CRIME SCENE EVIDENCE INVENTORY MANAGEMENT SYSTEM: THE CASE OF ZAMBIA POLICE SERVICE

BY

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DECLARATION

I, the undersigned, declare that this has not previously been submitted in candidature for any degree. The dissertation is the result of my 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: …….

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I dedicate to my three daughters Chipasha, Mapalo and Chengelo. They have always given me the spirit and courage to keep moving forward.

Thank you my darlings for your love and patience. Remember always to work whole heartedly, whenever you are doing something, and God will bless the works of your hands.

APPROVAL

This document by Peter Nsofwa is approved as fulfilling the requirements for the award of the degree of Maters of Engineering in Information and Communication Technology Security of the University of Zambia

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ABSTRACT

Crime solving comprises methodical law enforcement, an exhaustive investigation and collection of facts, and extensive evidence testing performed by criminalists and forensic experts. All the efforts might be in vein if the evidential items collected from the crime scene are not handled in a manner which adheres to the rules of evidence because it will not be accepted as evidence in Court. In order to archive this, evidential rules must be observed at each stage of the evidence life cycle. Law enforcement agencies in the western countries have gone aboard on computerizing and improving their information systems, in an effort to improve their services. These information systems include the use of inventory management systems.

The main objective of this study was to remodel and prototype a crime scene evidence inventory management for Zambia Police.

To archive this objective, a comprehensive review of relevant literature was done as to get an understanding of the concepts of processes, procedures and policies, associated with management of crime scene evidence. Interviews and questionnaire instruments were used to define the challenges, processes procedures and policies for the Zambia Police in regard to crime scene evidence management. The results from the baseline study showed that Zambia Police evidence inventory is done manually, mainly paper based and partly on spreadsheet. The system has no strong control procedures and has high chances of evidence tempering or pilfering. This also showed that the current system is not efficient. These baseline study findings were used to conceptualize and design the various components of crime scene inventory management system.

Based on the results from the prototype testing, it showed that the implementing the Crime Scene Evidence Inventory Management System will reduce the chance of evidence pilferage and tempering and will greatly improve the chain of custody.

Keywords: Exhibits, Integrity, Authenticity, Inventory management, Barcode, Chain of custody.

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ABBREVIATION

CID	Criminal Investigation Department
GPS	The Global Positioning System
IG	Inspector General of Police
SPSS	Statistical Package for Social Sciences
UNODC	United Nations Office on Drugs and Crime
UML	Unified Modelling Language (UML
XP	Extreme programming
UID	user-identifier
ERD	Entity Relationship Model

DEFINITON OF KEY TERMS

Chain of Custody	A process of registering the evidence movements and manipulations
Integrity	The quality of being unimpaired
Evidence Authenticity	The guarantee that all the evidence presented is in the same condition as it did when it was collected
Barcode	A barcode is an optical machine-readable representation of information that is formed by combinations of high and low reflectance regions of the surface of an object, which are converted to ‘1’s and ‘0’s
Criminal Investigation	A process of discovering, collecting, preparing, identifying and presenting evidence to determine what happened and who is responsible
Crime	An act (doing something) or omission (doing nothing) that is against the law and punishable upon conviction
Crime scene	A crime scene is any physical scene, anywhere that may provide potential evidence to an investigator.
Extreme programming	Software development methodology designed to improve the quality of software and its ability to properly adapt to the changing needs of the customer or client.
Zambia Police	Zambian Government institution that is mandated with the responsibility of providing and maintaining internal security of the country.
Exhibits	Anything from substantial objects to microscopic objects, produced as part of a crime and gathered from a crime scene or at related locations
EChain of Custody	Automated chain of custody

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CHAPTER ONE

INTRODUCTION TO THE RESEARCH

1.1 Introduction

The law enforcement evidence management function is important to the criminal justice process. Its effective and efficient operation is essential to an agency's quality of service to the community and the criminal justice system. The management of this function has gradually turned into a complex one, due in part to factors related to legislative obligations, the protection and preservation of evidence material and chain-of-custody [1]. The failure to manage the evidence function can affect the successful prosecution of criminals, resulting in agency liability or loss of public confidence [2].

Kiely [1] defined evidence as a testimony and presentation of documents, records, objects, and other such items relating to the existence or non-existence of alleged or disputed facts into which a court enquires. Okuda & Stephenson [3] defined evidence as a silent witness that reveals the events of an illegal act. Without it, the prosecution has little hope of tying the alleged criminal to the crime. Evidence can make or break a case therefore; it must be handled in a way that protects it from loss, damage, or contamination [3].

Evidence must conform to all regulations and statues in nature and the manner in the way evidence was obtained and managed throughout its life cycle for it to be admissible in court [2]. Reyes and Wiles [4] sums the requirement of evidence admissibility into two: evidences integrity and authenticity. Integrity of evidence refers to the quality of being unimpaired [5]. Authenticity refers to the guarantee that all the evidence presented is in the same condition as it did when it was collected [5]. It is required to prove to the court that the evidence did not change during the investigation otherwise it will be rejected [2].

Evidence chain-of-custody is one of the measures used to ensure evidence integrity and authenticity. Evidence chain-of-custody refers to the process of registering the evidence movements and manipulations [6]. Each and every person accessing the evidence must be identified and registered [7]. They must be provision of a complete documented

account of the progress of an item of evidence since its recovery from a crime scene up to the time it is presented in court. If this cannot be adequately demonstrated, the evidence in question may be ruled inadmissible by the court [1].

Automating the handing of evidence increases the accuracy by reducing human errors, minimize the likelihoods of illegal manipulation of evidences, and give access to data in real time [8]. The good approach to guarantee accountability and integrity of an institution that provides services to the public is through the use of effective information systems that leverage technology to enhance the productivity and overall operations [8].

This study focuses on to remodel and developing an Inventory Management System which will be used to ensure accountability for evidence by maintaining the chain-of-custody using the barcode technology.

1.2 Background Study

Crime scene management in the Zambia Police is done by Scenes of Crime Unit of the Forensic Investigation Wing of the Criminal Investigation Department (CID) [9]. At the time of this study most of the business processes under the CID were done manually including the documentation of evidence movement. These manual procedures present a lot of challenges which include; breakages in the Chain-of-custody which lends to: evidence inadmissibility; chances of mismatch between the evidence and their associated documentation; high chances of evidence tempering; evidence pilfering or loss; difficulties in tracking the evidence through the course of the investigation which could take weeks, months and sometimes years; difficulties in coming up statistical reports.

1.3 Statement of the Problem

Crime Scene evidence management by the Zambia Police has a problem. Despite having a Scenes of Crime Unit which is directly mandated to manage crime scene evidence the problem of evidence tempering and contamination is still occurring. This problem has negatively affected the prosecution of criminal cases which creates a bad image for the Zambia Police and the country at large. A possible cause of this problem is the failure to maintain the chain of evidence custody. The difficulty arising from this problem results

in loss of public confidence and the agency becomes a liability to the government. This is like an anchor indicating the need for the research paper. Perhaps a study which investigates the use of barcode enabled inventory management system will resolve this problem.

1.4 Aim

The main aim of this study was to re-design and prototype a crime scene inventory management system to support the operation Zambia police.

1.5 Objectives

The specific objectives of this research were as follows:

1. To investigate the challenges faced by law enforcement agencies in archiving and management of crime scene evidence.
2. To identify the problems and constraints of the current evidence management procedures used by the Zambia Police.
3. To develop a model for management of evidence following best business processes practices.
4. To build a prototype based on the model in (3).

1.6 Significance of the Study

Most academic research focuses on the usual handling of evidence and restricted on legal issues or the physical security of property. Research is rare in the areas of the criminal evidence management processes and chain-of-custody. This study bridged the known research gap by recommending a model for better chain-of-custody and evidence accountability. Law enforcement agencies will benefit from the consideration and use of this model due to the general significance of chain-of-custody and its implications.

1.7 Research Questions

This research was guided by the following research questions;

1. What are some of the challenges faced by the law enforcement agencies in the storage and management of crime evidence?
2. What are the problems and constraints of the current crime scene evidence management procedures used by the Zambia Police
3. What type of models exists which can be used to map the business processes through an inventory management system?
4. What tool can be developed based the model in (3) for crime scene evidence

inventory?

1.8 Conceptual Framework

This study conceptual framework was based on business process alignment and the supply chain management concepts of inventory management. To improve business processes involve process reengineering, process management, process analysis, process efficiency, process mapping, and process orientation [10]. Organizations benefit from the successful implementation of the changes associated with Business Process Reengineering because there is a significant and positive relationship between business process orientation and organizational performance [11]. The aim of this research study was to re-design the evidence management process and demonstrate significant benefits. An important component of this research study was to demonstrate the reduction of potential risk of evidence tampering and other benefits from improved evidence management.

Inventory management deals with the planning, tracking and control of quantifiable physical items. In this research study, those items are crime scene evidence collected.

1.9 Research Contributions

The research has contributed to the body of knowledge and to this effect a journal was published with the International Journal of Advanced Studies in Computer Science and Engineering (IJASCSE) Volume 5 Issue 4, published on 30th April 2016. This paper is index on Google scholar.

1.10 Organization of the Dissertation

The work done in this dissertation is organised into five chapters. Chapter 1 is the Introduction to the Research. This chapter outlined the overview of the entire research. Chapter 2 discusses the background of the study and related works. Chapter 3 looks at the methodology used and designing of the system. Chapter four discusses the results of the baseline study and how the system was implemented based on the findings. Chapter five looks at the research objectives and how they were archived and concludes this entire study.

1.11 Summary

This chapter outlined the introduction of the work in this dissertation. It begins by

looking at the importance of managing crime scene evidence. It also described how evidence can become inadmissibility if not managed well. The chapter went on and explained how the automation of evidence management process can ensure evidence authenticity and integrity. The background study, problem statement and the significance of this study have also been outlined in this chapter. The chapter also described the aim, objectives, conceptual framework, and research contribution. In closing the chapter describes the organization of this research document.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The keystone of a judicial process is the presentation of authentic evidence with preserved integrity because it assures the court that correct procedures were followed throughout all the processes [2]. Criminal evidence is a product of crime. A crime can be committed on any physical scene. This physical scene can be, a person's body, a building, a vehicle, places in the open air or objects found at those locations [12]. Investigators search, gather and preserve potential evidence from these crime scenes using criminal investigation techniques in order to prove that the crime was committed [13]. Physical evidence retrieved from crime scenes helps in resolving crime, by substantiating or challenging alibis, by excluding suspects or linking suspects to the crime, by recognizing the source of stolen materials, and by providing investigative clues [14].

Evidence that is properly handled and managed can lead to a conviction of suspect or to the freedom of the innocent [2]. According to Houck [15] evidence management starts from the crime scene. Houck [15] further explains that, if a crime scene is secured, protected, documented and correct sampling and storing processes are adopted, then it will help the evidence's admissibility in court.

2.2 Theoretical Framework

In recent years there has been an increasing trend to incorporate electronic record and business management systems across all operational areas. In the future it is expected that, the dependence on computer systems will continue to grow, rather than reduce. In the case of law enforcement and criminal justice, Custers and Bas [16] points out that technological development continuously offer new opportunities to contribute to better policing. Custers and Bas [16] further acknowledges that, the last decade has shown the growing interest in the development and deployment of evidence management systems that can maintain and track the evidence during the course of the process. Babera et al [17]explains that the main focuses of using technology is

about giving unambiguous identification of evidence, together with a suitable means of tracking. Law enforcement agencies all over the world are increasing efforts to optimize the use of technology [16]. This has been motivated by an increase in the number of successful stories that demonstrates the potential of technology to contribute to better, faster and cheaper policing and law enforcement [16].

2.3 Law Enforcement

Law enforcement encompasses several government agencies that are mandated with preventing crime, responding to criminal complaints, and recovering property within established jurisdictions [18] . Law enforcement agencies have a duty to investigate criminal complaints, establish the facts, and determine whether a crime has actually been committed or not.

Law enforcement is a branch of criminal justice which is directly in charge of crime. The criminal justice system is a set of processes that sums up the society activities to defend itself against the actions it defines as criminal [19]. These processes are established by governments to control crime and impose penalties on those who violate laws. Criminal justice activities reflect a broad range of social, legal, economic, political, and moral interests.

There are many different criminal justice systems in the world [20]. Despite different countries having different justice systems, literature shows that they all have something is common. The similarities in all the justice systems include the law, law enforcement, the courts and correction center [20] [19].

Figure 1 shows the criminal justice process.

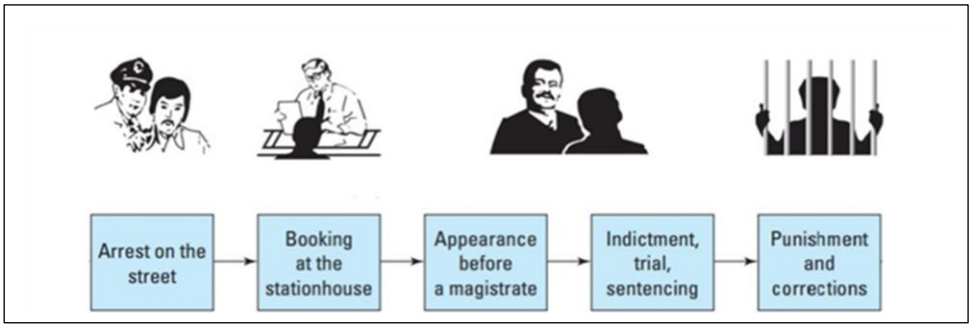


Fig 1: Criminal justice process

The criminal justice process consist mainly of three components; the law enforcement, the courts and corrections [21].

2.4 Crime

A crime is an act (doing something) or omission (doing nothing) that is against the law and punishable upon conviction [22]. To prove that a crime has been committed evidence is essential. This evidence can be an eye witnesses or other item from the suspect (such as semen, blood, fingerprints) found on the crime scene [23].

Crime is divided into two types' felonies and misdemeanors [24]. Felonies are considered to be more serious crimes (including crimes such as rape, robbery, murder) and are punishable by death or one or more years in a prisons. Misdemeanors are crimes that are not considered to be felonious (including crimes such as trespassing and simple assault). Misdemeanors are less serious in nature than felonies and are punishable by fines, probation, and/or imprisonment in a jail for a period of up to twelve months [24]

Adler et al [21] classifies all crimes into four broad categories: property and economic crimes, organized crime, violent crime and crimes against public morality.

1. **Property and economic crimes**

   These are types of crime which include traditional property crimes like larceny (theft), which not merely robs the owner of property but also can endanger lives [24]. Another type of crime that belongs to this category is white-collar crime which is a violation of the law committed by a person or group of persons in the course of an otherwise respected and legitimate occupation or business enterprise [21].

2. **Organized Crime**

   These are types of crimes committed by criminals who are organized like a business enterprise. These criminal enterprises can be transnational or local groupings which are highly centralized in their operations, whose aim is to involve in criminal activity, mostly for money and profit. These criminal groups uses violence and bribery to sustain its operations, threats of grievous retribution

(including killing) to uphold internal and external control, and involvement in election campaigns to buy political support for immunity from exposure and prosecution [21].

3. **Violent Crime**

   These are types of crime include taking of life or inflicting serious harm on a human being by another. Some violent crimes do not result in death, but assaults of various types, among them rape and robbery. Violent crime scenes regularly comprise an extensive variation of biological evidence, most of which can be subjected to DNA testing [25].

4. **Crimes against Public Morality**

   This category of crime was once known as "victimless" crime based on the assumption that people who engage in them choose to do so [21]. They include drug use, alcohol abuse, and prostitution and other sex acts between consenting adults

2.5 Criminal Investigation

Criminal investigation is defined as "*the process of discovering, collecting, preparing, identifying and presenting evidence to determine what happened and who is responsible"* [13].Investigators search, gather and preserve potential evidence from crime scenes using criminal investigation techniques. These investigative techniques include the use of scientific techniques called forensic sciences. The purpose of the investigation is to increase the possibility of successfully detecting and further prosecuting the perpetrator of the crime by combining the evidence collected across several investigations.

1. **Crime Scene Investigation**

   According to United Nations Office on Drugs and Crime (UNODC) [12], crime scene investigation is a practice that aims at recording the scene, recognizing and collecting all physical evidence that can be applicable to the solution of the crime. Fisher and Fisher [14] describes crime scene investigation as tool that aids investigators in detecting suspects and victims of crimes, clearing the innocent and

bringing the offenders to justice. Dror [26] describes crime scene investigation as a first stage in forensic evidence processing which is central to the entire investigation. Dror [26] further explains that once an evidence item is overlooked at the crime scene that constitute the sole link between the crime scene and the suspect(s) and the victim(s) the entire investigation can be compromised. Crime scene investigation uses established principles and procedures to guarantee that all physical evidence at a crime scene is discovered and investigated [27]. Information gathered at a crime scene can link possible suspects to the scene or eliminate them from suspicion [12]. Figure 2 shows an example of a crime scene.

Fig 2: Example of a Crime Scene

Crime scene investigators must have a variety of envelopes, containers, evidence tape, and other assorted packaging material at hand to properly collect and preserve physical evidence [25]. Figure 3 shows assorted packaging material that can be used.

Fig 3: Assorted Packaging Material for Crime Scene Investigators

One of the most important resolves of the crime scene investigation is to produce

a precise and all-inclusive account of the entire crime scene that is likely to be significant to the current criminal investigation and any consequent prosecution [27] . Crime scene documentation provides the only long-lasting record of the scene and is the only way of transmitting information about the scene to investigators, scientists, lawyers, and the court [27] [28]. Crime scene documentation encompasses taking photographs, sketches, and videos of the crime scene and the physical evidence. Photograph is the first step taken at a crime scene and must be done in a way that will not modify or damage the scene [28] [29]. Photographs are corroborated by crime scene sketches. As with photographs many sketches are prepared of a complete scene that includes all the objects present and their location [28]. Documentation of a crime scene creates a record for the investigation, therefore it is essential to record it accurately. The objective is to make sure that the important details of the crime scene and its layout are preserved and recorded as much as possible [27] [30]

2. Forensic Science investigation

Forensic Science investigation is the use of a wide spectrum of sciences to produce factual information which can serve as evidence in criminal prosecutions or civil litigation [1]. Weyermann and Ribaux [31] likens forensic scientists to archaeologists, who try to reconstruct the past. Forensic investigation attempts to answer the several questions that arise throughout the investigative process: "What? How? Why? Where? Who? When?" [1].

The key principle of forensic investigation is based on the concept that has become known as Locard's Exchange Principle. It states that "*whenever someone enters or exits an environment, something physical is added to and removed from the scene"* [32] [33]. This principle is normally summed up by stating that: "Every contact leaves a trace" [32] [33] [34] [35]. This could be a contact of a person with a person, contact of a person with a vehicle or location, or of a vehicle with a location [32] [33]. Forensic investigators identify those traces and analyze them to explain what happened [32] [33].

The contribution of forensic science to criminal justice is focused on the production of evidence dedicated to a court. Resnikoff et al [36] explains that in order to increase the confidence in the use of forensic information for decisions making in legal matters, there is need to for the validation of techniques used, accreditation of laboratories and certification of experts.

The process of forensic investigation involves four generic phases: collection, preservation, analysis of the information, and presentation [4] as shown in Figure 4.

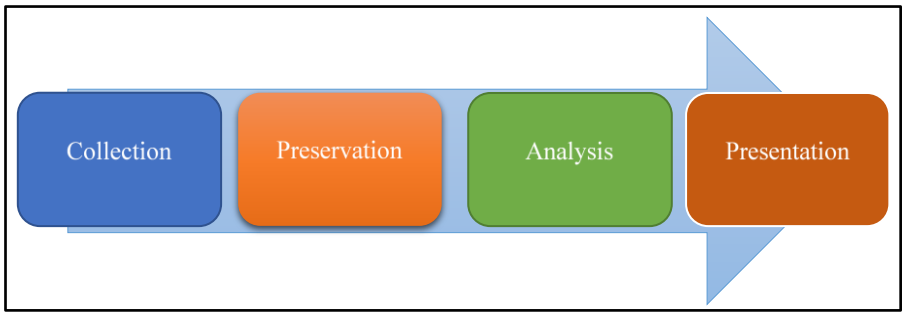


Fig 4: Forensic Investigation Generic Phases

The phases in Figure 4 are described as follows:

(i) Evidence Collection*:* - this phase is when items are identified, gathered and documented that could be considered to be of evidential value.

(ii) Evidence Preservation*:* this phase addresses the necessity to limit or, when possible, eliminate potential alteration, deterioration, or damage of evidence [15]. It protects the items collected from the crime scene in a manner that is reliable, complete, accurate, and verifiable. Jones and Craig [37] explains the terms reliable, complete, accurate, and verifiable more fully as:

(a) Reliable – yielding of consistent and dependable results.

(b) Complete - contains all of the relevant information, not just that which supports one side of the case accurate, in that it is free from error and biasness.

(c) Verifiable - any other investigator could come to the same conclusion if they were to examine the same information.

