POLYTECHNIC OF NAMIBIA

SCHOOL OF INFORMATION TECHNOLOGY

DEPARTMENT OF SOFTWARE ENGINEERING

TITLE:

Development of a Crime Mapping, Analysis and Prediction Tool for Windhoek

Thesis presented in partial fulfilment of the requirements for the degree of Master of Information Technology at the Polytechnic of Namibia

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November 2012

Declaration

I, **Sebastian Mukumbira**, hereby declare that the work contained in the mini–thesis, entitled "**Development of a Crime Mapping, Analysis and Prediction Tool for Windhoek"**, is my own original work and that I have not previously in its entirety or in part submitted it at any University or other higher education institution for the award of a degree.

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Abstract

The purpose of this study was to investigate the conceptual, technical and human aspects of how the Namibian Police Force can adopt the use of crime maps in its operations and reap the benefits thereof. Another aim was to find out how GIS information can be integrated with crime data to help in the analysis of crime and in understanding crime patterns.

Interviews were conducted with various units of the Namibian Police Force. The findings of the interviews were combined with knowledge gained from an extensive literature review to produce a prototype of the crime mapping tool that allows user interaction with the data. The use of this prototype was then demonstrated with sample crime maps to pairs of officers from four different police units followed by interviews and questionnaires to record the users' perception of the tool.

While the prototype is a proof of concept for the technical feasibility, the final evaluation revealed that crime mapping can indeed be implemented across many units of the Namibian Police Force and that the participants found the tool to be conceptually very useful. GIS data can be integrated with crime data to better understand why certain crimes occur in certain places.

Preface

This thesis documents the research done in partial fulfilment of the requirements of the Master of IT degree at the Polytechnic of Namibia.

The intended audience comprises of law enforcement agents, academics and students. The law enforcement agents will be introduced to new ways of visualising the crime data they collect. General knowledge of computers is assumed yet care has been taken to explain those terms which are deemed as not being part of common knowledge.

This thesis is part of a broader research project on mPolicing and part of this work on mPolicing has been published in the proceedings of the annual Research Conference of the South African Institute for Computer Scientists and Information Technologists (SAICSIT) which was held from the 1st to the 3rd of October 2012 (See appendix J). The APA style of referencing has been used.

The thesis is structured as follows:

- Chapter one provides an introduction and motivation for the research project. It highlights the background and the aim of the study together with its limitations.

- Chapter two defines the research problem and states the research questions.

- Chapter three discusses the research design and methodology used and the collection of data, including reasons why these methods were selected.

- Chapter four presents a review of existing literature pertaining to GIS and crime mapping. The literature review dwells on the definitions of GIS and crime mapping, focussing on those countries which have harnessed this technology and showcasing some of the benefits being reaped. Thus, it positions this study in the existing body of research.

- Chapter five contains a study of the existing practices at NamPol focusing on the technology in use and the units and procedures that could benefit from crime mapping.

- Chapter six looks at GIS information in Namibia. Specifically, it focuses on what GIS data is available, who the sources of that data are and what data would be more beneficial in crime analysis if it is integrated with crime data.

- Chapter seven discusses the methodology used in the development of the system. The designs of the system database and the interface are discussed and the implementation of the prototype is documented showing crime locations and integrating GIS data.

- Chapter eight presents the findings and the discussion from the interviews and the demonstration of the prototype to the various respondents. It will also contain the final evaluation of the resulting system prototype with police officers.

- Chapter nine contains the discussion and conclusions, looking at the implications and limitations of results and points to further research.

Acknowledgements

To my wife Greta thanks for the encouragement and patience. To Iman and Anesu, this one is for you.

Many thanks go to my supervisor, Dr K. L. Jensen. Your guidance and encouragement led to the successful completion of this project, for that, I am truly grateful. Special thanks go to the men and women serving in the Namibian Police Force especially the Crime Statistics Sub-Division, the Geo-policing Unit, the Crime Scene Unit and the Crime Investigation Unit. The interaction I had with you was very enlightening. To the colleagues at Land

Management, your empathy didn't go unnoticed. Finally, to Alex Mudabeti, thanks for holding my hand through the WebGIS minefield!

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Acronyms

Acronyms

RC0 – Release Candidate 0

COSS – Commercial Open Source Software

FDO – Feature Data Objects

FLOSS - Free/Libre/Open-Source

GPL – General Public licence

SAICSIT – South African Institute of Computer Scientists and Information Technologists

Chapter 1: Introduction

A fundamental part of any society is to uphold law and order. The extent to which a nation can prevent crime is thus a major factor in the growth and prosperity of its citizens. Therefore any initiative aimed at solving or preventing crime contributes immensely to the wellbeing of the society.

