile applications among respondents. While this indicates a reasonable foundation for introducing biometric features, targeted education and training programs may be necessary to ensure widespread understanding and acceptance. Identified benefits of biometrics integration include faster identification, enhanced security measures, and streamlined processes, aligning with the objective of improving operational efficiency within the Zambia Police Service.

Addressing concerns such as privacy issues and resistance to change is crucial for successful implementation. Additionally, while the questionnaire did not explicitly address Google Map integration, incorporating this feature for crime reporting and on-the-spot accident scenes aligns with modern technological trends. The use of geospatial data can enhance the accuracy and timeliness of incident reporting and response.

By integrating biometric features and Google Map functionality, the prototyped system offers a comprehensive and user-friendly solution that addresses the current automation system's limitations and introduces cutting-edge features. These enhancements not only improve the efficiency of police operations but also enhance the overall effectiveness of crime reporting and response mechanisms [97].

5.4 Developed mobile application

The prototype developed in alignment with business processes related to the capture and secure storage of both criminal and non-criminal forms streamlines processes for police officers. By leveraging Java technologies and third-party Software Development Kits for the fingerprint submodule, the system efficiently captures and stores data, saving time and improving overall efficiency.

The system's search functionality enables easy retrieval of records, surpassing the challenges associated with paper-based registries. If implemented on a broader scale, the system could provide substantial benefits to the government, enabling real-time reporting on crime statistics and enhancing service delivery within the police service.

The findings from this research directly influenced the development of the prototype by identifying user requirements and preferences, guiding the design and functionality of the system. By actively involving end-users in the development process and addressing their feedback, the developed system aims to better align with the specific needs and requirements of the Zambia Police Service.

5.5 Connecting to Existing Research

Comparing these findings to existing research in the field highlights the advancements and unique contributions of this study. While similar studies have explored aspects of automation and biometric integration in law enforcement, this research offers insights specific to the Zambia Police Service context.

By addressing user feedback and integrating state-of-the-art technologies, the developed system represents an innovative approach to improving police information management in Zambia. These findings contribute to the broader body of knowledge on law enforcement automation and biometric integration, providing valuable insights for researchers and practitioners in the field.

5.6 CONCLUSION AND RECOMMENDATIONS

The survey results offer valuable insights into the perspectives of Zambia Police Service officers regarding the current automation system and the proposed integration of biometric features and mobile applications. By aligning the findings with the research objectives and problem statement, actionable recommendations can be derived to address the identified challenges and achieve the overarching goal of improving police information management.

The problem statement highlighted the need to enhance the automation system and introduce biometric features to streamline police operations and improve overall efficiency. The survey findings confirm the existence of challenges within the current system and underscore the potential benefits of integrating biometric features and mobile applications.

Objective 1, focused on improving the current automation system, can be achieved by addressing specific improvement areas highlighted by the officers, such as user interface enhancements, better data integration, and faster processing speeds. These improvements directly address the challenges identified in the problem statement and contribute to a more efficient workflow within the Zambia Police Service.

Objective 2, centered on integrating biometric features and mobile applications, requires a strategic approach to education, training, and addressing concerns related to biometrics integration. Clear communication and comprehensive planning will be essential for successful implementation, ensuring that the new features align with officers' operational needs and overcome potential resistance to change.

5.7 Recommendations for Future Work

Based on the survey findings and aligned with the research objectives, several recommendations for future work emerge:

1. *User-Centric Development:* Adopt a user-centric approach in the development process, incorporating feedback on user interface improvements and real-time updates to ensure the system meets officers' operational needs.
2. *Training Programs:* Develop comprehensive training programs to address officers' concerns and enhance their familiarity with biometrics and the new system features. This will facilitate a smoother adoption process and maximize the benefits of the technology.
3. *Privacy Measures:* Implement robust privacy measures to address officers' privacy concerns and foster trust among users. Clear communication of the safeguards in place will be crucial in gaining acceptance and support for the new system.
4. *Pilot Programs:* Consider implementing pilot programs to test the new features, gather additional feedback, and address any unforeseen challenges before full-scale deployment. This iterative approach allows for adjustments based on real-world usage and user feedback.
5. *Collaboration with IT Experts:* Collaborate with IT experts and stakeholders to ensure seamless integration of biometric features and Google Map services, addressing technical challenges and optimizing system performance.
6. *Continuous Improvement:* Establish mechanisms for continuous improvement, encouraging officers to provide ongoing feedback to adapt and refine the system over time. This iterative process ensures that the system remains responsive to evolving operational needs and technological advancements.