(iii) Evidence Analysis*:* The analysis phase of the forensic process addresses the realizing of facts about the evidence importance to rendering a finding. Individual elements of information that may be of significant to the case are extracted from the evidence. For this evidential information to be used must have some characteristics which includes the following [37]:

(a) Admissible - It must be acceptable for use by the courts or other bodies.

(b) Authentic - It must be possible to show that the evidence is relevant and relates to the incident.

(c) Complete - It must be complete and not just material that provides evidence of the guilt of the suspect and should also include evidence that may prove their innocence.

(d) Reliable: It must be reliable and the procedures adopted for the analysis must not cast doubt on the authenticity and/or veracity of the evidence.

(e) Believable: It must be clearly understandable and believable to a judge, jury, or tribunal.

(iv) Evidence Presentation**:** The fourth phase of the forensic process is when the evidence that has been gained as a result of the previous three phases is presented in what may be a variety of forms. The aim of this phase is to present the evidence obtained in a form that is an accurate representation of the facts and that is understandable to the intended audience. The presentation, in whichever form is selected, will normally be supported by documentation, which may include declarations and depositions

2.6 Criminal Evidence

Criminal evidence is an item that is generated as part of a crime and recovered at the scene or at related locations which can be used for the following [12]:

1. To prove a crime has been committed,
2. To establish any key elements of a crime
3. To link a suspect with a scene.
4. To establish the identity of a victim or suspect.

5. To corroborate verbal witness testimony.
6. To exonerate the innocent.

Criminal evidence is divided into two; testimonial evidence and physical evidence. This study focused on physical evidence which is recovered from crime scene.

2.7 Testimonial Evidence

This is informational evidence obtained from statements from witnesses, suspects, and others who have some facts of the crime scene [33] [38]. The witness must state, under oath, what he or she experienced, saw or heard. [38]. Bulbul et al [30] explains that witness testimonies play a fundamental role in defining crime scene forensic procedures that any criminal investigator might need to take into consideration

2.8 Physical Evidence

Not every crime scene have an eyewitness, but based on Locard's principle of exchange, the criminal leaves and takes something from a crime scene [33]. Therefore traces of evidence left at the crime scene can provide help to the investigator. Physical evidence also called "Real evidence" has been defined as a fact, the existence of that which is perceptible to the senses [39]. United Nations Office on Drugs and Crime [12] describes physical evidence as anything from substantial objects to microscopic objects, produced as part of a crime and gathered from a scene or at related locations. According to Van-der and Luke [2] physical evidence is anything that is physically tangible, given that it can be observed using eyesight, where this may be macroscopic, microscopic or trace features.

Physical evidence is categorized in the following types [40]:

1. **Transient evidence**

   This is the type of evidence by its very nature is, temporary, easily charged, lost or destroyed by conditions at a scene if not protected or preserved [24] [40]. The most common transient evidence encountered during investigation include; odors (such as perfume, gasoline, urine, burning, explosives, cigarette or cigar smoke), temperatures (e.g. surroundings, car engine, coffee, water in a bathtub), imprints and indentions (e.g. footprints, teeth marks in perishable foods, tire marks on

certain surfaces) some are biological and physical phenomenon such as rigidity or the drying of blood [24] [41]. This type of evidences must be documented as soon as they are observed due to their very nature.

2. **Conditional evidence**

   Condition evidence is produced by specific set of events or actions. Condition evidence must be documented at the crime scene immediately as it's observed otherwise it can be lost forever [40]. Commonly come across conditional evidence include lighting (e.g. lighting conditions, lights on or off), Smoke (e.g. colour, direction of travel, density, odor), Fire (e.g. colour and direction of the flames, speed of spread, temperature and condition of fire) Location (e.g. location of injuries or wounds, of bloodstains, of the victim's vehicle, of weapons or cartridge cases, of broken glass), Vehicles (e.g. doors locked or unlocked, windows opened or closed, radio off or on, odometer mileage, Body(e.g. position and types of wounds; rigor, livor, and algor mortis), television and computer settings, or exact locations of specific evidences within the scene (e.g. condition of furniture, doors and windows, any disturbance or signs of a struggle) [40].

3. **Pattern evidence**

   Pattern evidence is produced by the direct contact of two objects. The patterns found on crime scene are in the form of imprints, striations such as fractures or depositions [40]. The variety of such imprints and makings commonly include fingerprints, firearms evidence, footwear evidence, tire impressions, and tool marks, blood spatter, and clothing.

4. **Transfer evidence**

   This is the traditional forensic evidence also referred to as trace evidence. It is defined as any material or particle such as paint, blood, liquids, hairs, fibers, and skin that is exchanged between an offender and the victim or the scene crime [42].

5. **Medical evidence**

   This is the type of evidence that includes a doctor's clinical notes or records, and the forms a doctor completes. Medical evidence may also include first aid records,

emergency room and hospital records, diagnostic testing results, CT/x-ray reports, and permanent functional impairment evaluations [43]. Medical evidence can come for a chiropractors, doctor, psychologists, occupational therapists, ergonomists, physiotherapists, or occupational hygienists. Medical evidence does not only consists of victim's, suspect's, or witness's injuries, the type and degree of injury the position and state of a wound, the number and size of the wounds, but also includes medical history of the person, the prescription history, including date and amount prescribed [40].

6. **Electronic and digital evidence**

This is the type of evidence that is produced from the crimes committed by the use of computer systems either as an object of crime, an instrument used to commit a crime or depository of evidence related to a crime [14]. Electronic and digital evidence can include computer system, digital audio, digital video, cell phones, and digital fax machines. Electronic evidence has a physical form which can be identified visually such as computer, mobile phone, camera, CD, hard disk. Digital evidence is that which is extracted or recovered from electronic evidence such as file, email, short message, image, video, log, text [44].

Evidence of digital crime in contrast with the traditional evidence of a crime has its characters, such as not easy to gain, to retain with difficulty, the performance shape is varied, and the content is covert [15]. Digital forensic experts gather, preserve and analyze potential evidence in order to produce evidence. Digital evidence being a product of a new type of crime, it poses challenges to the judicial practice [14].

7. **Associative evidence**

This is the type of evidence that can be used to provide associations between evidence and entities involved in a crime. Specific items found at a crime scene could be used as evidence to associate a victim or suspect with a particular crime scene. It may possibly be used to associate a victim to a suspect. Examples of

associative evidence may include suspect's personal belongings such wallet or a ring found at a crime scene, or a vehicle, receipts, tickets or business cards [40]

2.9 Significance of Criminal Evidence

Mohay et al [45] states that unless there is evidence, all theories are of no use and it is as if there had been no crime. Mohay et al [45] further explains that unless a culprit can be authentically recognized, and placed at the crime scene through untainted evidence, the case cannot be justly solved [45]. Even where no prosecution eventuates from the investigation, criminal evidence collected can support future criminal cases.

In criminal justice system, the judicial process relies on evidence to demonstrate the truth and as a result affects the outcome of the case [46] .According to Natural rule of Justice the decision maker must be free from bias and secondly the individual who is affected by the decision must be given the opportunity to be heard [47] .This implies that parties to any dispute will be given a fair trial with all the necessary opportunities to present their case. According to Beckett [48] evidence must be made available to all parties in a criminal trial. Most criminal justice systems are based on the foundation that allowing a guilty person to go free is better than incarcerating an innocent person. In such cases, the prosecution bears a heavy burden of proof. The accused are presumed not guilty. Satisfying the burden of proof requires the prosecutor or the accuser to offer proof of each elements that combines to constitute accused's alleged wrong [3].Evidence is necessary for the prosecution to effectively prosecute criminal proceedings and it is also constitution right for the suspect [48] .Suspects have a legal right to a fair trial as well as evidence which is dependable and available, and any lack of a fair trial is a violation of the suspect's rights to due process and a fair trial [49].

Dror [26] explains that criminal evidence often has decisive power in the judicial system. Dror [26] further states that criminal evidence offers testimony mostly from forensic experts who provide objective and impartial scientific input to the legal proceedings. Therefore evidence is heavily relied on by courts in determining what happened and administering justice [40]. Van-Asten [50] points out the importance of

evidence in criminal justice system by explaining that forensic information generated from physical evidence allows law enforcement officers to solve crime and helps judges and juries to take right decisions in court. Evidence, once it is recognized and properly controlled, offers the best prospect for providing impartial and dependable information about the case under investigation [40].

2.10 Evidence Management

The soundness of the evidence is subject to the care taken in collecting and storing it. Improper collection, management or storage has a direct influence on the integrity of the evidence and may destroy its value to the judicial system [2].

Evidence management system must adhere to the best practices which include work management, quality control and assurance, security, documentation, and training [29]. Beckett [25] reiterates that in property and evidence management policies and procedures are an essential element. These policies and procedures include:

1. **Labeling**

   During evidence collection at a crime scene, correct labeling of evidence is important to evidence management and to maintaining the chain of custody [48]. While labeling pots, cans, bottles, and vials, the lid together with its container has to be labeled to prevent unintentional mixing of caps and containers, which increases the possibility of contamination.

   Relevant information that should be included on each label includes [15]

   (i) the nature and place of discovery of the exhibit;
   (ii) the identity of the collector;
   (iii) the hazards (if any, such as chemical, biological) posed by the evidence, which can be marked with standardized hazard stickers applied to the containers and lids;
   (iv) the date and time of collection;
   (v) the case the evidence relates to;
   (vi) exhibit's serial number

2. **Packaging**

Paper is the main method used in packaging of physical evidence. Paper containers come in many forms like bags, cardboard boxes, envelopes and in many sizes [48]. In the case that evidence does not fit into or would be harmed by preexisting containers, crime scene examiners may be required to fashion relevant containers out of available paper materials. Paper containers will allow damp fabrics and biological material to dry and breathe, decreasing the risk of deterioration and decomposition. Exhibits that release vapors should never be placed in paper containers. In order to preserve the vapors for analysis, these exhibits must be packaged in sealed nylon bags or new paint cans. Regardless of the type of container used to collect evidence, the seal on the container must ensure that the evidence cannot be lost, contaminated, or tampered with. Seals may be made of sealing tape and covered by evidence tape to mark the judicial nature of the container. In France, wax seals bearing the police service stamp prevent tampering and clearly mark that the material is under judicial control [15].

3. **Training**

Each crime scene must be handled by investigators specialized in crime scene management. Other scenes like digital crime scenes needs to be handled by personnel specialized in digital investigation [30]. Property officers must also have training which is applicable to the duties and responsibilities of the property officer and should be provided by professional instructors in the field of property and evidence management. [51]

4. **Legal and ethical considerations**

Though there are universal principles associated to crime scene investigations, laws, rules and regulations govern many activities evidence and crime scene management. These relate to issues such as authority to enter the crime scene (i.e. depending on the nature and location of the crime scene, investigators might need to secure a search warrant from the courts) and handle evidence (e.g. evidence

sealing type and procedure required) [14]. Evidence cannot be used in court if existing laws, rules and regulations are not adhered to [12].

5. Digital evidence Management

Digital evidence is by its very nature fragile; hence it receives special attention [52]. It can be altered, damaged, or destroyed by improper handling and it is vulnerable to static electric and electromagnet waves [53]. Therefore digital evidence management must be conducted in a systematic, formalized and legal manner to ensure the admissibility [30].

Theoretically digital evidence is like any other evidence, it is information leveraged in an attempt to place people and events within time and space to create a connection for criminal incidents [54]. However, digital evidence has a broader scope, and requires diverse training and tools compared with other physical evidence [54]. Bulbul et al [30] states that digital investigation requires specialized education and training in order to be specific to its objectives, because it's a distinct body of knowledge. Any person handling digital evidence must therefore be knowledgeable in forensics and must have proper training required to process and manage a crime scene [30]. Researchers and authors [30] [55] [56] [57] [7] have suggested that the following general forensic procedural principle that must be applied when dealing with digital evidence:

(i) Actions taken to secure and collect digital evidence should not affect the integrity of that evidence.

(ii) Persons conducting an examination of digital evidence should be trained for that purpose.

(iii) Activity relating to the seizure, examination, storage, or transfer of digital evidence should be documented, preserved, and available for review.

(iv) An individual is responsible for all actions taken with respect to digital evidence while the digital evidence is in their possession;

(v) Any agency, which is responsible for seizing, accessing, storing, or transferring digital evidence is responsible for compliance with these principles.

The above five listed points has been adopted in the published "Proposed Standards for Exchange of Digital Evidence" by The International Organization on Computer Evidence (IOCE). United Kingdom Association of Chief Police Officers (ACPO) - Good Practice Guide for Digital Evidence has also incorporated and adopted the suggested guidelines [58]. Watson and Jones [55] describes the above guidelines as acceptable principle of handling forensic evidence. These guidelines must be followed because whenever digital evidence becomes involved in adversarial proceedings, regardless of whether they are civil, criminal, or administrative, an error or omission in the evidence management could lead to the analysis being excluded from consideration by the presiding authority [4].

6. Biological evidence Management

The biggest concern with DNA and biological evidence is cross-contamination [59] [41]. Investigators collecting evidence at a crime scene must understand that it is critical to eliminate, or at least minimize the unintentional transfer of their DNA to the evidence as much as possible [60]. Cross-contamination occurs among items of evidence; hence, collected items of evidence must be packaged separately. Comingled evidence items that are packaged together have a risk of biological material being transferred from one item to the other. Some biological evidence may also expose anyone handling to harmful infectious diseases [59]. The problem being that it is not possible to determine if every biological evidence collected from the crime scene is hazardous or not; therefore, all biological evidence are presumed to be hazardous to ensure safety [60]. Bodily fluids and tissues are usually contaminated with bloodborne pathogens [60]. Because of potential risk of lifelong infection and the risk of death associated with infection once an individual is exposed, handling of biological evidence must only be done

by personnel trained to for that particular job [41]. Pfefferli [41] explains the need for strict and mandatory use of personal protective equipment (PPE) whenever assessing biological evidence.

Hazardous biological evidence packages must be appropriately labeled with biohazard labels and signage. Without the biohazard label (see Figure 5) other employees could inadvertently be exposed to risk or could contaminate the evidence.

Fig 5: Different types of biohazard labels

The labeling and signage guidance also applies to any shelves or rooms where these items are being stored. Additionally, a ventilation system may be required to ensure that employees are working in a safe workplace

2.11 Challenges of Evidence Management

1. Crime Scene Documentation

If the crime evidence is not documented and labeled well this might pose the following risks on evidence; physical damage, deterioration, contamination, infection, decomposition, loss and tempering [15]. Proper labeling and documentation well dictate on how certain evidence must be handled and kept. Therefore evidence management which includes labeling and tagging of evidence must begin at the crime scene. Pfefferli and Peter [41] explains that "*the weakest link in the chain of forensic evidence still is and will always be the crime scene investigation - in terms of evidence management, evidence assessment, and evidence handling*". Each evidence item is essential to the investigation, and any evidence item that is initially neglected at the crime scene may be lost forever [61]. Poorly and imperfectly managed crime scenes can result in reduced quality of evidence being used and increases the risk of fruitless investigations and/or

unjust verdicts. Ribaux et al [62] explains that crime scene management to a large extent controls the quality and quantity of information available for investigation and eventually for court. Most officers fail to appreciate the importance of crime scene documentation and ends up losing vital information [14].

Another central issue in crime scene investigation is unity of time, place and action. Weyermann, and Ribaux [31] explains that criminal investigations must consequently aim at proving this unity of time, by demonstrating that a suspect was on the crime scene (place) at a certain time(unity of time). Ribaux and Wright [63] explains that crime scene investigators obtain specimens from the scene and use it to develop the hypothesis about the activity, objects and individuals.

2. **Temporary Storage Location**

   According the survey conducted by Beckett [30] it showed that most Police stations in remote regions have no laid down procedure on how to handle and keep evidence. However the wide-ranging geographical areas covered by law enforcement agencies necessitate the use of provisional storage of evidence at stations in remote regions. These provisional storage increases on the potential errors and lapses in evidence documentation [30].

3. **Chain-of-custody**

   When evidence has been collected from the crime scene, it is the responsibility of the crime scene officer to safeguard its integrity against unintentional or purposeful tampering. Evidence items must not be left unattended. An officer must be assigned to guard the evidence at the scene of the crime if many days will be needed to manage it. Destruction of evidence, or modification of its integrity, should be noted, and the appropriate judicial authorities should be notified. Maintaining the Chain-of-custody is usually a challenge and is often recognized as the week link the evidence life [64].

2.12 Evidence Chain-Of-Custody

Chain-of-custody refers to the chronological and careful documentation of evidence including collection, storage, transportation, as well as noting a person who has taken

control of the evidence [23]. Verismo et al [65] understands chain-of-custody as tool used in handling evidence in order to keep its integrity and authenticity. According to International Union of Pure Applied Chemistry cited by Tomlinson et al [66] "*a chain-of-custody is the set of traceable records that provide unbroken control over a document, raw data, or a sample and its containers from initial collection to final disposal*". Chain-of-custody is required in the handling of samples that are bound by legal or regulatory directives [66]. From the beginning to the end of the evidence life cycle, it is crucial to demonstrate every single step undertaken to ensure "traceability" and "continuity" of the evidence from the crime scene to the courtroom. Verismo et al [65] states that in every process, evidence must be identified and identifiable and the person accessing it must be identified and registered at any time. Verismo et al [65] explains and recommends that there is a need to have a central authority to be responsible for the safeguard of evidence in order to minimize the risks of loss or alteration on evidence under custody. Cosic and Cosic [6] explains that evidence that is well recovered and preserved can be lost if the chain-of-custody is not properly maintained. The chain-of-custody helps to prove and demonstrate that the integrity of the evidence has been maintained throughout the all process [14]. Jones et al [37] reiterates that if the crime under investigation is likely to take stage and become part of criminal justice system, there must be documented a chain-of-custody so that the submitted items may be tracked from origin. When there is a need of post-convection testing, the chain-of-custody can be used to locate the evidence years down the road.

Chain-of-custody is often recognized as the weak link in criminal investigations [64]. Should the defense counsel demand the chain-of-custody for any evidence item, a documented path of continuity can demonstrate that the evidence item presented at court is actually the same evidence item gathered from the crime scene. If there are any inconsistency about where the evidence item has gone to or who has had possession of the item throughout the process, the judge may rule that the chain-of-custody has been broken and the item may not be admitted into evidence [15]. Many studies [37] [64] [7] [67] [68] have pointed out that any break in the chain-of-custody

opens the prosecution to allegations that the evidence has been tampered with or other evidence substituted for it. Cosic and Cosic [6] further explains that without the valid chain-of-custody, evidence cannot be accepted by the courts. Chain-of-custody helps to know where exactly, when and who came into contact with the evidence at each stage of the investigation [25]. The chain-of-custody answers the following questions [15] [25] [6] [66] [65]:

1. What is the evidence reported to be?

2. Can a uninterrupted trail of possession by each individual handling the evidence item be established from the time it was collected until the time it was presented in Court;

3. Can a person who had possession of the evidence item confirm that it essentially remained in the same condition from the moment he or she received it, to the moment he or she released it.

From the above questions Beckett [25] explains that chain-of-custody gives investigators the ability to accurately give an account in court as to the manner in which evidence was acquired maintained, examined, transported, by who, to where and for what purposes. Beckett further refutes that chain-of-custody is not relevant to admissibility of evidence in court but, it is relevant to maintaining the quality and validity of evidence.

Items collected from the crime scenes must have identifying information pertaining to the crime written on the container or tags as well as logs to establish the chain-of-custody. Fisher and Fisher [14] states that, the following type of information is needed to establish the chain-of-custody:

1. Name of the individual gathering the evidence and each person consequently having custody of it.
2. Dates the evidence item was collected and transferred
3. Agency, case number, and type of crime

4. Property official number
5. Victim's or suspect's name
6. Storage location
7. Brief description of the item

Storage of physical evidence has legal implications [15]. Evidence must be held in a secured area after it is gathered and before transportation to court. Evidence reasonably assumed to have been tampered with by unauthorized persons because it was kept in an unsecured area may be inadmissible in court [6]. Evidence should be maintained in a specific secured area, with limited access by only authorized persons [14].

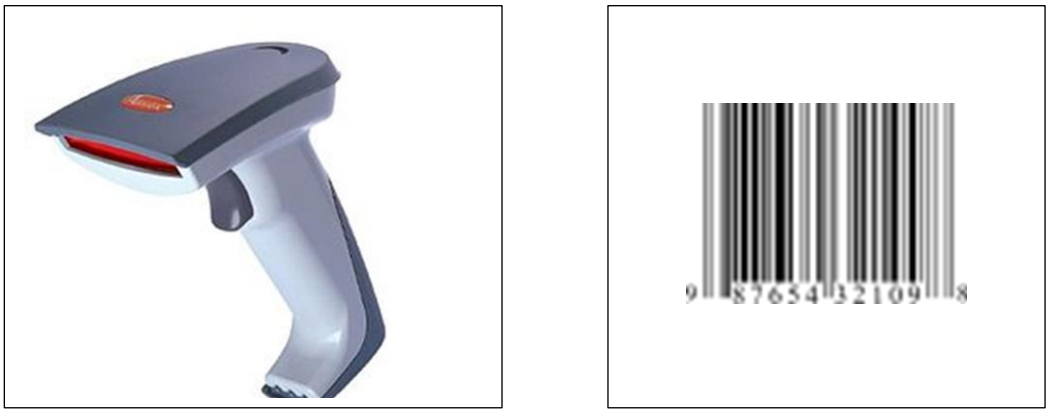
2.13 Technologies

The basic functionality of an inventory systems is to track an item in the distribution network, to record its arrival time at the predefined point, to register its departure time and send a message regarding its arrival and departure to the database [69].The message may contain only three basic attributes: the identity of the entity at the point, the location of the point, and the time [70].The last location (and the time of pass) of the tracked item can then be interrogated from the tracking database using a barcode reader.