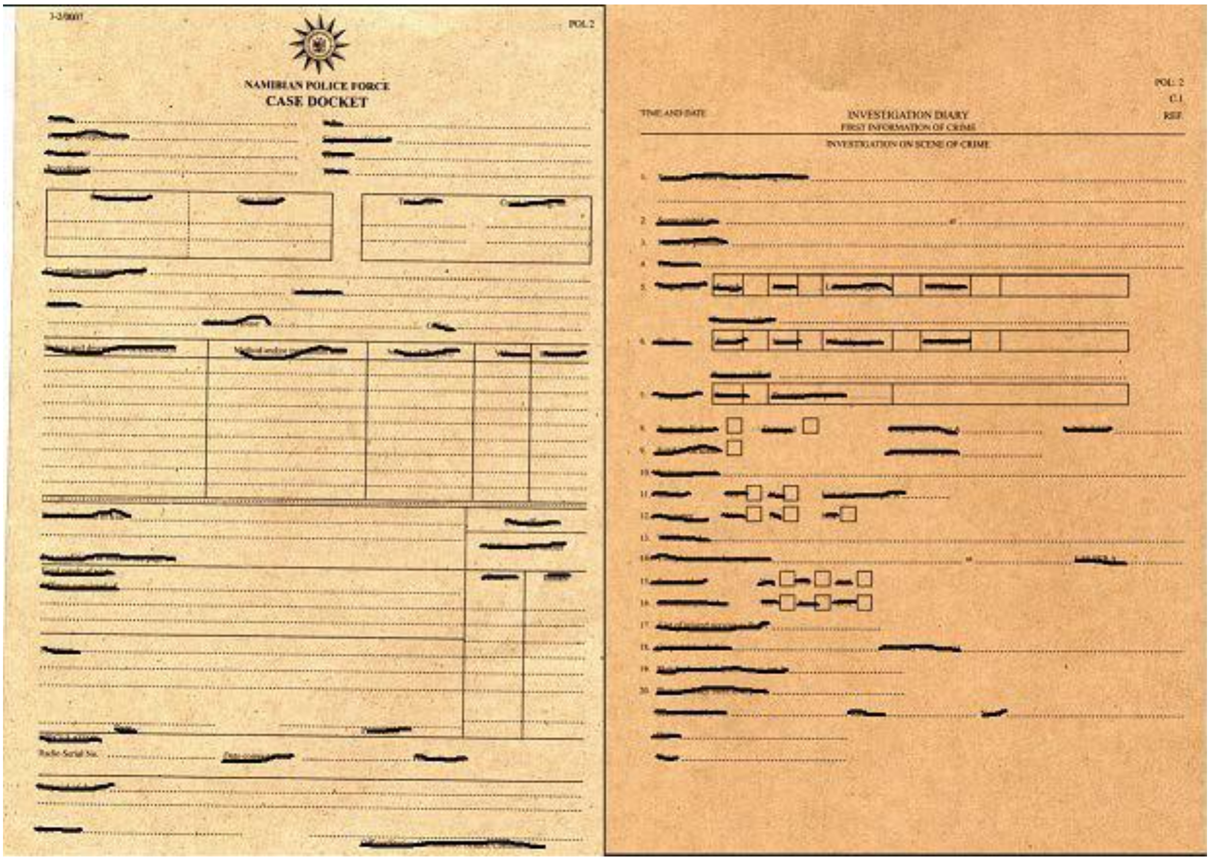
In today's modern age where computers have become a way of life, it is clear that there has been a slow uptake to the use of computers in the Namibian Police Force (NamPol) as evidenced by the current reliance on paper forms for data collection and storage. This is more apparent in record keeping where information pertaining to a particular crime is still recorded on paper dockets as shown in figure 1.1. With a growing population and increasing sophistication in criminal behaviour, time has come to computerise the storage of crime information and hence benefit from resultant capabilities such as crime mapping.

A crucial parameter is the effectiveness and efficiency of crime prevention and crime fighting, but law enforcement agents have limited manpower and budgets with which to operate. In his 2006/2007 budget motivation speech, the late former Minister of Safety and Security Peter Tsheehama outlined that: "With 90 per cent of its (Namibian Police Force) budget going towards covering personnel expenditure, the remaining 10 per cent was barely enough to fight crime and maintain law and order. The acute financial constraints meant that over the last year, the force was not able to recruit new members or promote existing ones" (Namibian, 2006). For a country like Namibia, it thus becomes a priority to improve the usage of these limited funds.