By aligning the dissertation with these recommendations and leveraging the insights from the survey results, the Zambia Police Service can create a comprehensive and actionable plan for improving the automation system and introducing innovative features within the Service, directly addressing the problem statement and research questions outlined in this study.

5.8 Future works

This research study has implemented several business processes; however, there are certain functionalities that have not been incorporated yet, which could provide significant benefits to the system users. In the future, the prototype should be expanded to include the following:

1) Addition of option to upload images of crime scene to substantiate the crime being reported with picture evidence.
2) Integration of a facial recognition component considering the advancements in technology and the substantial potential it holds for capturing criminals.

5.9 Chapter Summary

This study has shed light on the current challenges faced by the Zambia Police Service in terms of information management and workflow efficiency. Through a comprehensive survey, valuable insights have been gathered, highlighting the need for improvements in the existing automation system and the potential benefits of integrating biometric features and mobile applications. By addressing specific improvement areas and adopting a strategic approach to education and training, the Zambia Police Service can enhance its operational capabilities and streamline its workflow. Recommendations for future work include user-centric development, comprehensive training programs, robust privacy measures, pilot programs for testing, collaboration with IT experts, and continuous improvement mechanisms. Implementation of these recommendations will enable the Zambia Police Service to create a more efficient and technologically advanced system, ultimately contributing to improved public safety and law enforcement efforts.

APPENDIX A

A.1: Code structure

The diagram below shows the code structure of the developed software prototype. Note that the hierarchy is as it is seen in the Microsoft Visual Studio.

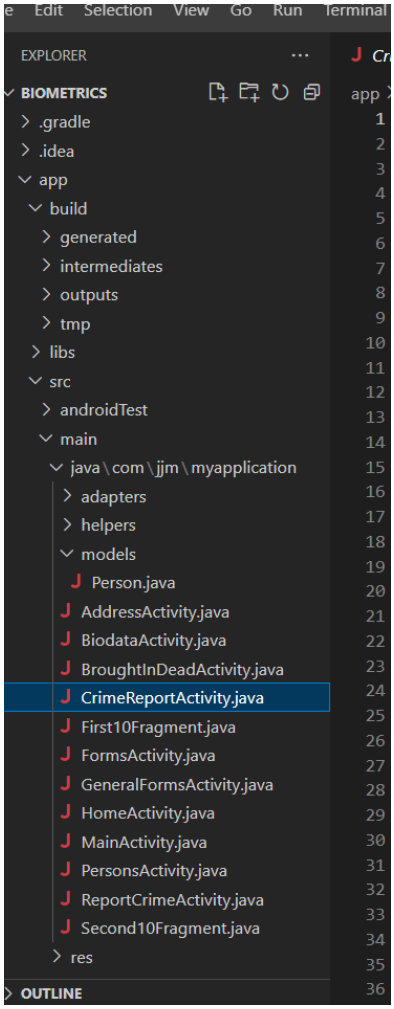


Figure 22: Code structure of ZPIMS

A.2: Code samples

The Class CrimeReportActivity handles all geospatial on spot crime reporting integrated with the fingerprint. When the call is complete, it sends a message to the user's screen that the crime has successfully been reported.

```
package com.jjm.myapplication;


import android.app.ProgressDialog;
```

```
import android.content.Intent;
import android.os.Bundle;

import com.android.volley.AuthFailureError;
import com.android.volley.Request;
import com.android.volley.RequestQueue;
import com.android.volley.toolbox.StringRequest;
import com.android.volley.toolbox.Volley;
import com.google.android.material.floatingactionbutton.FloatingActionButton;
import com.google.android.material.snackbar.Snackbar;

import androidx.appcompat.app.AppCompatActivity;
import androidx.appcompat.widget.Toolbar;

import android.view.View;
import android.widget.EditText;
import android.widget.Toast;

import java.util.HashMap;
import java.util.Map;

public class CrimeReportActivity extends AppCompatActivity {

private EditText mCrimetype, mLocation, mNarration;

private String url = "https://kumwela.com/zpims/api/crime.php";
private ProgressDialog pDialog;

private double lat, lng;
```

```
@Override
protected void onCreate(Bundle savedInstanceState) {
super.onCreate(savedInstanceState);
setContentView(R.layout.activity_crime_report);
Toolbar toolbar = findViewById(R.id.toolbar);
setSupportActionBar(toolbar);

mCrimetype = findViewById(R.id.etCrimetype);
mLocation = findViewById(R.id.etLocation);
mNarration = findViewById(R.id.etNarration);

}

public void reportCrime(View view) {

pDialog = new ProgressDialog(this);
// Showing progress dialog before making http request
pDialog.setMessage("Submitting Please Wait...");
pDialog.show();

RequestQueue requestQueue = Volley.newRequestQueue(this);
StringRequest stringRequest = new StringRequest(Request.Method.POST, url, response -> {
Toast.makeText(CrimeReportActivity.this, "Crime Reported successfully! ",
Toast.LENGTH_SHORT).show();
startActivity(new Intent(getApplicationContext(), HomeActivity.class));
hidePDialog();

}, error -> {
```

```
Toast.makeText(CrimeReportActivity.this, "Submission Failed!", Toast.LENGTH_SHORT).show();
hidePDialog();

}){
@Override
protected Map<String, String> getParams() throws AuthFailureError {
HashMap<String,String> map = new HashMap<>();
map.put("userID","1");
map.put("crime_type",mCrimetype.getText().toString());
map.put("location",mLocation.getText().toString());
map.put("lat", String.valueOf(lat));
map.put("lng", String.valueOf(lng));
map.put("narration",mNarration.getText().toString());
return map;
}
};
requestQueue.add(stringRequest);
}
private void hidePDialog() {
if (pDialog != null) {
pDialog.dismiss();
pDialog = null;
}
}
}
```