Barcodes technologies are usually used to implement auto identification systems in many industrial products [71].This research uses barcode technology to track crime scene evidence.

2.13.1 Barcode

A barcode is an optical machine-readable representation of information that is formed by combinations of high and low reflectance regions of the surface of an object, which are converted to '1's and '0's [72]. The use of barcodes, barcode scanner and appropriate inventory software is one the most effective method of conducting an inventory [51]. Kato et al [72] recognized barcodes as the most prevalent automatic identification and data capture technologies. Figure 6-A and Figure 6-B show a barcode scanner and a barcode respectively.



A B

Fig 6: Barcode Scanner (A) and a Barcode (B)

Barcodes must represent only one specific item in order to conduct a thorough and accurate inventory [51]. One of the most commonly used forms of barcode is the Universal Product Code (UPC). The UPC is a barcode widely used in North America, the United Kingdom, Australia, and New Zealand for tracking items in retail stores [73]. The South Africa National forensic laboratory uses barcodes to monitor the movement of evidence [2].

1. Structure of Barcode

The barcode symbol is mainly made up of a start character, data characters, a stop character and quiet zones [74]. Figure 7 presents the data structure of Code 128.

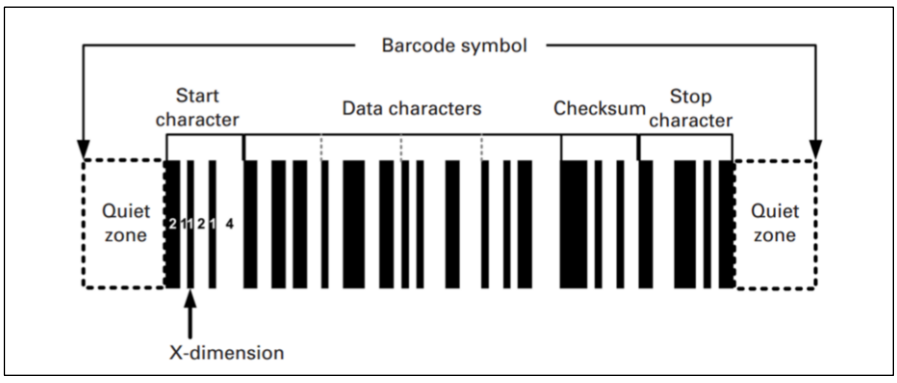


Fig 7: General structure of barcode: example – Code 128 symbol

(i) Quiet zone

Also known as Clear Area the Quiet Zone should be ten times the width of the narrowest element in the bar code [74]. The quiet zone must be free from any printing

and be the matching color and reflectance as the background of bar code symbol [72]. The quiet zone is before the start character and after the stop character of a 1D barcode symbol.

(ii) Start Character

The start character is unique and is normally located at the leftmost edge of a horizontally oriented symbol and also indicates the start of the barcode [74] [72]. These characters provide a scanner with reading instructions such as the scanning direction and when to start.

(iii) Data characters

The data characters or message characters appear after the start character [72].

(iv) X dimension

The X dimension is the width of the narrowest element (either bar or space) of a barcode symbol. It is stated in mils, or one thousandths of an inch. The larger the X dimension is, the stronger barcode reading can be realized [72]. Most symbologies oblige that the quiet zone be 10 times the X dimension.

(v) Checksum

Check digit (not always present) is a mathematical sum, whose value is used for the purpose of ensuring that the barcode is accurately decoded [74]. It is an extra digit positioned at the end of a bar code to permit the scanner to confirm that it read the bar code correctly [72]. It is normally detached from the data and not transmitted to the host.

(vi) Stop Character

The stop character specifies the stopping point of the barcode and is positioned at the rightmost edge of a horizontally oriented symbol. These characters afford a scanner with interpretation of instructions such as the scanning direction and when to stop reading [72]. The start and stop characters also permits barcode symbols to be read bi-directionally.

2. How the Barcode Operates

The barcodes are ordinarily read by scanning the symbols with a laser beam and distinguishing the diffuse reflections [75]. The dark bars of barcode absorb the light but the light is reflected by the spaces. Due to the different reflection abilities between

spaces and bars, the photodiode measures the reflected light converts it into electric signals which can be identified [74] [76].

3. Barcode Symbologies

A symbology type is a protocol for encoding information into a barcode format that make up a particular kind [77]. The different types of barcode in existence at the time of this study are, 1D barcodes, 2D barcodes and 3D barcodes. These barcodes were developed to respond to different needs in various fields and do not compete against each other [72].

(i) Linear 1D

Linear barcodes are composed of bars and spaces all in a single line. Barcodes representing data in the lines and the spacing of parallel lines such as Code128, Code 39, and UPC, also referred to as one-dimensional (Linear or 1D) barcode symbologies [77]. Figure 8 shows example of 1D barcodes.

Fig 8: Example of Linear 1D Barcodes

(ii) 2D Barcodes

2D barcodes are made up of black and white "cells" or modules organized in either a square or rectangular. 2D barcodes can encode significantly more data than 1D and can store up to 2 kilobytes of data [78]. However a translation key is needed to decode most 2D barcodes [73]. The most popular 2D barcodes include: PDF417, DataMatrix, Micro PDF417, and 2D Pharma [78]. Figure 9 shows an example of 2D barcode

Fig 9: Example of 2D Barcode

Since a 2D barcode carries data within itself, it has the potential to offer a superior results for applications where the use of a backend database is impractical, high-speed processing is required and space is a problem [72]. Since a 2D barcode carries data within itself, there is no need to access a backend database in 2D barcode systems.

(iii) 3D Barcode

This is a type barcode which is directly embossed on the surface of the material also called 'bumpy' barcode. To create 3D barcode both the 1D and 2D can be used. 3D barcode readers use the bumpy aspect of the symbol to locate symbols, measure the width spaces and bars (or the size of cells when 2D barcode is used) and decode them, instead of visual contrasts between different colours [72]. Figure 10 presents an example a 3D barcode

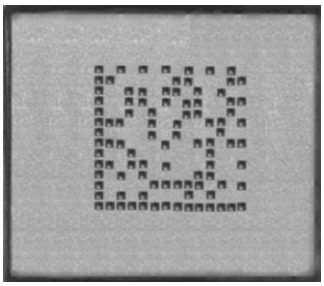


Fig 10: Example of 3D Barcode

4. Barcode Applications

(i) Commerce – The uses of barcode technology in commerce includes but not limited to the following: library (inventory, shelf, checkout), video stores, music, catalogues, banking (ATM, cheques, documents, money and inventory), publications, books (bookshop, price code) [72].

(ii) Industry – In industries the barcode technology is used for quality control

(confirmation of correct parts, traceability of components), materials (material flow, stock control, tracking material, inventory), , electronic proof of receipt, production control, control machinery, paper production, material resource planning and similar systems, electronic proof of shipping [72].

(iii) **Retail** – Self-checkout, checkout, ordering, receipt , inventory control, purchasing

(iv) **Distribution** – Material movement, packaging, package delivery, postal codes, warehousing, truck loading, total data information [72].

(v) **Medical** – Patient history, smart card, equipment, patients, staff authorization, pharmaceuticals controlling shelf life [72].

(vi) **Documents** – Payroll, forms, scheduling, order forms, sales, accounting, shipping and receiving, accounting [72].

(vii) **Innovative and foreseeable barcode use** – The blending of two mobile technologies, that is, 2D barcodes and camera phones, has gained popularity as a promising ever-present computing tool in recent years. When used with camera phones, 2D barcodes work as a tag to connect the physical world and the digital world. Saved on mobile phones, 2D barcodes likewise can be used as portable data files such as e-coupons or e-tickets. E-coupons or e-tickets can be bought and exchanged by the use of the Internet. E-tickets on the phone display can be scanned and confirmed at the check-in counter without attendants, which consequently speedup ticket handling.

5. Advantages of using Barcodes

The advantages of barcode technology include the following [72] [79]:

(i) Fast, precise and dependable keyless data entry can be attained.

(ii) The technology is adaptable and functions economically using paper and ink.

(iii) The technology can help to provides real-time information and in turn allows the decisions to be made accordingly for the current operations.

(iv) The barcode technology can afford secure operation. When data are encoded in the format of a barcode, it cannot be altered devoid of physical alteration.

6. Disadvantages of using Barcodes

The disadvantages of barcode technology include the following [72] [79]:

(i) A clear line of sight is required to read barcode symbols.

(ii) Only one barcode symbol can be read at a time.

(iii) The technology have no ability to scan an object inside a container.

(iv) The reading distance is relatively short. More or less scanners need physical contact to read the barcode symbols.

2.14 Related Works

2.14.1 Starlims

Starlims is a web based laboratory information management system (LIMS) designed for forensic laboratories. The goal of this system is to streamlines the entire forensic process by helping save time and achieve compliance.

1. Features of Starlims

Starlims Forensics has four main modules; Crime Scene Module, Laboratory module, Quality assurance module, and Property unit module. This system operates on a concurrent license model which means users can only buy the modules they need. Figure 11 shows the screen shot of Starlims Crime Scene Module.

Fig 11: Screenshot of Starlims Crime Scene Module

(i) Crime Scene Module

Capture details of the scene, including who was on the scene, what they did, and what evidence was collected. The electronic chain-of-custody feature begins immediately upon collection.

(ii) Laboratory Module

Achieve time savings and reduce typographical errors via instrument integrations and file parsing.

(iii) Quality Management Module

Eliminate the redundancy and shortcomings of two separate systems by using the Integrated Solution help maintain efficiency.

(iv) Property Unit Module

Store and track highly sensitive crime scene evidence and other property. Accurately document every movement and account for every item, from receipt to disposition, with real-time barcoded tracking. Officers can save time by pre-logging evidence directly from their vehicle computer.

2. Starlims System Architecture

Starlims software is based on client-Server application. The communications between client and server depend on standard web service messaging over Hypertext Transfer Protocol (HTTP).

STARLIMS's code is split into business logic (which is executed on the server side), and presentation code (run by a .net control on the web client). The STARLIMS application servers utilize hardware resources by dynamically creating execution threads that concurrently handle business logic requests. The scalable distributed server farm is continuously monitored by a balancing server, which analyzes the workload and routes to the optimal server.

The STARLIMS client uses standard web browser that hosts a .NET control that dynamically presents the user interface. In addition to the classic GUI controls (labels, buttons, textboxes), this technology supports more complex controls, such as

hierarchical data grids, tab controls, and selection boxes. For data-aware components, special business actions, termed data providers, are used to interface between the GUI and the data model residing on the server. For increased security, client-side scripting code is run in an isolated ("sand-boxed") environment, and the server-side business logic code is separated from the client-side [80].

3. Starlims Advantages

(i) The system Comply with ISO 17025, ASCLD-LAB, CALEA

(ii) Reduce error rates. Our solution actively interacts with users to prevent errors. For example, expired reagents and offline equipment will not be available for selection

4. Starlims Disadvantages

(i) The system can only work Microsoft windows operating system.

(ii) STARLIMS works only in Internet Explorer browser and requires .NET Framework component on your client computer [81].

(iii) The system is expensive and it sold per module.

2.14.2 Evidence Hound

Evidence Hound is a PC based evidence tracking software system which was created by TEKLYNX International and Data Support Inc. Evidence Hound can run either on a single workstation or in a network environment A single PC in the Evidence room can have a scanner attached to allow for the scanning of both evidence barcodes and user ID barcodes. Evidence Hound uses on-screen forms to enter evidence information into its database. The evidence can be grouped according to a case or many cases in order to associate the item with other evidence or even other investigations. Evidence Hound has several drop-down menus on which a user can select the desired entry rather than type in the information. Figure 12 show the screenshot of Evidence Hound.

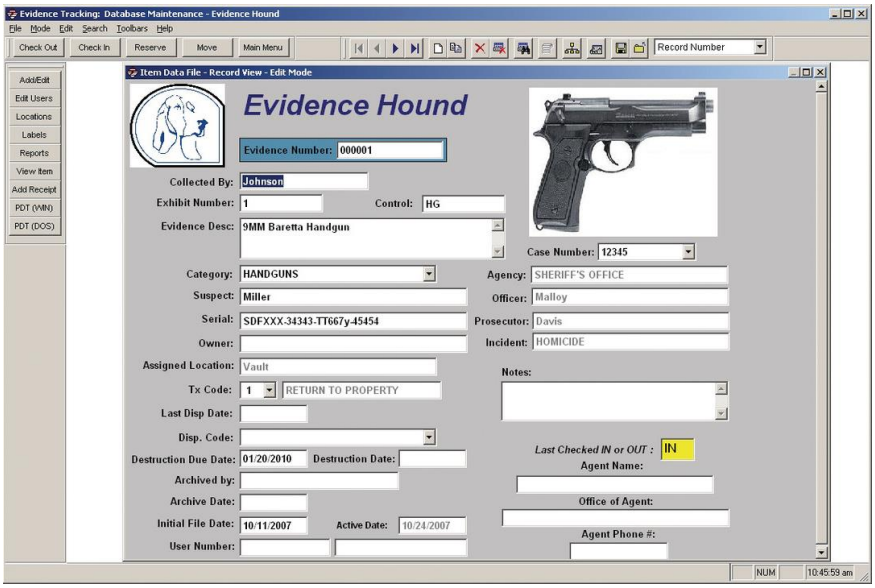


Fig 12: Screenshot Evidence Hound

Evidence Hound also offers major advances in reporting with many pre-formatted reports. It eliminates manual report writing and reduces errors since tracking reports are printed instantly directly from the system.

1. Features of Evidence Hound

The Evidence Hound includes an integrated barcode label design and printing software. The Evidence Hound uses the barcode technology to maintain evidence chain of custody. The Evidence Hound has Integrated report writing.

2. Advantage of Evidence Hound

(i) It has an integrated report writing feature

(ii) Flexible labelling – user can design and print their own barcode and human-readable tags.

2.14.3 Wolfcom Evidence Management Solution

The WOLFCOM Evidence Management Solution is a digital evidence management solution that manages video assets, photos, audio files, and documents. The WOLFCOM Evidence Management Solution is compliant with IACP standards for digital evidence management. A user, with proper rights and privileges, will be able to tag, view, verify integrity of the asset, generate an audit trail report, setup file sharing

for specified users for a set period of time and automatically purge the files based on the department's retention policies. Figure 13 shows the screenshot of WOLFCOM Evidence Management Solution

Fig 13: Screenshot of Wolfcom Evidence Management Solution

1. Features Wolfcom Evidence Management Solution

The Wolfcom Evidence Management Solution has GPS GeoTagging capability. The GPS coordinates are stamped onto every video and picture file, frame by frame and picture by picture. The route of the video simultaneously on the map next to the video will be see when reviewing videos and as the video moves so does the dot on the map. Officer's activities are categorized by a Case Number or similar identifier, this allows the officers to organize all digital evidence from that case to a specific Case Number. All activity is logged by the system. An audit trail report displays who, what, when and where files have been accessed. The system is able to maintain the chain of custody.

2. Advantages of Wolfcom Evidence Management Solution

(i) It can be taller made to suit unique challenges of a particular organization.

(ii) Evidence can be viewed from any department computer on the network.

(iii) Provides a complete backup and restore solution. Wolfcom solution can have all or specific assets sent to multiple locations for local and/or offsite redundancy.

3. Disadvantages of Wolfcom Evidence Management Solution

(i) It can only operate on Microsoft windows operating system.

(ii) The software solution will automatically purge assets based on the department's retention policies.

2.14.4 Centurion Evidence Management Software

The Centurion Evidence Management Software allows users to enter, track and manage your evidence inventory. The software system is customizable to adapt to the procedures and terminology used a particular agency. It can be used by multiple agencies and/or multiple locations within an agency. The entry of items is done using an easy to follow step-by-step method. Figure 14 shows Screenshot of Centurion Evidence Management Software.

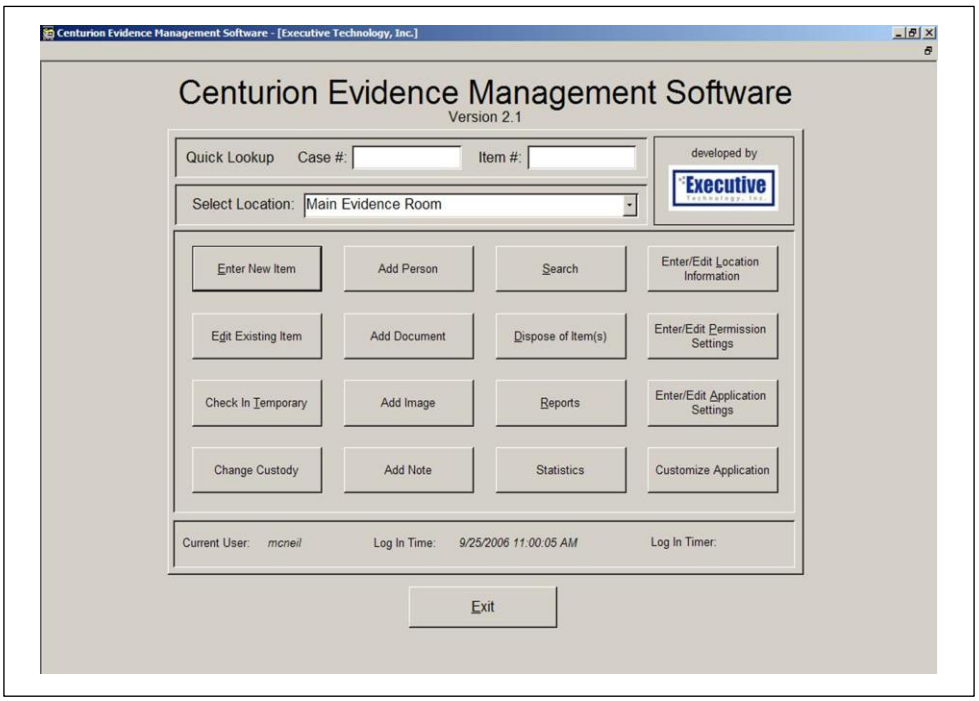


Fig 14: Screenshot of Centurion Evidence Management Software

1. Features of Centurion Evidence Management Software

The system can produce and read bar code labels for easy access to evidence items. The system groups evidence according to case number. Statistical reports are provided and can be customized to provide the specific information needed by a particular agency

2.15 Summary

In this chapter an overview of the background theory of evidence management has been outlined. The chapter outlines the importance of evidence to law enforcement and the criminal justice at large. The chapter further also describes and explains the importance of chain-of-custody in evidence management. The chapter closed by outlining some of related works.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter outlines the methodology used in conducting this study, the method used during data collection, techniques used, sample size, and target population. The chapter also looks at how the current Zambia Police Evidence Management System operates. The chapter highlights on business processes and how they were mapped and used in the designing and developing of the prototype.

3.2 Baseline Study

Mixed Methods Research Methodology was used in this research. Structured questionnaire was used to collect quantitative information from officer operating under crime scene investigation across all the ten provincial headquarters of Zambia Police. For qualitative data, interviews with provincial heads of Scene of Crime units were conducted. The purpose of the baseline study was to get an understanding of the concepts of challenges, processes, procedures and policies, associated with management of crime scene.

3.3 The Zambia Police Force

The Zambia Police Force is an institution under the Ministry of Home Affairs established under article 103 of the Constitution of Zambia and it has been in existence since 1964 [9]. It is one of the Government institutions that is mandated with the responsibility of providing and maintaining internal security of the country. The functions of Zambia Police Force are provided for in the Constitution under Article 104 and the Zambia Police Act Chapter 107. The Zambia Police Force is mandated by law to [9]:

1. Protect life and property;
2. Preserve law and order;
3. Detect and prevent crime;
4. Cooperate with the civilian and other security organs established under the constitution;

5. Apprehend offenders against peace; and
6. Preserve peace.

The Inspector General of Police is the head of Zambia Police Force who is assisted by the deputy Inspector General. There are a number of Commissioners of Police who head specialized sections and Divisions Figures shows the organizational structure of Zambia Police Force.

3.3.2 Zambia Police Departmental Structure

The organizational structure of the Zambia Police constitutes of Police Headquarters and Police Divisions as shown in Figure 16.