APPENDIX B: CONSENT FORM

B.1: Survey Consent Form

Purpose of the study: Jeremiah Mwiinga, a Master's student at The University of Zambia, School of Natural Sciences, is undertaking a Computer Science study with the objective of enhancing police information management. The research aims to integrate automated fingerprint technology and geospatial data, scrutinizing the existing data management and crime reporting procedures within the Police Service. The primary focus is on biometrics and Information Management Systems to identify deficiencies and explore opportunities for automation, improving overall efficiency. An integral outcome of this research involves the development of on-the-spot crime reporting, incorporating integrated fingerprint functionality.

What will be done? You are required to participate in a survey that will require 20-30 minutes of your time. The survey encompasses inquiries related to the biodata, automation

improvement, beliefs on automation improvement and familiarity with integration of biometrics systems.

Benefits of the study: Your contribution to this field of study will assist in identifying strategies to improve security and address performance issues within the existing workflow through the utilization of technology. This effort aims to develop a prototype software system designed to tackle the identified challenges. The intended pilot location for this proposed system is Choma Main Police, with the anticipation that it will enhance the overall productivity of the Zambia Police. Furthermore, the significant findings from this research will be communicated to the decision-making authorities within the Zambia Police for thorough analysis and consideration

Risks or discomforts: No risks or discomforts are anticipated in this study.

Confidentiality: All data will be gathered anonymously, and no personally identifiable information will be obtained during the course of this survey.

How the findings will be used: The study findings will exclusively serve scholarly purposes. The outcomes will be shared in academic environments and during professional conferences, potentially being published in a professional journal within the Computer field.

Contact Information:

If you have any concerns or questions about this study, please contact any of the following;

Directorate of Research, University of Zambia, Email: *drgs@unza.zm*

The Dean, School of Natural Sciences, The University of Zambia, Email: dean-ns@unza.zm

Research Team, Email: jeremiah.mwiinga@cs.unza.zm OR *jackson.phiri@unza.zm*

By initiating the survey, you confirm that you have reviewed this information and consent to engage in this research.

- ☐ *I agree:*
- ☐ *I do not agree:*

B.2: QUESTIONNAIRE

These questions aim to collect both quantitative and qualitative data to provide a comprehensive understanding of the police officers' perspectives on automation and biometrics integration within the Zambia Police services. Adjust the response options and wording as needed to suit the specific context and preferences of your study.

Section 1: Bio Data

1.1. Personal Information:

1.1.1. Full Name: _____

1.1.2. Badge/ID Number: _____

1.1.3. Rank/Position: _____

1.1.4. Years of Service: _____

1.1.5. Highest Level of Education:

- ☐ High School
- ☐ Diploma
- ☐ Bachelor's Degree
- ☐ Master's Degree

- Doctorate

Section 2: Automation Improvement

2.1. Current Automation System:

2.1.1. How satisfied are you with the current automation system?

- Very Satisfied
- Satisfied
- Neutral
- Dissatisfied
- Very Dissatisfied

2.1.2. In which areas do you think the current automation system needs improvement? (Open-ended)…….

2.2. Potential for Enhancement:

2.2.1. Do you believe there is potential for enhancing the system's automation beyond its current state?

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

2.2.2. If yes, please provide suggestions on how the system can be further improved. (Open-ended)

Section 3: Biometrics Integration

3.1. Integration of Biometrics:

3.1.1. How familiar are you with the concept of integrating biometrics with mobile applications?

- Very Familiar
- Familiar
- Neutral
- Unfamiliar
- Very Unfamiliar

3.1.2. In what ways do you think integrating biometrics with mobile applications could enhance the operational efficiency of Zambia Police services? (Open-ended)