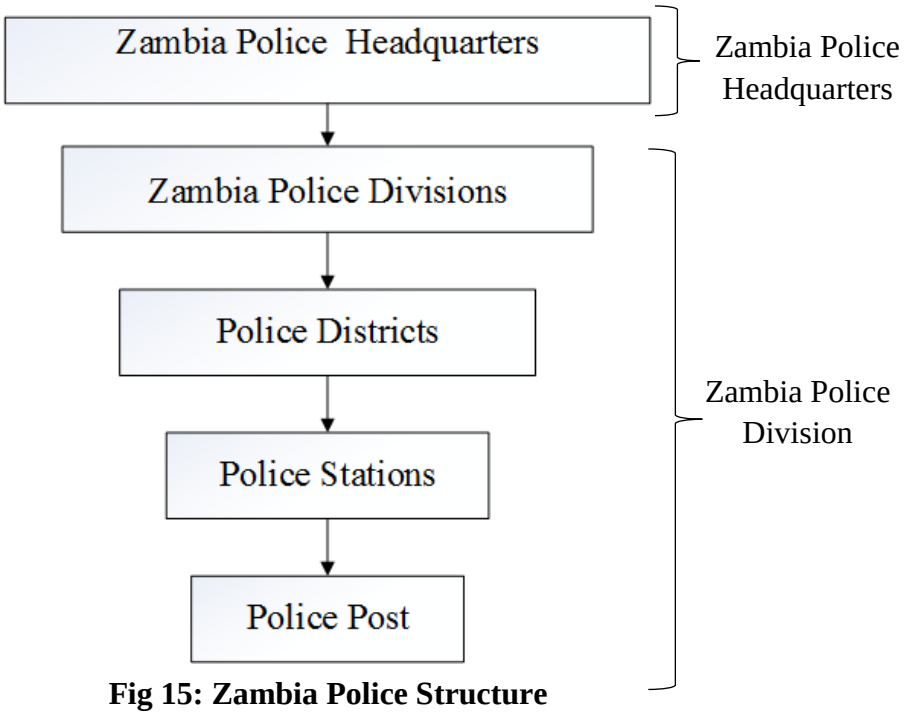


Fig 15: Zambia Police Structure

1. Zambia Police Force Headquarters

The Zambia Police Headquarters comprises the office of the Inspector General of Police and two Deputy Inspector Generals of Police who are in charge for administration and Operations respectively. The force headquarters also has five Directorates under which are Sections and Units.

(i) The Inspector General of Police (IG)

The IG is the highest in the hierarchy of authority of the Zambia Police. The IG directs and controls the functions of the Zambia Police Force. The assistants to the IG

are the two Deputy Inspector Generals of Police.

(ii) Directorates

The Zambia Police Force Headquarters is made up of five Directorates which are Administration, Medical, Crime Prevention and Support Services, Criminal Investigation and Technical Services. All the Directorates are headed by Deputy Commissioners of Police.

2. Zambia Police Divisions

The Zambia Police Force has 17 divisions, 10 are named according to the geographical locations of provinces and 7 are named according to their function. Those named accord to provinces are; Lusaka, Copperbelt, Central, Northern, Eastern, Luapula, North western, Western, Southern, Muchinga and those named according to functions are State House, School of Public Order and Maintenance, Protective Unit, Paramilitary, Lilayi Police Training School, Tanzania Zambia Railway Authority(TAZARA) Division and Airports Divisions. The divisions are headed by commanding officers [82]**.**

(i) Police Districts

The Zambia Police Force had a total number of 24 Police Districts. The police district reports to the division police. The districts are headed by officer commanding.

(ii) Police Stations

The Zambia Police Force has a total number total of 148 police stations countrywide. The police stations are head by officer in charges who reports to the Officer Commanding of a police district [82].

(iii) Police Post

The Zambia Police Force has a total number of 294 Police Post stands as at the time of this study. The police post is the lowest operational level in Police divisions and is headed by a police officer of the rank of Inspector.

3.3.3 Care and Custody of Exhibits

The Zambia Police Force Instruction Number 98 stipulates on how evidence cared for by the Zambia. The following are the extracts from the Zambia Police Force

Instruction [82].

1. Article likely to be required as exhibits in connection with a criminal offence will be taken into custody by the investigating officers and registered without delay.
2. The chain of witnesses as to the discovery and subsequent custody of all exhibits will be reduced to as few persons as possible and whenever practicable, the police officer who first discovers or obtains possession of an exhibit will produce it to the court. Such witnesses must be prepared to give evidence regarding the method adopted for the safeguarding the exhibit from being tampered with.
3. All exhibits will be placed under lock and key to prevent access to, or possibility of interference by, any unauthorized person.

   Cash and valuables will be lodged in a safe, securely fixed cash box, or other safe place. Arms and ammunition will be stored in the station armory.
4. Exhibits form part of the evidence in a case and once handed in to court as evidence must remain in the custody of the court. It is for the magistrate to order disposal of exhibits, and members of the Zambia Police Force must not take back into Police custody or dispose of such exhibits except on the written order of the magistrate.
5. Any exhibits sent to Police headquarters for examination will be sealed with an official police seal affixed so that the impression in the wax is cleared and distinct and identifying number of the seal is readily distinguishable. The sealing must be effected so that it will be impossible to open or temper with the exhibit without breaking the seal.

3.3.4 Evidence Management Challenges Faced By Zambia Police

1. Lack of appropriate tools for maintaining the chain of custody

The Zambia Police Instruction number 98 talks about maintaining the chain of custody without describing how and what tool to use [82].

2. Lack of standardized procedure on Evidence management

The Zambia Police Instruction number 98 leaves it upto the officer to adopt an appropriate method for safeguarding the exhibit from being tampered [82].

3. Lack of chain of custody form

The evidence is not accompanied by the chain of custody form instead officers use the handwritten handover certificate written in the officer official notebook [82].

4. Non adherence to rules by officer

The study results indicated that 11.54% of the respondents use the written measures in ensuring evidence integrity.

The baseline study revealed that the Zambia Police Evidence Management System was done manually. The researcher developed a diagrammatical representation of the current evidence management system as shown in Figure 16.

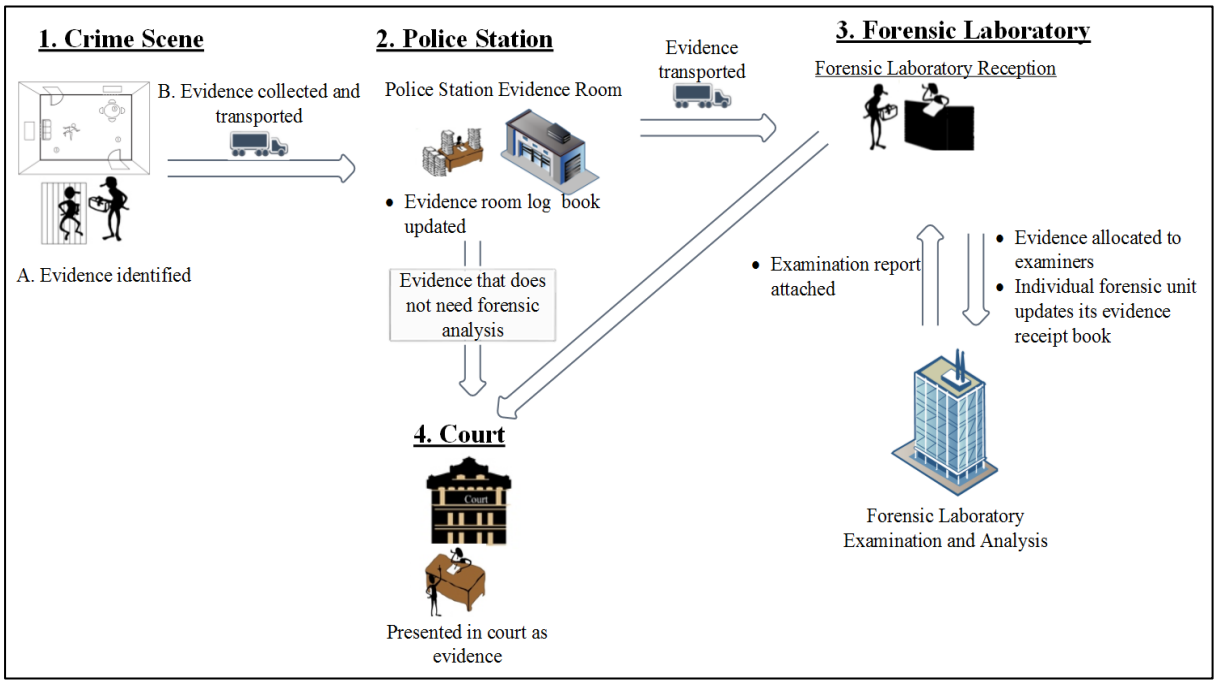


Fig 16: Current Zambia Police Evidence Management System

(i) Crime Scene

The evidence is identified and collected from the crime scene. Evidence items are recorded in the police note book and transported to the Police Station.

(ii) Police Station

Evidence is handed over to the exhibit room through the exhibit clerk. Evidence is recorded in the exhibit book.

(iii) Forensic Laboratory

Evidence requiring scientific analysis is transferred to the forensic laboratory. The

forensic receptionist receives the evidence records it in a book and sent to the forensic unit responsible for that type of evidence. After the examination the analyst gives back the evidence to the requesting officer together with the examination report.

(iv) Court

The case officer presents the evidence as exhibits in court.

3.3.5 Sampling

Purposive sampling technique was used in this study. The reason purpose technique was used was to have a deliberate choice of participants. The target was the Zambia Police Staff with knowledge and experience of evidence management and storage. This sampling technique was used to identify and select the appropriate staff to give questionnaires and conduct interview with. The technique provided sample elements from the target population. The selected sample was 50 which was representative of the Zambia Police Scene of Crime staff who are under the Criminal Investigation directorate in all the ten provinces.

3.3.6 Inclusion Criteria

The subjects that were included in the study are Zambia Police Officers working under Scenes of Crime Unit and those working under exhibit management unit.

3.3.7 Data Collection

In this study, source information was collected only through primary data collection method. The primary data collection methods which were employed are questionnaires and interviews.

Data collection process started on 20Ma May, 2016 and ended on 30th June, 2016. Questionnaires were distributed to the respondents in all the ten provincial Zambia Police Headquarters and the forensic Department. The questionnaire had both open-ended and closed questions. The questionnaires were collected from the respondents in the first two weeks of the March 2016.

Figure 17 shows the methods of data collection also indicating the key data source.

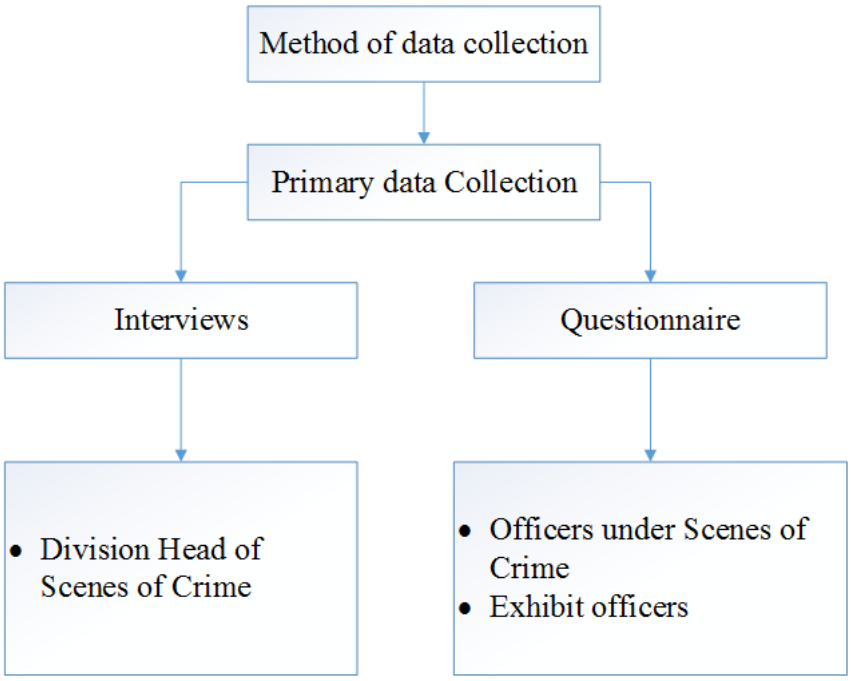


Fig 17: Data Collection Methods

Interviews were conducted at the time when the questionnaires were been collected they were conducted with provincial heads of Scenes of Crime Units.

3.3.8 Data Processing

Statistical Package for Social Sciences (SPSS) software was used to process and analyse the data that was collected. Descriptive statistics was used on information that showed variable frequency distributions from various responses obtained and presented in charts and graphs.

3.3.9 Ethical Consideration

Respondent's identities in this research were protected, this was archived by not reviewing their personal identifiable information.

3.3.10 Baseline Study Limitations

Organizational structure was one of the limitations of this study because it affected access to staff. Each province falls under a different command and this made the researcher to seek permission from provincial command. Centralized communications and direction through the chain of command mitigated this limitation. Another challenge was limited finance and time, the ideal situation was to collect data from all Police Stations in Zambia, but the researcher self-sponsored this research and also had

to divide time between work and this research.

3.4.0 System Automation

The system automation was based on the baseline study and literature review information. The baseline study reviewed the current Zambia Police evidence management system and literature review discussed the best business practice in evidence management.

3.4.1 Business Process Mapping

The study mapped the best business practice discussed in chapter 2 with the Zambia Police business processes. Figure 18 shows business process mapping for the Zambia Police evidence management system.

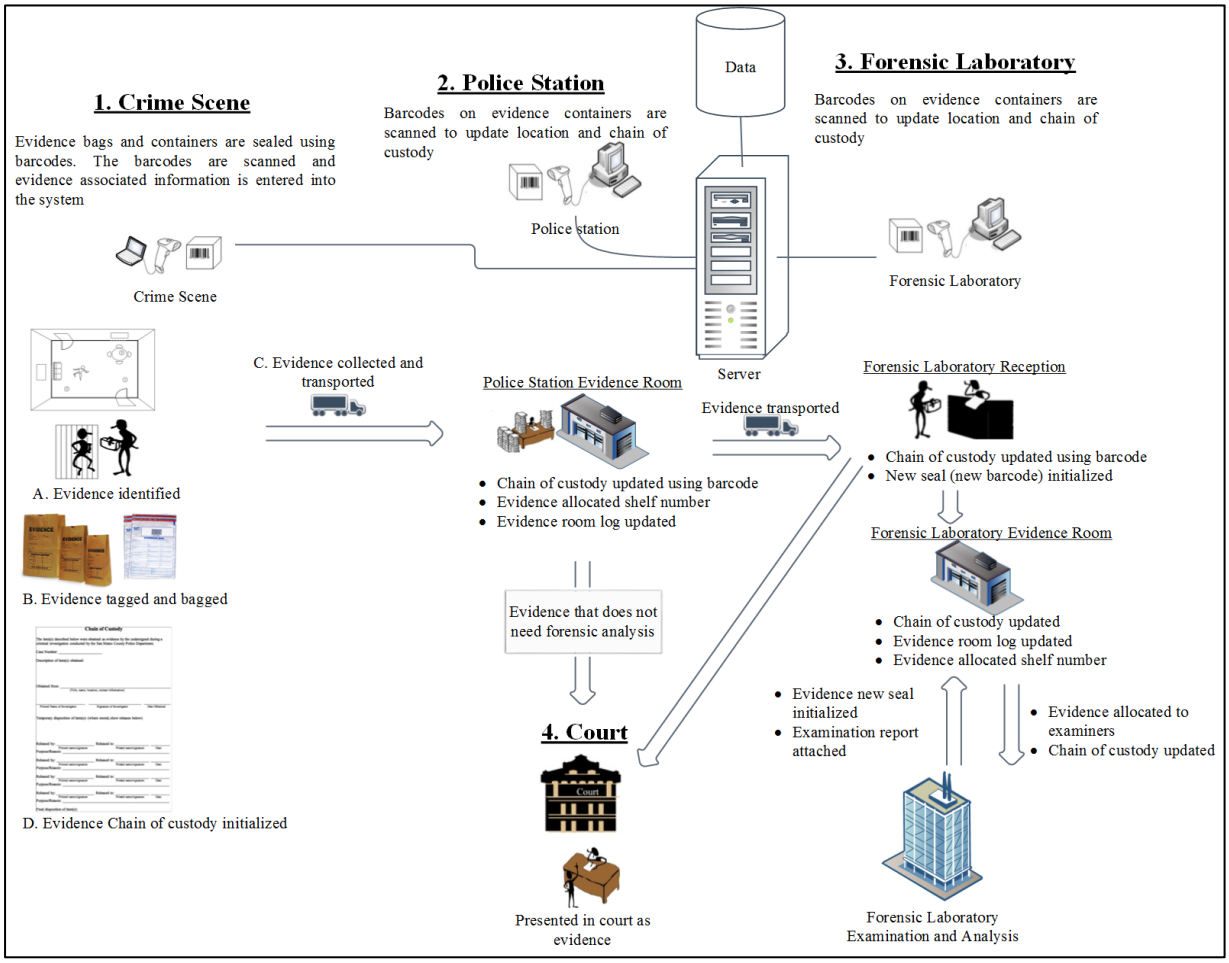


Fig 18: Business process mapping for evidence management

The crime scene is a source of evidence. Crime scene investigator identifies, collects and documents the evidence at the crime scene on to the system. Once the evidence is bagged and sealed, it receives a barcode with its identification code. At this point the evidence chain of custody is initiated on the system. The identified evidence is then

transported to the police station. At the police station the barcodes on evidence bags is scanned to update the chain of custody and the location before it is put in the evidence exhibit rooms.

3.4.2 Proposed System

The proposed system is based on the best business practices in evidence management. Chapter 2 discussed the best practices that ensure evidence integrity and authenticity. The aim of this study was to re-design the evidence management process in order to ensure evidence integrity and authenticity and improve organizational performance. To improve business processes involve process reengineering, process management, process analysis, process efficiency and process mapping [10]. Therefore some of the business processes were reengineered in order to improve the organization performance and ensure evidence integrity and authenticity. This study come up with the five stages of evidence movement based on the evidence activity, location, personnel interacting with the evidence and tools used for documentation. Figure 19 shows the five stages of the evidence life cycle

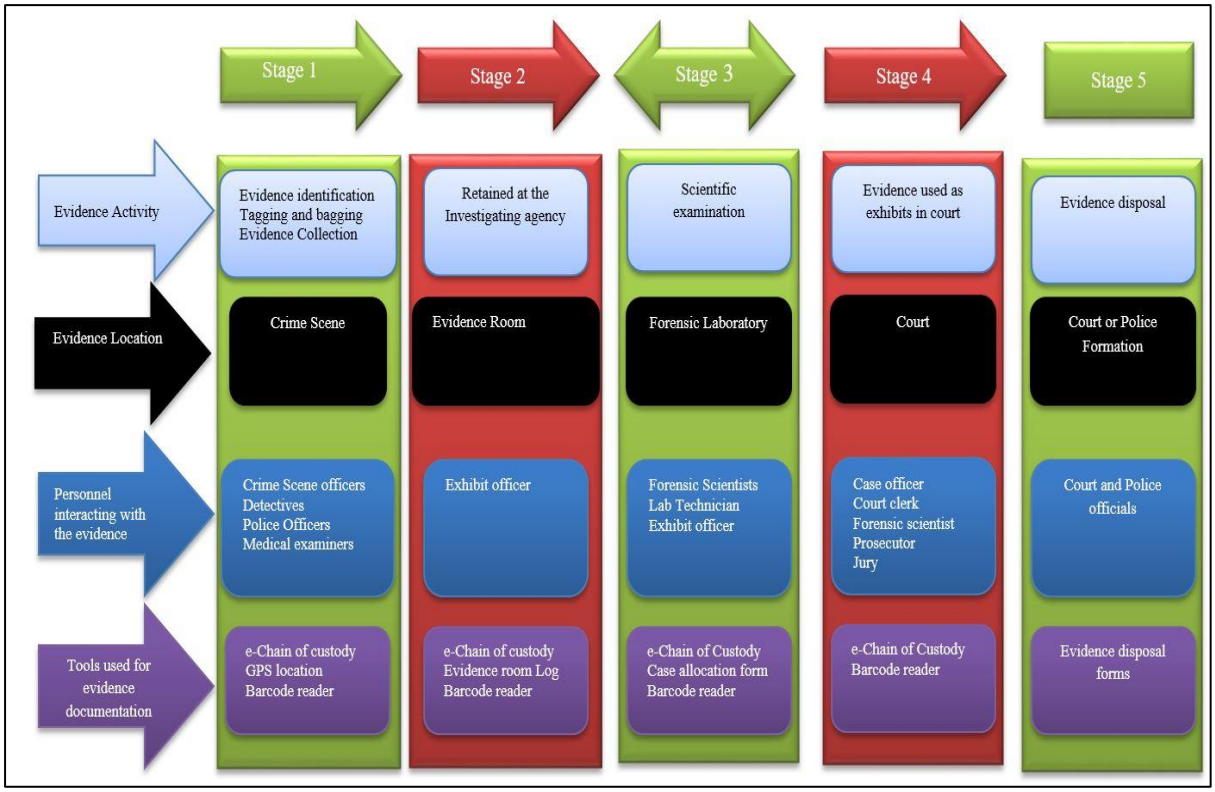


Fig 19: Proposed business processes

1. **Stage1**

The evidence is identified and recovered by officers from crime scene. The evidence recovered is packaged (bagged), tagged and labelled. The barcode is used as part of the evidence seal. All the other details of the evidence including the barcode are record into the system. The chain of custody is automatically initiated by the system. The details of the officer will be captured by the system through authentication and will be recorded as the first in the chain of evidence custody. The GPS location of where the evidence is also recorded.

2. Stage2

The evidence is received, recorded and stored in the evidence room at the police station evidence room. The evidence is recorded by means of a barcode reader. Since the evidence information is in the database, only the evidence location and the chain of custody are updated. The chain of custody is updated automatically through authentication of the user receiving the evidence on the system. Any subsequent movement of the evidence, the system will automatically updated the chain of custody using system user authentication.

3. Stage3

The evidence is received by the forensic laboratory receptionist. The barcode on evidence bag is scene to update its location in the database. The seal (barcode) is broken and the evidence bag is opened to verify its content. After the content is verified the new seal (barcode) is initialized and the evidence is sent to forensic laboratory evidence room. The evidence is then allocated forensic analysts by forensic department unit heads. After the analyst examines the evidence, an examination report is attached, a new seal initialized and sent back to the forensic laboratory evidence room.

4. Stage 4

Case officer collect the evidence from the store room. The chain of custody is updated and the evidence is taken to court to be presented as exhibits.

5. Stage5

After case is closed the evidence is disposed.

3.4.3 System Design

The system was designed based on baseline study findings which were used to

conceptualize and design the various components of crime scene inventory management system. Unified Modelling Language (UML) was used to design the diagrammatic representation of the system. The methodology which was used in developing the system was extreme programing. Extreme programming (XP) is a software development approach that encompasses many of the ideals of agile methods – in the context of software development, agile means responsive to changes in software requirements or changes in the understanding of the problem. One of the Extreme Programming principles is to deliver the software early, obtain feedback on the system and implement any required change.

3.4.3.1 System Flow Chart

The user must first logon to access the system. When the use is logon then the evidence information can be capture in to the system through system input form. The time and location of the evidence will be captured automatically by the system. If it is not a new case the user must provide the case number for the existing case. The system will link the logged on user to the evidence been collected. Figure 20 shows the flowchart of the evidence capturing.

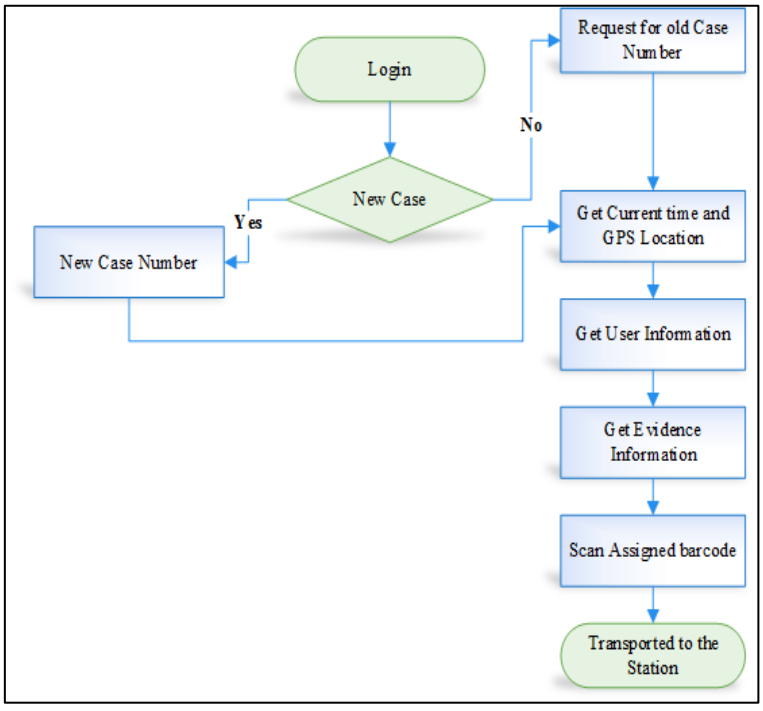


Fig 20: Evidence capturing flowchart

The evidence collected from the crime scene is transported to the Police Station to be

stored in the evidence room. If the evidence requires further analysis, it is transported to the forensic laboratory. At the forensic laboratory the evidence stored in the evidence room before it is assigned to forensic analysts. After concluding the examining the analyst writes a report and takes back the evidence to the evidence store room. Figure 21 shows the evidence management system flow chart.

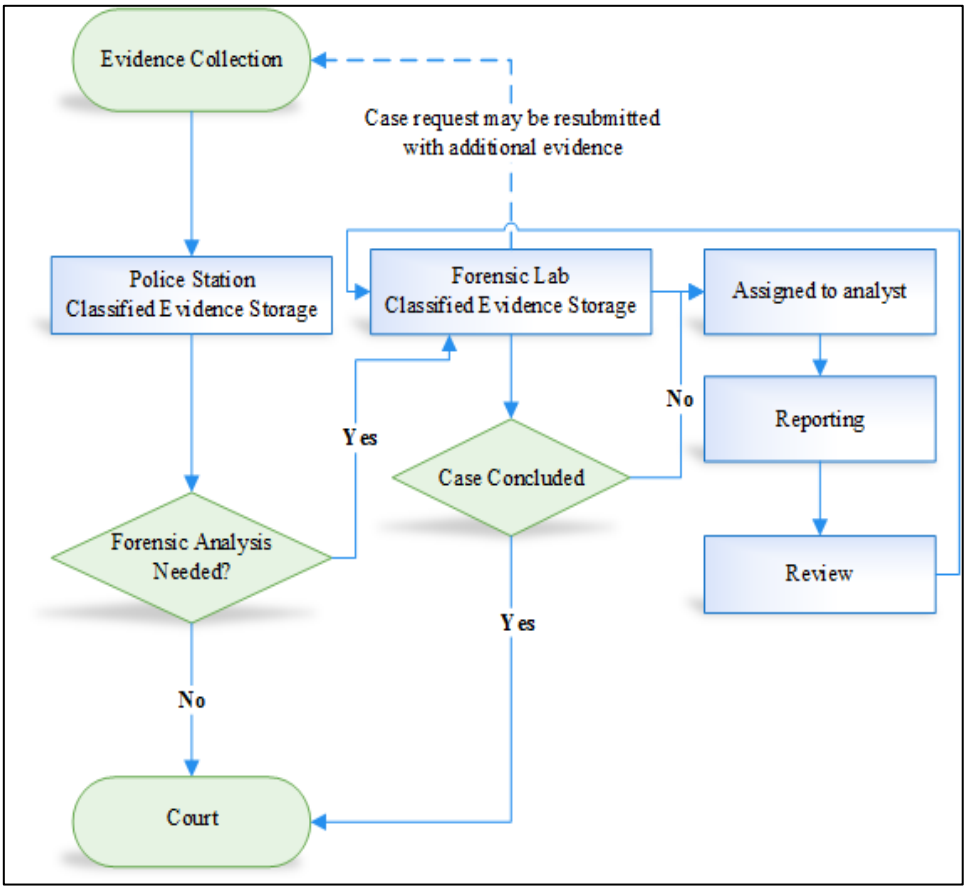


Fig 21: System flowchart

3.4.3.2 Use Case

The use cases represent the possible interactions that are described in the system requirements. Actors in the process may be human or other systems. Lines link the actors with the interaction.

The first scenario depicts the interaction of the user with the system. The user must be registered in the system as police a with the police man number as the user name and last name as the default password which must be changed on the initial login. Figure 22 shows the User use case.

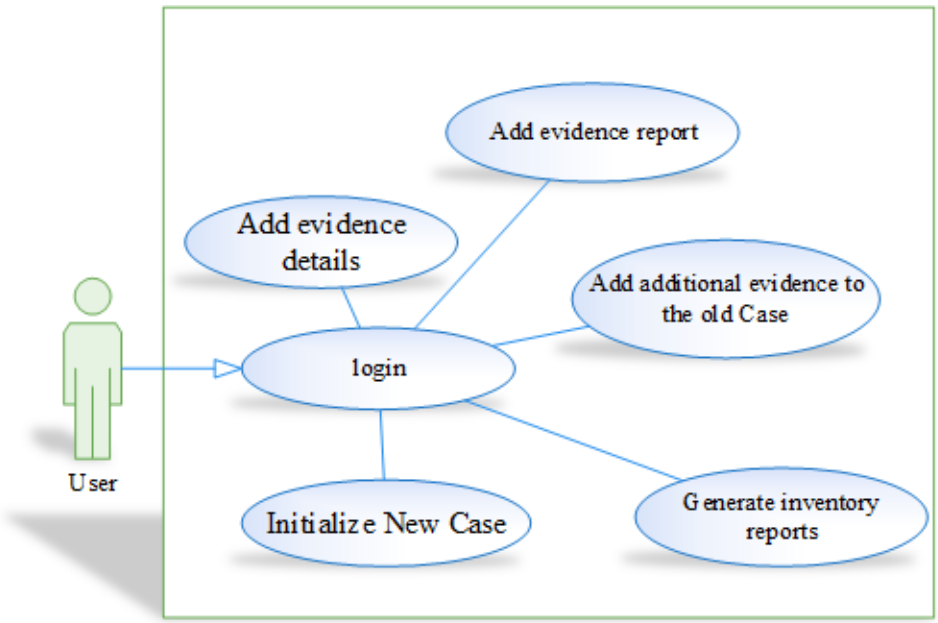


Fig 22: User use case

Table 1 explains user use case in Figure 22.

Table 1: User use case explanation table

Input Events from Actor-User	System Events and Responses
Select login	• Displays login form • User must provide username and password
Select new case	• Evidence case number is generated and displayed
Select existing case	• Displays the test box for entering the existing case number
Exceptional scenario: User does not provide correct authentication details system displays error message	

The second scenario depicts the interaction of the department heads with the system. The head of department must first login into the system before any other system interaction. Figure 23 show the use case for heads of departments.

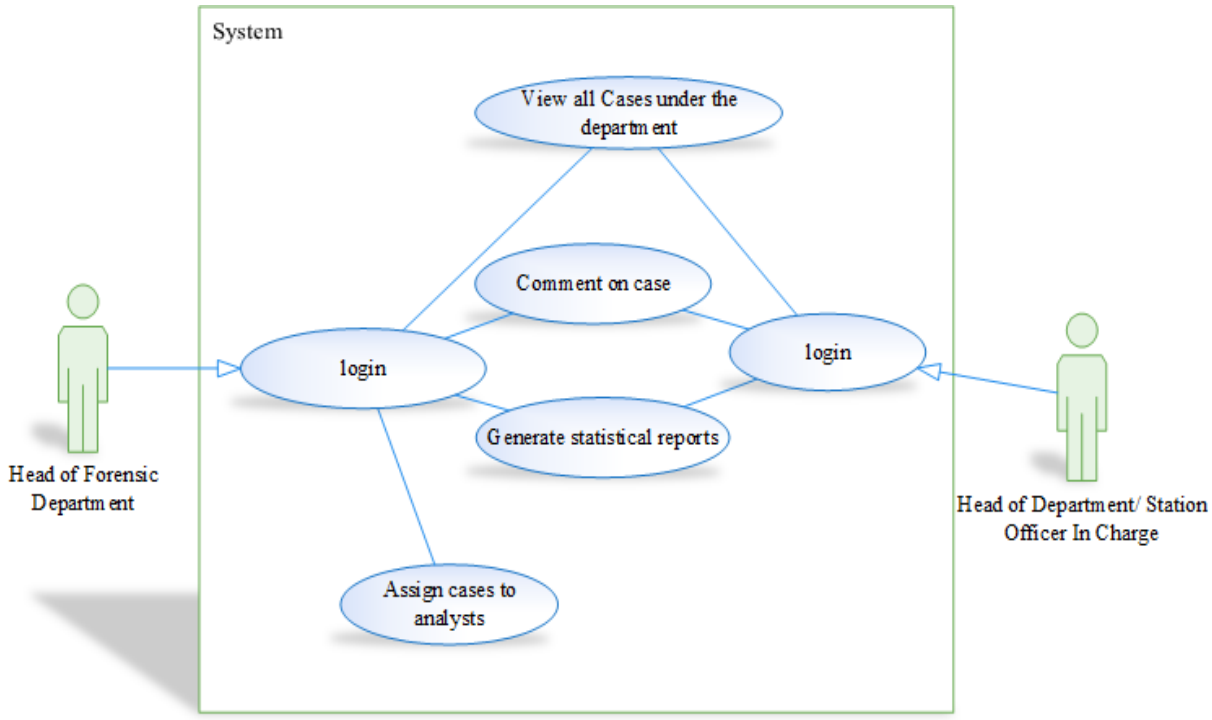


Fig 23: Heads of departments use case

Table 2 explains Heads of departments use case shown in shown in Figure 23.

Table 2: Heads of departments use case explanation table

Input Events from Actor- Head of department	System Events and Responses
Select login	• Displays login form • Head of department must provide username and password
Select task to performed	• Displays system predefined tasks
Exceptional scenario: User does not provide correct authentication details system displays error message	

The third scenario depicts the system administrator interaction with system. The system administrator must first login in to the system before any further interaction. The system administrator has elevated system access, which including suspending user accounts for officers on suspension and deleting user account for officers. Figure 24 shows the use case for the system administrator.

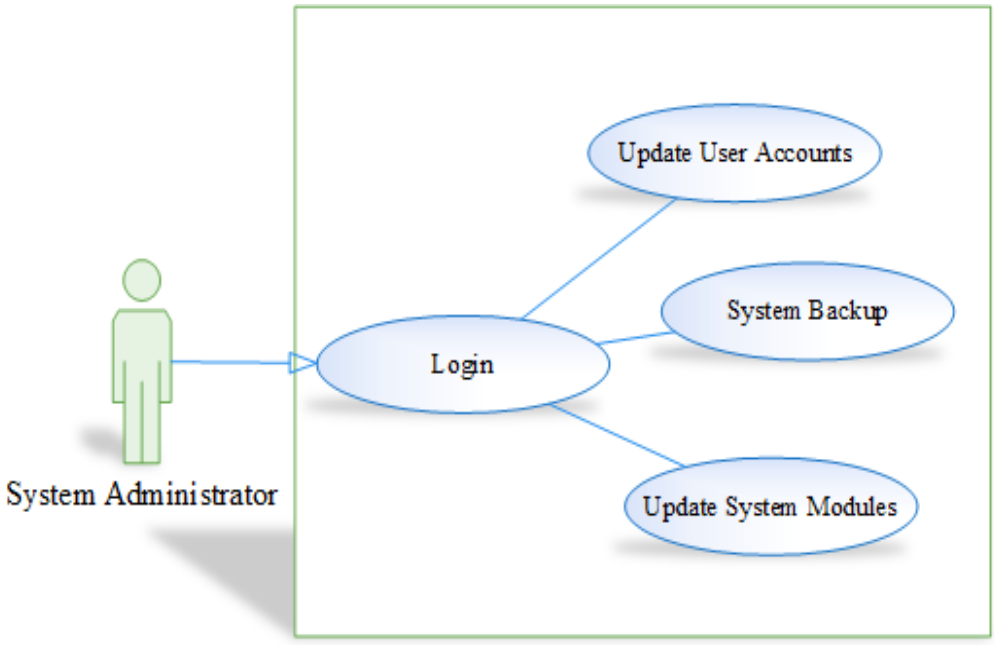


Fig 24: System administrator use case

Table 3 shows explanation of the systems administrator use case which is shown in Figure 24.

Table 3: System administrator use case explanation table

Input Events from Actor- System administrator	System Events and Responses
Select login	• Displays login form • System administrator must provide username and password
Select task to performed	• Displays system predefined tasks
Exceptional scenario: User does not provide correct authentication details system displays error message	

The third scenerio depicts the barcode reader interaction with the system. The barcoder reads the barcode and inputs the data into the system. The barcode is linked to the evidence information and become the primary key to the information. Figure 25 show the barcode use case.

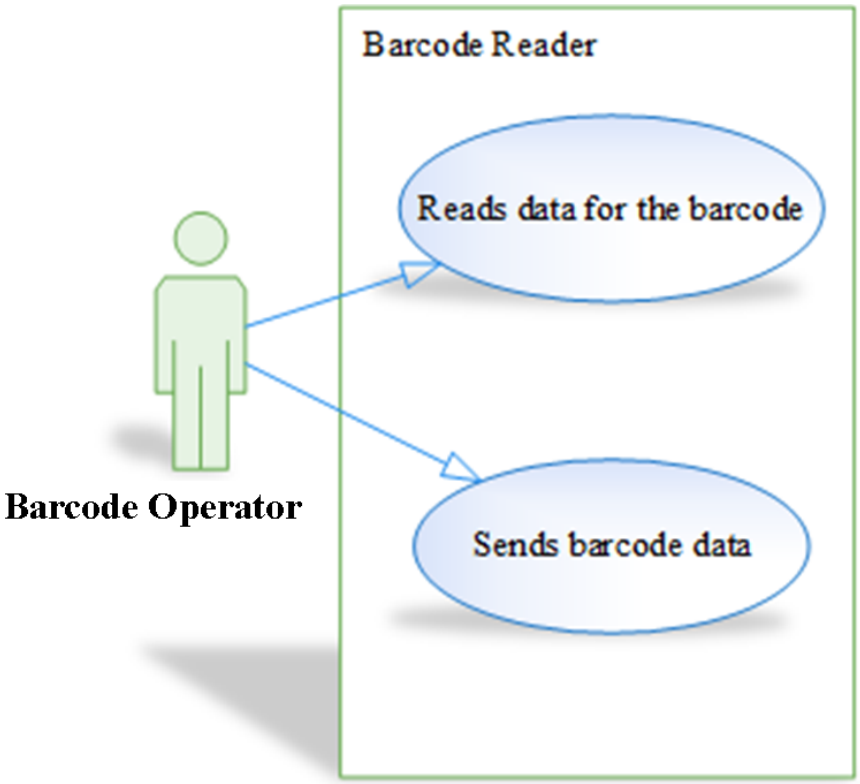


Fig 25: Barcode use case

Table 4 shows the explanation of the barcode operation based on the barcode use case which is shown in Figure 25.

Table 4: Barcode use case explanation table

Input Events from Actor- Barcode reader	System Events and Responses
Scan the barcode	• Inputs the data in the barcode text box

3.4.3.3 Sequence Diagram

Figure 26 shows the sequence diagram of the system. The member of staff logs on the system. If a member of staff wants to update evidence data, his/her user-identifier (UID) permissions are checked using the authorization system. After authorization, the staff can now update the evidence data. On completion of the transaction the status message is issued and the staff logs out.

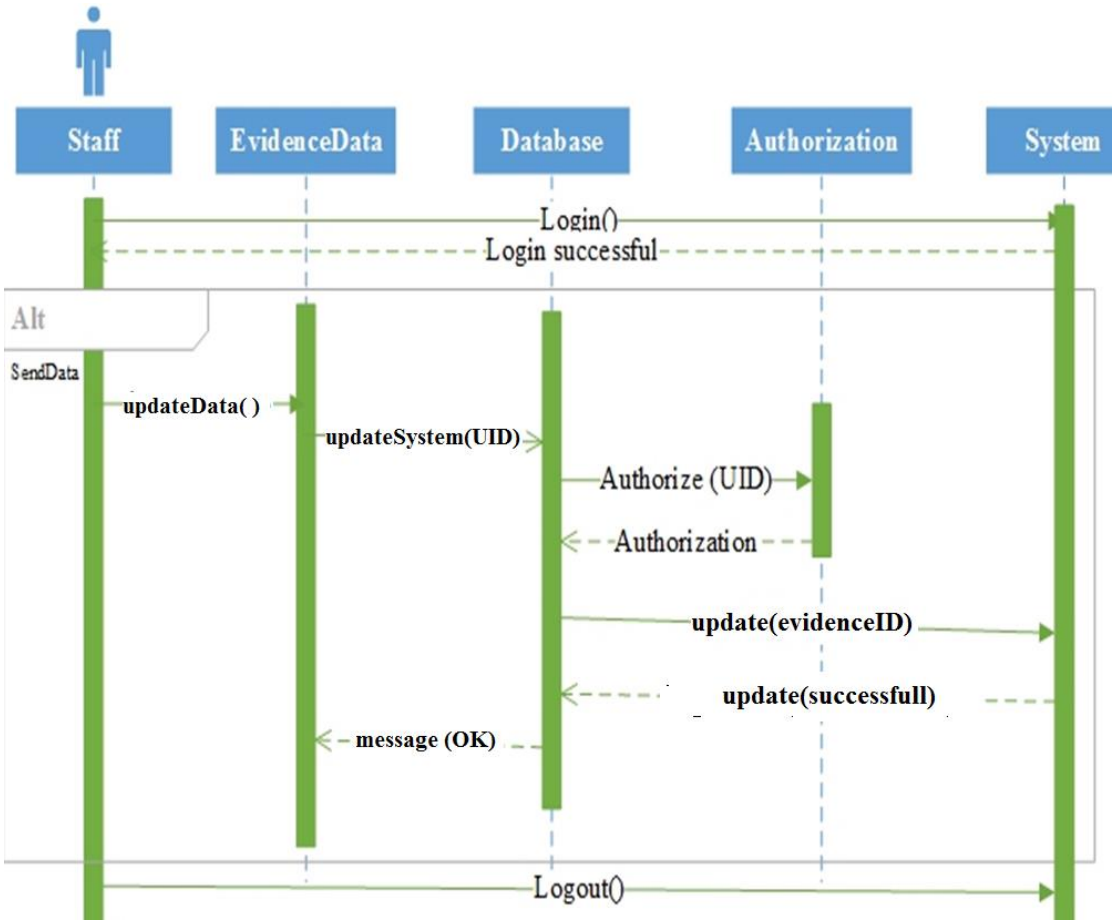


Fig 26: Sequence Diagram

3.4.3.4 Entity Relationship Model

Entity relationship model diagram is a type of flowchart that illustrates how "entities" such as people, objects or concepts relate to each other within a system. It is a conceptual design which helps to transform the system requirements into a formal description of the entities and relationships that appear in the database. The entity relationship model (Model) consist of identification of entities user requirements, enterprise rules and development of the of Entity relationship diagram which shows the relationship between and among entities. Figure 27 shows the diagrammatic representation of the system entities and the relationships between them.