3.1.3. Are there any concerns or challenges you foresee in implementing biometrics integration? (Open-ended)

APPENDIX C:

C.1: 4th African International Conference on Industrial Engineering and Operations Management, 2023

Paper Acceptance - 2023 IEOM Zambia Conference External Inbox ×

IEOM 2023 Zambia <noreply@xcdsystem.com> Fri, 10 Mar 2023, 16:36
to me, jackson.phiri

Paper Acceptance - 2023 IEOM Zambia Conference

Dear Jeremiah:

Congratulations! The IEOM program and publication team has recommended that your paper (ID 8: Biometric Authentication and Geospatial Data) has been *accepted for presentation and publication* for the 4th African International Conference on Industrial Engineering and Operations Management to be held in Lusaka, Zambia virtually and onsite at Hilton Garden Inn Lusaka Society Business Park during April 4-6, 2023. Host is University of Zambia, Lusaka. If you have submitted a full paper, you can see the review feedback using login to your IEOM 2023 Zambia submission system: https://www.xcdsystem.com/IEOM/abstract/index.cfm?ID=woSEe0L

Each technical presentation is for 15 min - 12 min for presentation and 3 min.

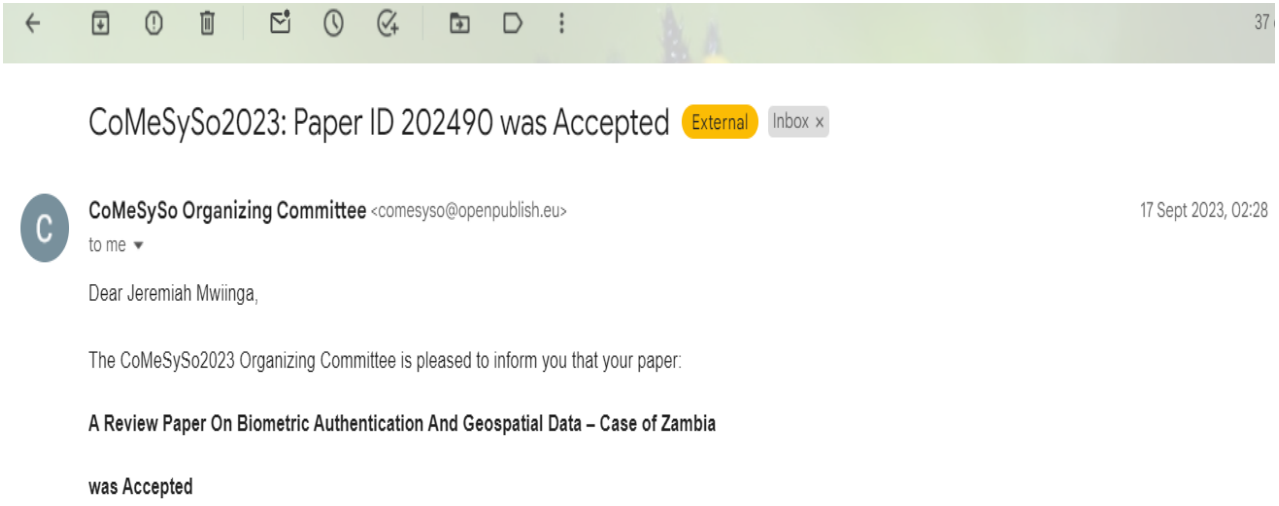
Paper Template WORD (*.docx)

Abstract Template WORD (*.docx)

Paper Checklist – Paper Formatting and Guidelines
IEOM Reference Format – http://ieomsociety.org/ieom-reference-format.docx

Please note the following points for the final paper preparation:

C.2: 7thCoMeSySo (Computational Methods in Systems and Software) Conference 2023



CoMeSySo2023: Paper ID 202490 was Accepted External Inbox ×

CoMeSySo Organizing Committee <comesyso@openpublish.eu> 17 Sept 2023, 02:28
to me

Dear Jeremiah Mwiinga,

The CoMeSySo2023 Organizing Committee is pleased to inform you that your paper:

A Review Paper On Biometric Authentication And Geospatial Data – Case of Zambia

was Accepted

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