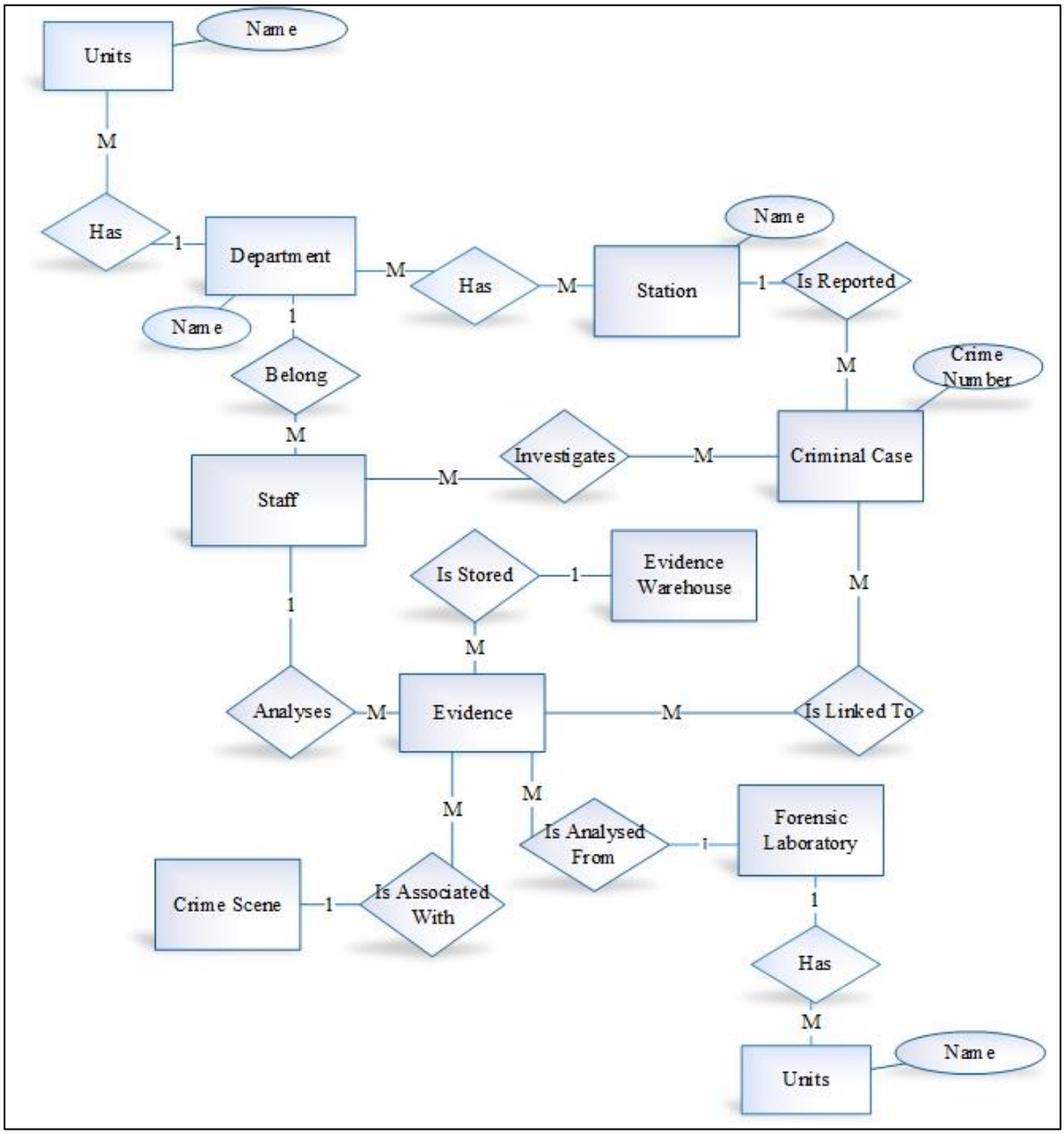


Fig 27: Entity relationship model Diagram

3.4.3.5 Data Design

This section describes data specifications that were used in the database design of the system.

1. User Login Table

Table 5 shows the user login table. It has four fields: username which must be created by the user, ManNumber, which is Zambia Police man number given to the officer when joining Police.

Table 5: User Login Table

Field Name	Data Type	Size
UserName	Text	20
ManNumber	Integer	Integer
PassWord	Text	32
AccessLevel	Text	15

2. Staff table

The staff table has eight fields: ManNumber field is the primary key of this table. This table captures personal identifiable information an officer. Table 6 shows staff table.

Table 6: Staff table

Field Name	Data Type	Size
ManNumber	Integer	Integer
Firstname	Text	15
LastName	Text	15
DepartmentId	Text	15
Gender	Text	10
Rank	Text	15
EmailAddress	Text	20
UnitId	Text	15

3. Evidence Information table

The evidence information table captures the details of the evidence including the location where the evidence was found the date the evidence was picked, barcode number assigned to the evidence and whether the evidence is hazardous or not. Table 7 shows the evidence information table.

Table 7: Evidence Information table

Field Name	Data Type	Size
ManNumber	Integer	Integer
EvidenceId	Text	15
OccuranceNumber	Text	15
DateTime	Date/Time	Date/Time
BarcodeNumber	Text	10
HazardousOrNot	Text	15
CrimeScenId	Text	20

4. Crime scene Table

The crime scene table captures the location other crime scene and crime scene number assigned by the system. Table 8 shows the crime scene table.

Table 8: Crime Scene Table

Field Name	Data Type	Size
CrimeSceneId	Text	15
Location	Text	20
OccuranceNumber	Text	20

5. DeptUnit Table

This table connects the Unit table and the station table. Table 9 shows the UnitStation table

Table 9: UnitStationTable

Field Name	Data Type	Size
UnitId	Text	15
UnitName	Text	20
StationId	Text	20

6. Station Table

The table captures the Police Station name and the Police Station identity number assigned by the system. Figure 10 shows the station table.

Table 10: Station Table

Field Name	Data Type	Size
StationId	Text	15
StationName	Text	20

7. DeptStation

This table connects department and station tables. Table 11 shows the deptstation table.

Table 11: DeptStation

Field Name	Data Type	Size
DepartmentId	Text	15
StationId	Text	20

8. Department table

This table capture the name of the department and the department identification assigned by the system. Figure 12 shows the department table.

Table 12: Department Table

Field Name	Data Type	Size
DepartmentId	Text	15
DepartmentName	Text	20

9. CrimeOccurranceNumber Table

This table captures the type of crime, the date and time the crime was reported. Table 13 shows the CrimeOccurranceNumber table.

Table 13: CrimeOccuranceNumber Table

Field Name	Data Type	Size
OccurrenceNumber	Text	15
TypeOfCrime	Text	20
ComplainantName	Text	20
DataTimeReported	Date/Time	Date/Time

10. Database Design

Figure 28 shows the database for the entire system which has been normalized to second normal form.

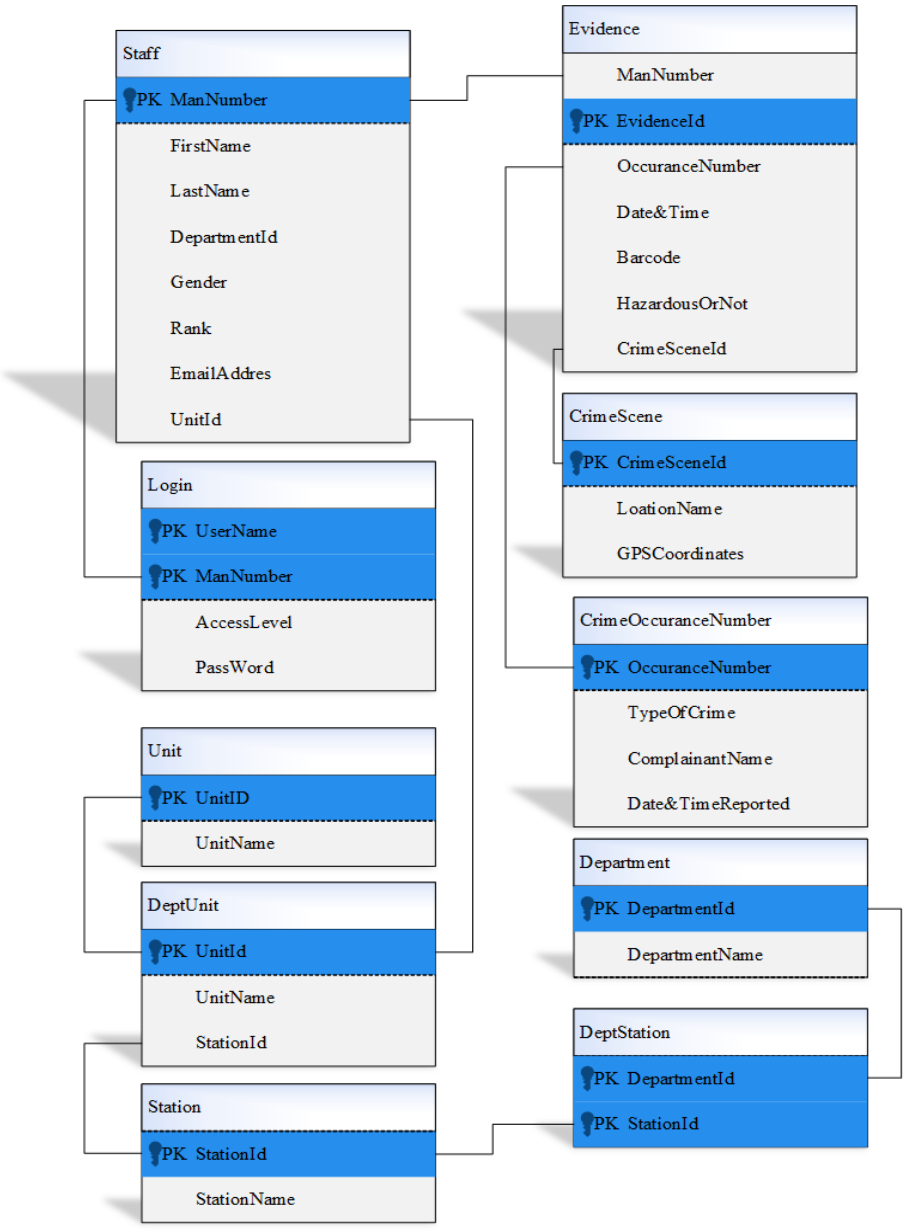


Fig 28: Database Design

3.4.3.6 System Functional Requirements

1. The system will facilitate for the registration of system users.
2. The system will facilitate for the Police Officer to record crime scene evidence details.
3. The system is able to track the current position of the evidence.
4. The system is able to generate the evidence chain of custody
5. The system is be able to allow the head of departments to assign cases.
6. The system is able to read barcode from the evidence packaging.
7. The system is able use the barcode to track evidence.
8. The system is able to generate evidence statistics.
9. The system is able to retrieve evidence information using barcode

3.4.3.7 System Non-Functional Requirements

1. **Appearance**

   The graphical user interfaces are kept simple and are not over crowded.

2. **Response Time**

   The response time for the pages to load must take acceptable time.

3. **Processing Power**

   The hosting server must have a good processing power because the system will have allows multiple accesses.

4. **File Size**

   The file size must be as small as possible so that the pages could load faster as it is among the factors that determine the response time.

3.5 Summary

This chapter describes the methods which were used in information gathering for this study. The system design has also been outlined in this chapter.

CHAPTER FOUR

RESULTS

4.1 Introduction

This study was conducted using quantitative and qualitative methods. The interview and questionnaire questions were tailored in order gather information including following:

1. The availability of computers in Police Stations
2. Whether the computer in Police stations are connected to the organization computer network.
3. How evidence Chain-of-custody maintained by the Zambia Police.
4. Access and retrieval of evidence information.

4.2 Baseline Line Study

The results show that the current system is manually operated. 15.38% spread sheet and 84.62% paper based as shown in Figure 29.

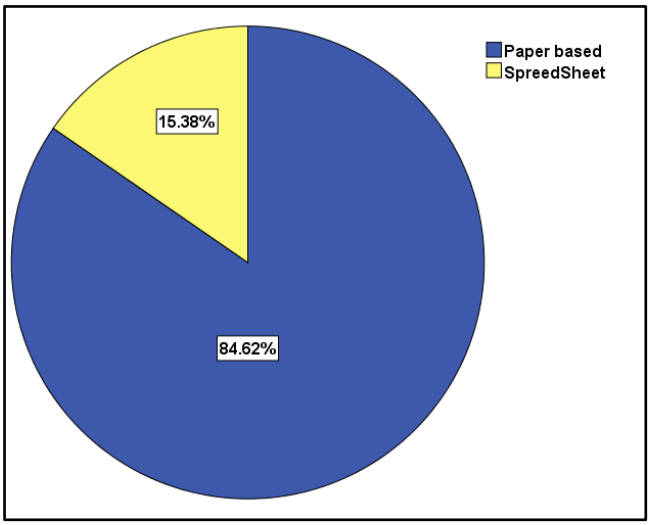


Fig 29: Type of system used to maintain the records

The results also showed that 56% have problems record management, 34% have problems with Statistical data, 6% have problem in matching evidence documentation to cases and 4% have difficulties in discovering evidence pilfering as shown in Figure 30.

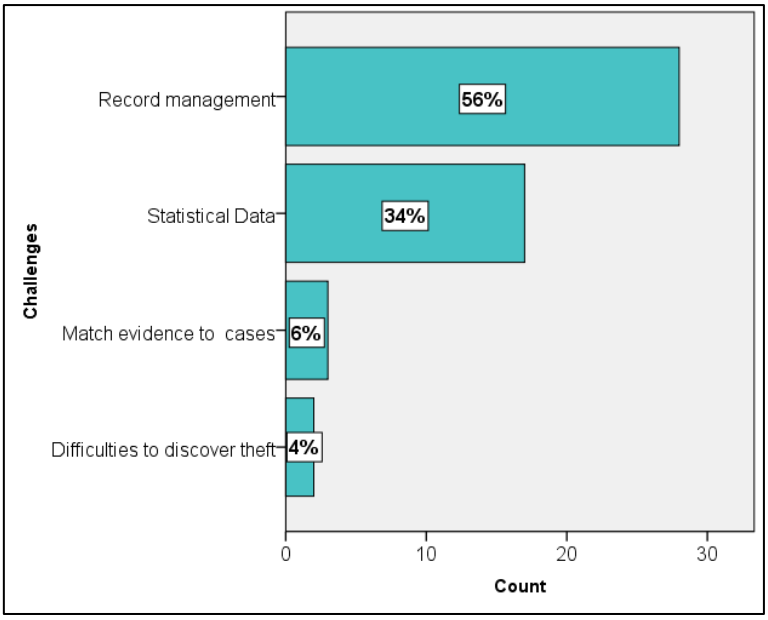


Fig 30: Current System Challenges

Regarding the starting point of evidence chain of custody documentation, Figure 31 shows 42.31% of respondents who said that they start at police station, 21.3% start at crime scene, 19.23% starts at the laboratory, and 17.31% start 'when preparing evidence for court.

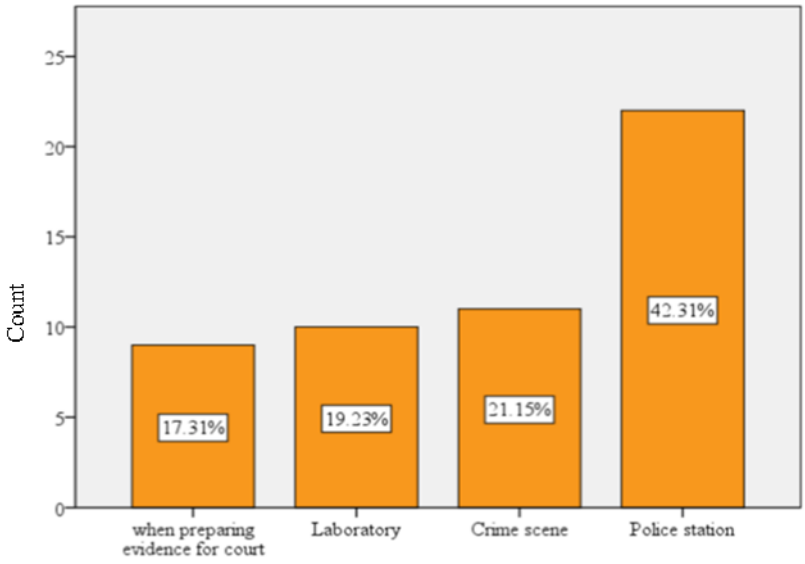


Fig 31: Chain of Custody Initiation

Figure 32 shows results indicating that 11.54% of the respondents had measures to ensure the integrity of the evidence is maintained 88.46% had none.

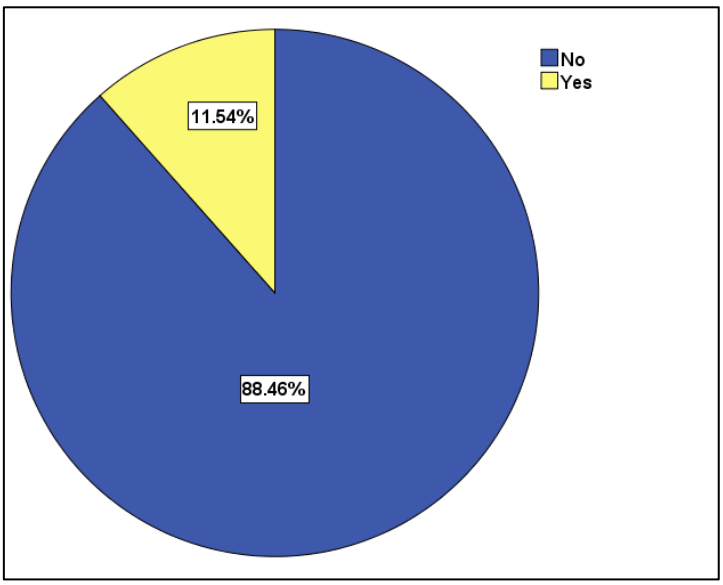


Fig 32: Measures to ensure Evidence Integrity

Figure 33 shows that 69.23% of the respondents had no implemented measures to track the evidence and 30.77% have implemented evidence tracking measures.

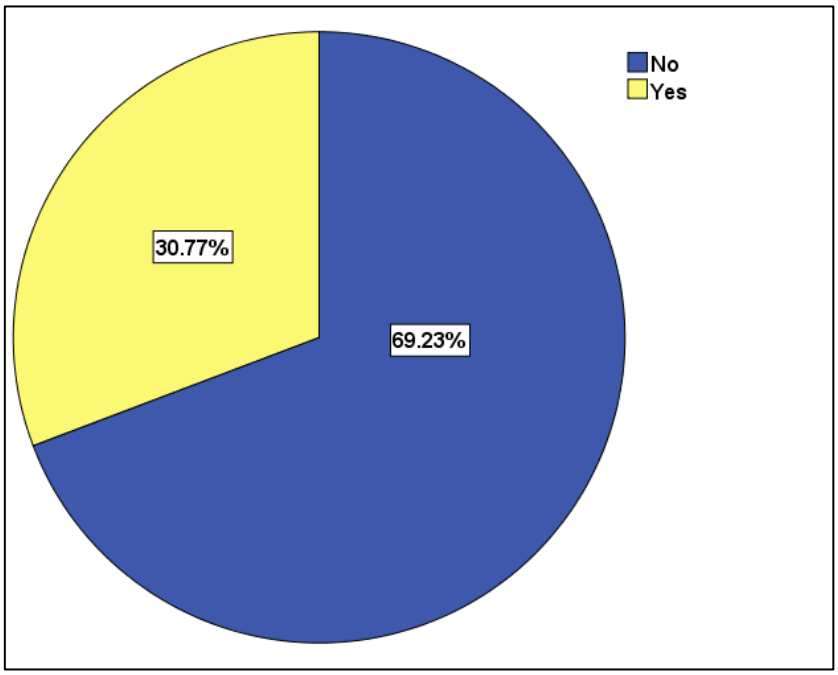


Fig 33: Evidence tracking Measures

Table 14 indicates that 17.3% of the respondents have handled cases which later got spoiled due evidence mismanagement as shown in table 14.

Table 14: Spoiled Cases due to evidence mismanagement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	3	5.8	33.3	33.3
	3	2	3.8	22.2	55.6
	4	3	5.8	33.3	88.9
	5	1	1.9	11.1	100.0
	Total	9	17.3	100.0	
Missing	System	43	82.7		
Total		52	100.0		

4.3 System Implementation

This section looks at how the system was implemented based on the information gather through the baseline study and literature review. This section shows some of the screenshot from the developed system.

1. Evidence capturing page

On this form the user is able to create a new case and enter the synopsis of that particular case. The barcode reader is used to scan and enter barcode into the system through the textbox labelled barcode. One case can have more than one evidential item and each item must have its own barcode and chain of custody. Figure 34 shows the evidence capturing form.

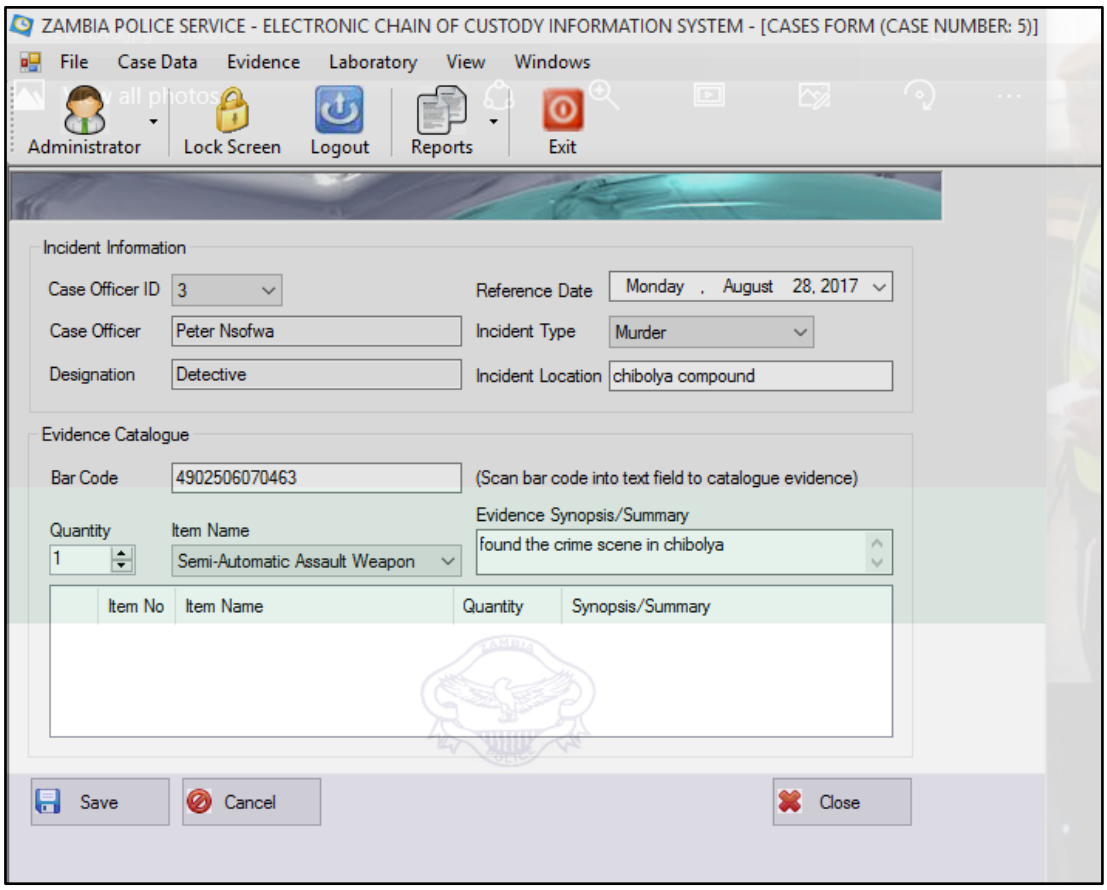


Fig 34: System Evidence Capturing Page

Figure 35 show the evidence been barcode been captured during the testing of the systems.

Fig 35: Capturing Evidence Barcode

2. Evidence Submission form

The evidence submission form is used used to submite evidence from the crime scene to the station and from the station to the laboratrory. When evidenceis recived at the police station the barcode will be scannned the evidence location and the chain of custodyis updated on the system. Figure 36 show the evidence submission form.

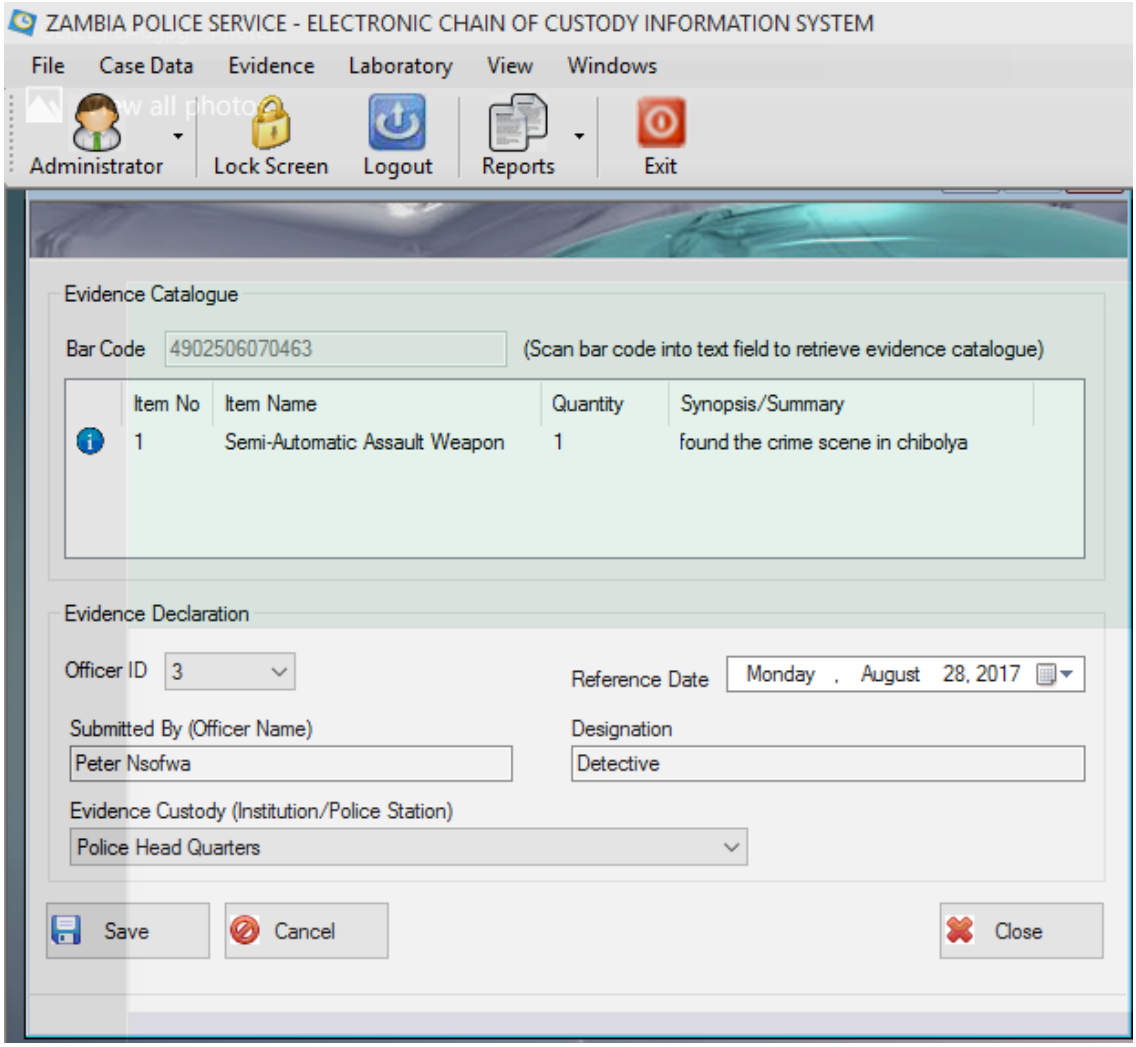


Fig 36: Evidence Submission form

3. Chain of custody form report

The chain of custody report indicates the officer who picked the evidence, the location and the date and time it was picked. Figure 37 shows the evidence chain of custody.

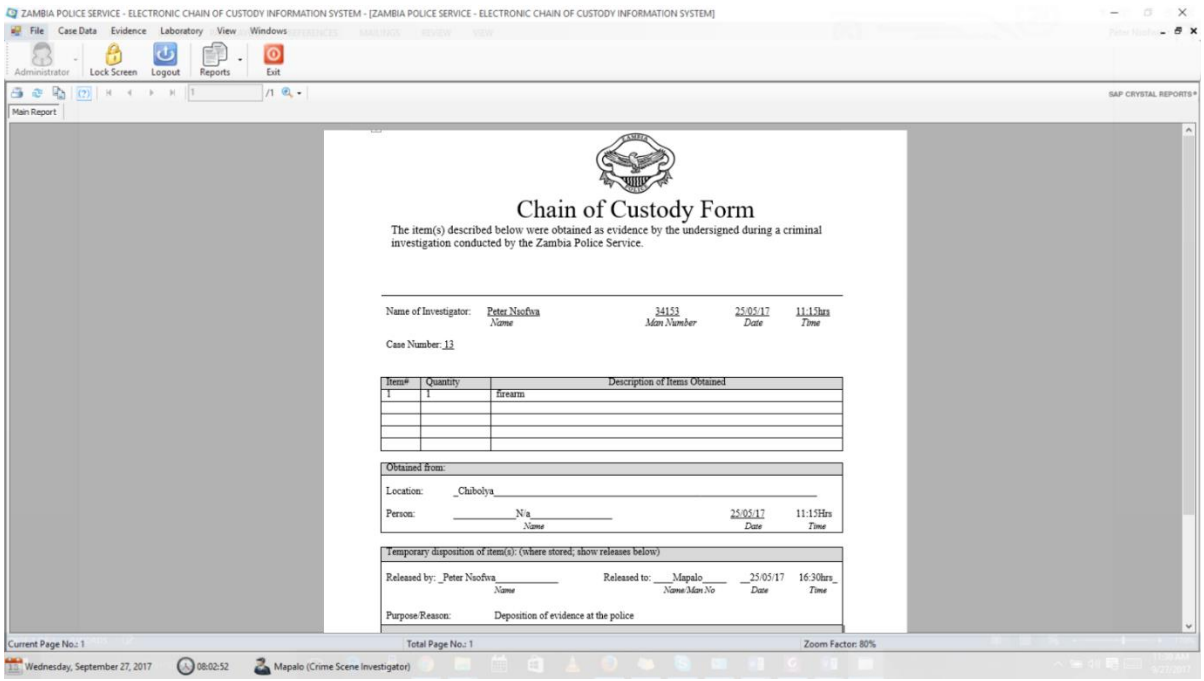


Fig 37: Chain of Custody

4.4 Hardware and Software Requirements

The minimum system requirement for this system is a CPU running at 2.10GHz with a minimum of 2GB RAM. The system was test on Windows 7, 8 and 10 64-bit operating systems, but the system is able to work on Windows XP. The other software requirements included sap crystal reports and Microsoft .Net framework 3.5.

4.5 System Architecture

The system was derived from the baseline study result together with information gathered during literature review. The system was design using the Model-View-Controller architectural pattern (MVC). The MVC divides an interactive application into three components. The model contains the core functionality and data. Views display information to the user. Controllers handle user input. Views and controllers together comprise the user interface. A change-propagation mechanism ensures consistency between the user interface and the model. Figure 38 shows the generic MVC based system architecture.

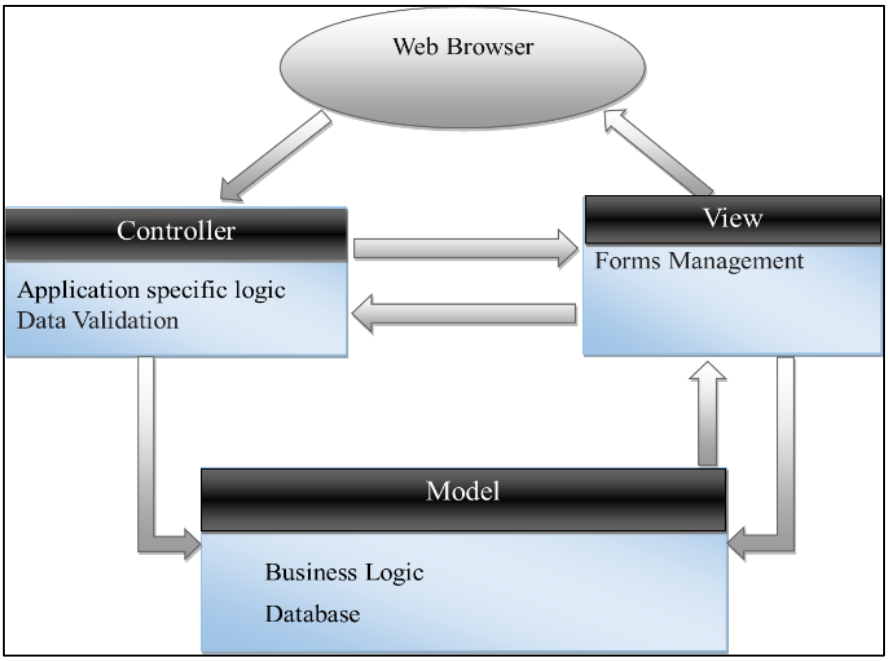


Fig 38: Generic MVC system architecture

The architecture of the system includes internet connection, the web server, the backend database and user interfaces on the end terminals as shown in Figure 39.

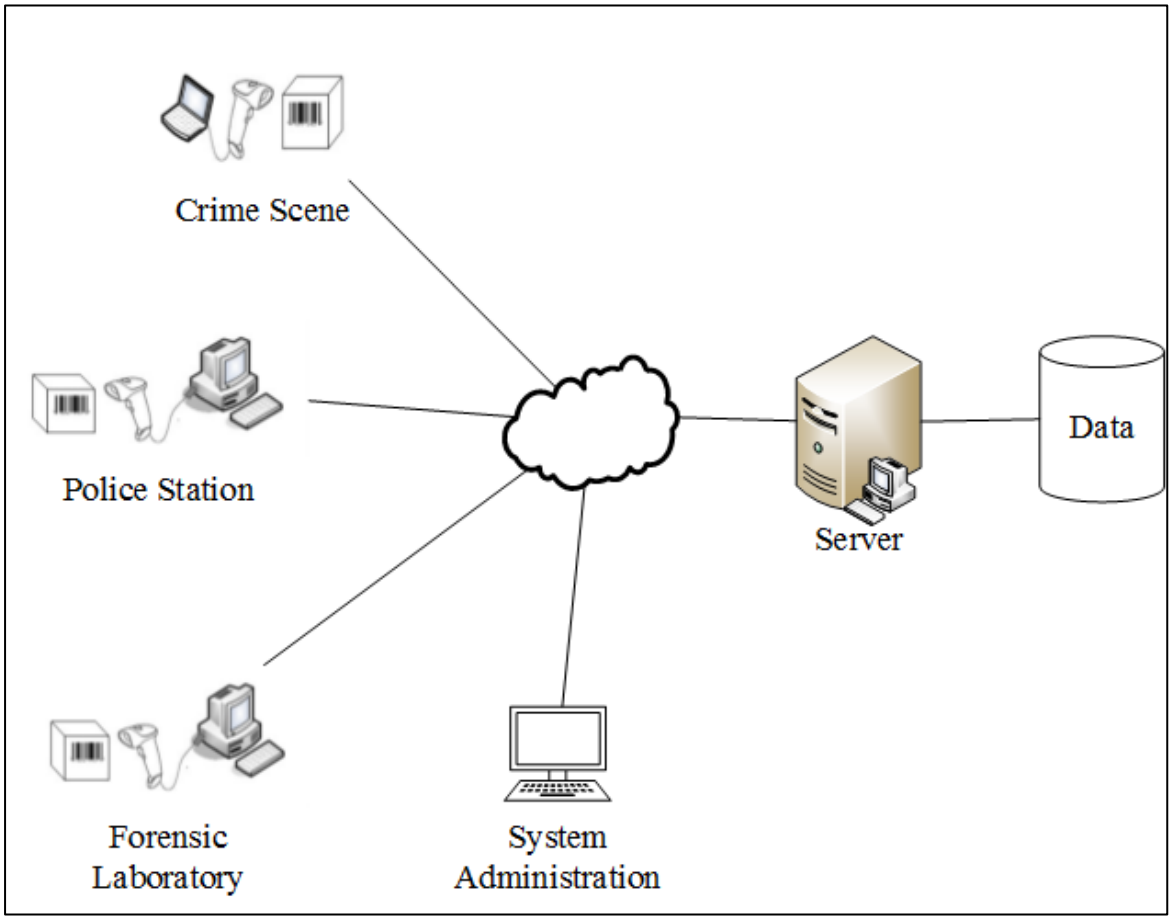


Fig 39: System Architecture

.

4.6 Summary

This chapter outlined the current system used by Zambia Police and how the business processes were reengineered. The chapter also highlights on how the system was design and implemented using the best business practices. The prototype was successfully developed and it is able to register the evidence detail and keep a trial the evidence including anyone who handled it.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 Introduction

For every investigation to be fruitful they must evidence to approve or disapprove the case. Failure to manage the evidence function can affect the successful prosecution of criminals, which may result in agency losing of public confidence. Therefore law enforcement agents must invest in the evidence management system.

5.2 Challenges of Crime Scene Evidence Management

This objective was archived through a comprehensive review of the literature. Literature reviewed that the biggest challenge is the maintaining the chain of custody. This challenge mainly is due to the wide geographical areas covered by the law enforcement agencies. Hence once evidence is collected from a remote location it is temporally kept at remote Police station of which most of them have no rules on evidence management.

5.3 Problems of the Current Evidence Management System

The second objective of this study was to establish the challenges faced by the Zambia Police in managing evidence. The baseline study showed that there is no consentience in maintaining the chain of custody chain and it is done informally. The baseline study showed that 42.31% of respondents said that they start evidence documentation when evidence is brought at the police station, 21.3% said they start at the crime scene, 19.23% starts at the laboratory, and 17.31% start there documentation when preparing evidence for court. This showed that only 21.3% of respondents starts evidence documentation at right point (crime scene). It was reviewed that documentation process is done manually, 84.62 % of the respondents stated that the record management is maintained using paper and 15.38% stated they use spreadsheet. The baseline study showed that 56% had challenges with record management, 34% has challenges in coming up with statistic data, 6% had challenges with matching and linking evidence documentation to the actual evidence, 4% had challenges in discovering loss and pilferage.

5.4 To Develop a Model of Evidence Management System

The model was developed to handle the challenges which were discovered in objective one and two. Flowcharts, Entity Relationship diagrams, Use case diagrams and Sequence diagrams were used to do the modelling.

5.5 To Build a Prototype Based On the Model

The prototype was developed based on the model developed in objective three. The system is able to read barcodes from evidence bags and post it together with associated evidence documentation in the database track as well as recording a person who has taken control of the evidence.

5.6 Comparison with Other Similar Works

Four different systems where reviewed during in this study. Most of these systems are sold as off shelf and cannot be fully customised to a particular agency with different needs. The biggest setback for these systems is they are expensive, they are sold per module. The following are the related systems which were reviewed during this study:

1. Starlims
2. Evidence Hound
3. Wolfcom Evidence Management solution
4. Centurion Evidence Management

The system which was developed is tailor made for the Zambia Police Service, and it can also be used any other law enforcement agency which handles just with minor changes.

5.7 Possible Application

The possible application of this system is to be used as an evidence management system by law enforcement agencies. The system will be able to help law enforcement agencies in maintaining evidence integrity and authenticity through the use of the integrated chain of custody capabilities.

5.8 Conclusion

The soundness of the evidence is subject to the care taken in collecting and storing.

Improper collection, management or storage has a direct influence on the integrity of the evidence and may destroy its value to the judicial purposes.

The study was conducted which disclosed the challenges in the documentation and tracking of crime scene evidence. Based on the results of this study it can be conclude that Zambia Police crime scene evidence management is done manually which presents the following challenges:

1. Breakages in the chain of custody which lends evidence inadmissibility.
2. High chances of mismatch between the evidence and their associated documentation,
3. High chances of evidence tempering, because of luck of a good trial as it moves from a police station to the forensic laboratory and between laboratory units,
4. Difficulties in tracking the evidence through the course of the investigation which could take weeks, months and sometimes years.

The results also showed that only 21.3% of the respondents start evidence chain of custody documentation from the correct point in the evidence lifecycle.

Hence the following recommendation to increase the effectiveness of evidence management was put forward.

Automating the management of evidence from the crime scene up to the time it is dispatched for court session.

5.9 Future Works

The system can be enhanced to include a mobile application which can be used by field officer. The system can also be developed into a full case management system which can make this system developed in this study a module.

5.10 Summary

This chapter discussed the objectives of this research and how they were achieved. The chapter also outlined the future works in line with this research.

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APPENDIX

APPENDICES

APPENDIX 1 RESEARCH AUTHORIZATION

OIC – Forensics
Let the Officer
come and see me
for more guidance

ASS. COMMISSIONER
P.O. BOX 50194, LUSAKA
12 MAY 2016
ZAMBIA POLICE SERVICE
C.I.D HEADQUATERS

THE ASSISTANT COMMISSIONER – C3

Sir,

RE: PERMISSION TO CONDUCT ACADEMIC RESEARCH IN YOUR ORGANISATION – MR PETER NSOFWA

Folio 17 refers.

No. 7738 D/Insp Nsofwa Peter is a Postgraduate Student in the School of Engineering at University of Zambia with Student number 514703521. The officer needs to undertake research work as part of his Dissertation for a Master of Engineering degree and his research is entitled "Crime Scene Evidence Inventory Management System: The Case of Zambia Police Service".

In view of the above, kindly allow the officer to do his research as the Police high Command has given a go ahead.

You may wish to take note.

K. Kataka
SENIOR STAFF OFFICER – CID

SHQ53/2/19

12/05/2016

Noted and officer informed accordingly

ZAMBIA POLICE SERVICE
HEADQUATERS
12 MAY 2016
FORENSIC SCIENCES DEPT
OFFICER IN-CHARGE
P.O. BOX 50194, LUSAKA

APPENDIX 2 QUESTIONNAIRE

Questionnaire for Zambia Police Scenes of Crime Investigation Staff

1. Instructions

1. Answer all questions
2. Tick `the correct answers where they are provided
3. Write answers for the other questions in the spaces provided.

2. PART A

1. Rank _____
2. Number of years in Service_____
3. Age:
   1. 20-35 Years ☐
   2. 35-45 Years ☐
   3. 45-55 Years ☐
4. Name of the Police Station _____
5. Location of the Station(Town/City)_____
6. Province _____
7. Have you done any course in criminal investigation or scenes of crime?
   1. Yes ☐
   2. No ☐
   3. Other, specify_____

      _____

8. Have you attended a seminar in criminal investigation or scenes crime management?
   1. Yes ☐
   2. No ☐
   3. Other, specify_____

_____

9. Have you done any forensic science course?

1. Yes
2. No
3. Other, specify_____

_____

3. PART B:

10. Does your Police Station keep evidence?

1. Yes
2. No
3. Do Not Know

11. At what point do you start evidence documentation

1. Crime Scene
2. Police Station
3. Forensic Laboratory
4 Where preparing evidence for court

12. Does your Police Station have an evidence and property room

1. Yes
2. No
3. Do Not Know

13. List the types of evidence categories that are currently stored by your Police Station?

_____

_____

_____

14. Do you have any measures in place to help in tracking the evidence under your Police Station?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

15. If the answer to (7) is yes, what are those measures?

_____

_____

_____

16. What type of system do you use to monitor evidence handling and storage?

1. manually maintained with spread sheets, ☐
2. an in-house system ☐
3. Do Not Know ☐
4. Other, specify _____

17. Approximately how many people are engaged in handling of a particular evidence up to its disposal?

1. Two ☐
2. Three ☐
3. Four ☐
4. More than five ☐
5. Other, specify _____

18. What type of transportation do you use to transfer evidence from the station to the forensic lab?

1. Public transport ☐
2. Organizational Vehicles ☐
3. Other, specify _____

19. Who accompanies the evidence?

1. The officer handling the case ☐
2. Any officer ☐
5. Other, specify _____

20. Are there any measures to ensure the integrity of the evidence is maintained?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

21. If the answer to (18) is yes, what are those measures?

_____

_____

22. Is the evidence accompanied by the chain of custody document?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

23. Are you given any reference number for your evidence after depositing it at the forensic laboratory?

1. Yes ☐

2. No ☐

24. Who receives your evidence at the forensic laboratory?

1. Forensic examiners ☐
2. Receptionist ☐
3. Never been there ☐

25. Do you experience theft of evidence from exhibit rooms?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

26. How often do you experience theft of evidence at your station?

1. Daily ☐
2. Weekly ☐
3. Monthly ☐
4. Quarterly ☐
5. Every six months ☐
6. Annually ☐
7. Other, specify _____

27. What type of evidence is usually stolen?

_____

_____

28. What is the approximate number of case were evidence is lost annually?

_____

_____

29. How long does it take for you discover that evidence is missing from the exhibit room?

1. One day ☐
2. One week ☐
3. One month ☐
4. More than two months ☐
5. One year ☐
6. Other, specify _____

30. When it is discovered that evidence is missing, how long does it take for you report the theft?

1. One day ☐
2. One week ☐
3. One month ☐
4. More than two months ☐
5. One year ☐
6. Other, specify _____

31. Are there any measures to ensure implemented to mitigate theft?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

32. If the answer to (29) is yes, what are those measures??

_____

_____

_____

_____

_____

33. Does evidence get spoiled in the exhibit rooms?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

34. How long does it take for you to discover that the evidence has been spoiled?

1. One day ☐
2. One week ☐
3. One month ☐
4. More than two months ☐
5. One year ☐
6. Other, specify _____

35. What challenges do you face regarding monitoring evidence in the exhibit rooms?

_____

_____

_____

_____

_____

36. Do you keep records of stock you currently have in the exhibit rooms?

1. Yes ☐
2. No ☐

3. Do Not Know ☐

37. In what form do you keep records relating to inventory in the exhibit rooms?

1. Paper
2. Excel Spreadsheet
3. Database
4. Other, specify_____

38. How many computers, if any, do you have at your station?

1. One computer ☐
2. Two computer ☐
3. Three computer ☐
4. Four computer ☐
5. None ☐

39. Is organization computerized and networked?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

40. Are computers at your station linked to the organization network?

1. Yes ☐
2. No ☐
3. Do Not Know ☐

41. Do you have printers at your station?

1. Yes ☐
2. No ☐

3. Do Not Know ☐

42. How often do you have power outages at your station?

1. Daily ☐
2. Weekly ☐
3. Monthly ☐
4. Quarterly ☐
5. Every six months ☐
6. Annually ☐

43. What type of standby power supply such do you have at your station?

1. Generator ☐
2. UPS ☐
3. No standby power supply ☐

THANK YOU

APPENDIX 3 INTERVIEW QUESTIONNAIRE

Interview Questions for Zambia Police Provincial Heads of Scenes of Crime Investigation Unit

Part A.

1. How does information about evidence reach your office?
2. How many offices do the information pass through before reaching your office?
3. How long does the information take to reach your office?
4. Are the processes efficient?
5. What suggestions would you recommend?

Part B

1. How is the evidence kept in the exhibit room?
2. Is evidence managed by officers dedicated for the purpose?
3. How many offices does evidence inventory reports passes through before reaching your office?
4. How often do you receive these reports?
5. How often do you actually need to receive these reports?
6. What would cause the delay if any?

Part C

1. How would rate the computer literacy levels?
2. What strategies are in place to train officers?
3. Do you support by the current budget?

APPENDIX 4 CODE SNIPPETS

Chain of Custody Code

```
Imports CrystalDecisions.CrystalReports.Engine
Imports CrystalDecisions.Shared
Imports System.Data
Public Class frmCustodyReport

    Private applicationReport As ReportDocument
    Private Sub ConFigureCrystalReports_Custody()

        applicationReport = New ReportDocument()

        Dim reportPath As String = My.Application.Info.DirectoryPath & "\Custody Chain.rpt"

        applicationReport.Load(reportPath)

        Dim myDataSet As DataSet = DataSetConfiguration._custodyDataSet

        applicationReport.SetDataSource(myDataSet)
        myCrystalReportViewer.ReportSource = applicationReport
        myCrystalReportViewer.Zoom(80)

    End Sub
    Private Sub frmCustodyReport_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load

        Me.MdiParent = frmMain

        'conFigure crystal report
        ConFigureCrystalReports_Custody()
        Me.WindowState = FormWindowState.Maximized

    End Sub
End Class
```

Crime Scene Evidence Capturing Code

```
Dim rs As New ADODB.Recordset
    Dim SQL As String
    Dim x As Boolean
    Dim autoItem_No As Integer
    Dim autoCase_No As Integer
    Dim autoItemRef_ID As Integer
    Dim autoCaseRef_ID As Integer
    Dim sameCase As Boolean


    Private Sub frmCrimeScene_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load

        'connect to system database
        cn.Open("Provider=Microsoft.Jet.OLEDB.4.0;Data Source=" & My.Application.Info.DirectoryPath &
"\ECCIS.mdb;")

        'set MDIParent form
        Me.MdiParent = frmMain
        Me.WindowState = FormWindowState.Normal

        'setup listview control
```

```
        lvEvidence.View = View.Details

        lvEvidence.Columns.Add(" ", 30, HorizontalAlignment.Left)
        lvEvidence.Columns.Add("Item No", 50, HorizontalAlignment.Left)
        lvEvidence.Columns.Add("Item Name", 180, HorizontalAlignment.Left)
        lvEvidence.Columns.Add("Quantity", 70, HorizontalAlignment.Left)
        lvEvidence.Columns.Add("Synopsis/Summary", 230, HorizontalAlignment.Left)

        'set focus to case id field
        txtRFID.Focus()

        'regulate status bar behaviour
        ErrorMsgToolStripStatusLabel.Text = ""

        'call resetICtrls
        resetICtrls()

    End Sub

    Private Sub cmdClose_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
cmdClose.Click
        'close form
        Me.Close()
    End Sub
    Private Sub initInstLV()

        Dim itemNum As Integer
        Dim i As Integer

        'clear listview items
        lvEvidence.Items.Clear()

        '--------------------------------------------------------------------
        'create a select query on table INST
        SQL = "SELECT * FROM Crime_Scene_Evidence where bar_code='" & txtRFID.Text & "' ORDER BY
item_no ASC"
        rs.Open(SQL, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -1)


        '--------------------------------------------------------------------
        If rs.EOF And rs.BOF Then
        Else
            'populate the listview with data from the select query
            Do Until rs.EOF

                i = itemNum

                lvEvidence.Items.Add("", 0)
                lvEvidence.Items(i).SubItems.Add(rs.Fields.Item("item_no").Value)
                lvEvidence.Items(i).SubItems.Add(rs.Fields.Item("item").Value)
                lvEvidence.Items(i).SubItems.Add(rs.Fields.Item("qty").Value)
                lvEvidence.Items(i).SubItems.Add(rs.Fields.Item("synopsis").Value)

                itemNum = itemNum + 1
                rs.MoveNext()

            Loop

        End If

        'close recordset object
        rs.Close()
```

```
        '-----------------------------------------------------------------------
        If lvEvidence.Items.Count = 0 Then

            'give user feedback when select query returns empty
            lvEvidence.Items.Add("No Evidence Available", 0)
            lvEvidence.Items(i).SubItems.Add("")

        End If

    End Sub

    Private Sub resetICtrls()

        'reset input controls
        cboCaseOfficerID.Items.Clear()
        cboCaseOfficerID.Enabled = True
        txtCaseOfficer.Text = ""
        txtDesignation.Text = ""
        dtpRef_date.Value = FormatDateTime(Now, DateFormat.LongDate)
        dtpRef_date.Enabled = True
        cboIncidentType.SelectedIndex = -1
        txtIncidentLocation.Text = ""
        txtIncidentLocation.ReadOnly = False
        txtRFID.Text = ""
        txtRFID.Enabled = True
        txtRFID.Focus()
        nudQuantity.Value = 1
        cboItemName.SelectedIndex = -1
        txtEvidenceSynopsis.Text = ""

        'reset boolean variable
        sameCase = False

        'get case number
        Case_No()

        'clear listview items
        lvEvidence.Items.Clear()

        'get case officers
        getCaseOfficers()

        'regulate status bar behaviour
        ErrorMsgToolStripStatusLabel.Text = ""

    End Sub


    Private Sub cmdCancel_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
cmdCancel.Click
        'call resetICtrls to reset controls
        resetICtrls()
    End Sub

    Private Sub getCaseOfficers()

        'create select query on table USER_ACCs
        SQL = "SELECT man_no,full_name FROM USER_ACCs"
        rs.Open(Sql, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -1)

        Do Until rs.EOF
            cboCaseOfficerID.Items.Add(rs.Fields("man_no").Value)
            rs.MoveNext()
```

```
        Loop


        'close recordset object
        rs.Close()

    End Sub

    Private Sub cboCaseOfficerID_DropDownClosed(ByVal sender As Object, ByVal e As System.EventArgs)
Handles cboCaseOfficerID.DropDownClosed

        'flag invalid case officer selection
        If cboCaseOfficerID.SelectedItem = "" Then
            ErrorMsgToolStripStatusLabel.Text = "Please select a case officer ID from the dropdown list provided."

            cboCaseOfficerID.Focus()
            Exit Sub
        End If

        'clear previous flagged error in status bar
        ErrorMsgToolStripStatusLabel.Text = ""

        'create select query on table USER_ACCs
        SQL = "SELECT man_no,full_name,user_role FROM USER_ACCs where man_no='" &
cboCaseOfficerID.SelectedItem & "';"
        rs.Open(SQL, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -1)

        txtCaseOfficer.Text = rs.Fields("full_name").Value
        txtDesignation.Text = rs.Fields("user_role").Value


        'close recordset object
        rs.Close()

    End Sub

    Private Sub cmdSave_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
cmdSave.Click

        Dim item_number As Integer = 1

        'flag invalid case officer selection
        If cboCaseOfficerID.SelectedItem = "" Then
            ErrorMsgToolStripStatusLabel.Text = "Please select a case officer ID from the dropdown list provided."

            cboCaseOfficerID.Focus()
            Exit Sub
        End If


        'flag invalid incident type selection
        If cboIncidentType.SelectedItem = "" Then
            ErrorMsgToolStripStatusLabel.Text = "Please select an incident type from the dropdown list provided."

            cboIncidentType.Focus()
            Exit Sub
        End If

        'flag invalid incident location
        If txtIncidentLocation.Text = "" Then
            ErrorMsgToolStripStatusLabel.Text = "Please input an incident location"

            txtIncidentLocation.Focus()
```

```
        Exit Sub
    End If

    'flag invalid bar code input
    If txtRFID.Text = "" Then
        ErrorMsgToolStripStatusLabel.Text = "Please input a bar code to catalogue the evidence."

        txtRFID.Focus()
        Exit Sub
    End If

    'flag invalid numeric up/down input
    If nudQuantity.Value = 0 Then
        ErrorMsgToolStripStatusLabel.Text = "Please input a catalogue quantity greater than 0"

        nudQuantity.Focus()
        Exit Sub
    End If


    'flag invalid item name input
    If cboItemName.SelectedItem = "" Then
        ErrorMsgToolStripStatusLabel.Text = "Please input the item name"

        cboItemName.Focus()
        Exit Sub
    End If


    'regulate status bar behaviour
    ErrorMsgToolStripStatusLabel.Text = ""


    If sameCase = False Then

        'create select query on table Cases
        SQL = "SELECT * FROM Cases"
        rs.Open(SQL, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -
1)
        'add evidence catalogue to database
        rs.AddNew()

        rs.Fields("case_no").Value = autoCase_No
        rs.Fields("man_no").Value = cboCaseOfficerID.SelectedItem
        rs.Fields("ref_date").Value = dtpRef_date.Value

        'update DBMS transaction
        rs.Update()

        'requery database
        rs.Requery()

        'close recordset object
        rs.Close()

    End If

    'make call to Item_No sub routine
    Item_No()

    'create select query on table Crime_Scene
    SQL = "SELECT * FROM Crime_Scene_Evidence"
    rs.Open(SQL, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -1)
```

```
        'add evidence catalogue to database
        rs.AddNew()

        rs.Fields("case_no").Value = autoCase_No
        rs.Fields("item_no").Value = autoItem_No
        rs.Fields("bar_code").Value = txtRFID.Text
        rs.Fields("qty").Value = nudQuantity.Value
        rs.Fields("item").Value = cboItemName.SelectedItem
        rs.Fields("synopsis").Value = txtEvidenceSynopsis.Text
        rs.Fields("incident_type").Value = cboIncidentType.SelectedItem
        rs.Fields("incident_location").Value = txtIncidentLocation.Text
        rs.Fields("ref_date").Value = dtpRef_date.Value


        'update DBMS transaction
        rs.Update()

        'requery database
        rs.Requery()

        'close recordset object
        rs.Close()

        'initialize listview control
        initInstLV()

        If (MessageBox.Show("Do yo wish to package more evidence from this " & vbCrLf _
                    & "crime scene in the same evidence container?", "Evidence Catalogue", MessageBoxButtons.YesNo,
MessageBoxIcon.Question) = vbNo) Then

            'call resetICtrls to reset controls
            resetICtrls()

        Else
            'reset boolean variable
            sameCase = True

            'increment numeric up/down value by 1
            'nudQuantity.Value = nudQuantity.Value + 1

            'reset input controls
            cboCaseOfficerID.Enabled = False
            cboIncidentType.SelectedIndex = -1
            txtIncidentLocation.ReadOnly = True
            cboItemName.SelectedIndex = -1
            txtEvidenceSynopsis.Text = ""
            dtpRef_date.Enabled = False
            txtRFID.Enabled = False

        End If


    End Sub

    Private Sub txtRFID_KeyDown(ByVal sender As Object, ByVal e As System.Windows.Forms.KeyEventArgs)
Handles txtRFID.KeyDown

        If e.KeyCode = Keys.Enter Then
            'call to BarCodeExists
            BarCodeExists()
        End If
```

```
    End Sub

    Private Sub txtRFID_Leave(ByVal sender As Object, ByVal e As System.EventArgs) Handles txtRFID.Leave

        'call to BarCodeExists
        BarCodeExists()

    End Sub

    Private Sub txtRFID_TextChanged(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
txtRFID.TextChanged

        If txtRFID.TextLength >= 10 Then
            'regulate status bar behaviour
            ErrorMsgToolStripStatusLabel.Text = ""
        End If

    End Sub

    Private Sub Case_No()

        'auto create case ref no
        'create select query on table Crime_Scene
        SQL = "SELECT max(case_no) AS auto_Case_Ref_ID FROM Cases"
        rs.Open(SQL, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -1)

        x = Convert.IsDBNull(rs.Fields("auto_Case_Ref_ID").Value)

        If x = True Then
            autoCase_No = "1"
        Else
            autoCase_No = rs.Fields("auto_Case_Ref_ID").Value
            autoCase_No = autoCase_No + 1
        End If

        Me.Text = "CASES FORM (CASE NUMBER: " & autoCase_No.ToString & ")"

        'close recordset object
        rs.Close()

    End Sub

    Private Sub Item_No()

        'auto create case ref no
        'create select query on table Crime_Scene
        SQL = "SELECT max(item_no) AS auto_Item_Ref_ID FROM Crime_Scene_Evidence where bar_code='" &
txtRFID.Text & "';"
        rs.Open(SQL, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -1)

        x = Convert.IsDBNull(rs.Fields("auto_Item_Ref_ID").Value)

        If x = True Then
            autoItem_No = "1"
        Else
            autoItem_No = rs.Fields("auto_Item_Ref_ID").Value
            autoItem_No = autoItem_No + 1
        End If

        'close recordset object
        rs.Close()
```

```
    End Sub

    Private Sub BarCodeExists()

        'create select query on table Crime_Scene
        SQL = "SELECT * FROM Crime_Scene_Evidence where bar_code='" & txtRFID.Text & "';"

        If (rs.State = 1) Then
            rs.Close()
            rs = Nothing
        Else
            rs.Open(SQL, cn, ADODB.CursorTypeEnum.adOpenDynamic, ADODB.LockTypeEnum.adLockOptimistic, -
1)
        End If


        If (rs.EOF And rs.BOF) Then
            'close recordset object
            rs.Close()
        Else

            MessageBox.Show("The currently scanned bar code already exists in the " & vbCrLf _
                    & "system. You don't have access to update data.", "Evidence Catalogue", MessageBoxButtons.OK,
MessageBoxIcon.Information)

            'close recordset object
            rs.Close()

            'reset bar code input control
            txtRFID.Text = ""

            'exit procedure
            Exit Sub

        End If


    End Sub

End Class
```

APPENDIX 5 LIST OF PUBLICATIONS

This work was published on 30th April 2016 in the International Journal of Advanced Studies in Computer Science and Engineering.

1. P. Nsofwa and J. Phiri, "Developing an E-Chain-of-custody and Inventory System for the Zambia Police Force," *International Journal of Advanced Studies in Computer Science and Engineering,* vol. 5, no. 4, pp. 9-15, 2016