According to Chief Inspector Nuuyi of the Namibian Police force's Public Relations Division, "now more than ever, the number of crime incidents that the police have to handle has increased and criminals are becoming more sophisticated in their activities" (S. Nuuyi, personal communication, October 31, 2012). Faced with these plus limited resources with which to operate, NamPol’s task of preventing and solving crime becomes more difficult.

“A crime is a harmful act or omission against the public which the State wishes to prevent and which, upon conviction, is punishable by a fine, imprisonment, and/or death” (BusinessDictionary.com, 2010), although the death sentence was abolished at independence in Namibia (Chenwi, 2007).

One promising avenue is the use of modern technology which would enable law enforcement agents to optimise the limited resources at their disposal in the fight against crime. The degree to which NamPol can successfully solve and prevent crimes is relative not only to the officers’ expertise in their field, but also to the technology at their disposal in their endeavours.


POL 2

NAMIBIAN POLICE FORCE

CASE DOCKET

[redacted]

INVESTIGATION DIARY

FIRST INFORMATION OF CRIME

INVESTIGATION ON SCENE OF CRIME

Fig 1.1: Case Docket with fields anonymised (Jensen et al, 2012)

Currently when an incident is reported to a police station, it is first recorded in an Occurrence Book. This is a physical book and the officers manually write in that book. If the incident warrants prosecution, it is then transferred to the Crime Register which is also a physical book. Detailed information about a particular crime is then recorded on a case docket as shown in Fig. 1.1. This docket is in paper form and it doubles up as a folder for holding any other documents pertaining to that particular case (J. Kumangamanga, personal communication, October 31, 2012).

“These so-called 'dockets' are then circulated around to members of the police with the authority to validate the data as well as to make these data forms available to all stake holders, e.g. the lawyers, insurance companies and for the police statistics department to make summaries and reports. Afterwards, the data is then stored in central filing facility called the Crime Register” (Jensen, Iipito, Mukumbira & Onwordi, 2012).

It is therefore imperative for NamPol to migrate from the manual system to a digital and partially automated system in order to reap the associated benefits. Case dockets go missing in manual systems yet this can be eliminated by computerising the data storage. Storing crime information in a database would lead to more efficient data sharing within the force. This would mean that investigating officers have access to up to date information from any location where there is a computer. This can be achieved via the use of web interfaces. Once data is stored in a database various visualisation techniques can be employed in an attempt to communicate the database contents to the various stakeholders.

Crime maps can be created from the collected data. These can be used to display locations where crimes are occurring leading to the identification of crime patterns and hotspots. Data stored in a database can be easily integrated with other data enabling deeper analysis of crime trends.

1.2 Aims and Objectives

The purpose of this project is to investigate how the Namibian Police force can harness GIS technology to enhance their day to day operations and how in turn existing technologies can be adapted to suit the operations of the police force. Particular focus is on how the Namibian Police force can benefit from the use of crime mapping.

The study has three main aims:

1. To investigate the foundations and develop a tool for mapping and analysing the occurrence of crime in the Windhoek. This would show where crime is occurring and hence provide a platform from which questions such as why that type of crime is occurring at that particular location can be answered.
2. To define suitable system architecture including necessary interfaces for data collection and dissemination. This sought to create an easy-to-use interface that requires no understanding of databases or GIS. Generated maps would improve the comprehensibility of the regular reports generated by the police. The interface should enable various types of querying, e.g. time-based, trend/pattern-based, by type-of-crime, etc.

3. To define an effective and efficient database model for data storage. This should enable easy integration with other variables and datasets including road surface information, population density, area properties, and riverbeds

Chapter 2: Research Problem

At the time of writing of this report, the Namibian Police are still using manual systems for the collection as well as storage of data. This means that the police force is not benefiting from some of the advantages that digital and partially automated systems offer, chief among which is crime hotspot identification, a major benefit of crime mapping. The police force is also missing out on the benefit of deploying its resources based on crime patterns identified on crime maps.

2.1 Hypothesis of the Study

It is hypothesised that the proposed online crime mapping tool will greatly improve the capability and efficiency of NamPol. Primarily, no crime mapping is currently taking place in NamPol and the manual recording of crime data does not provide the benefits that can be derived from computerised systems. The proposed crime mapping tool is a suitable platform to visualise crime data. Not only will crime hotspots be easily identified but NamPol will be able to deploy its resources more efficiently.

Thus, the main hypothesis is: It is possible and feasible to implement crime mapping in Namibia and crime mapping will add value to the operations of NamPol.

2.2 Research Questions

This research is therefore designed to answer the following questions:

1. What data is required to map the occurrence of crime in Windhoek?
2. How can GIS data be integrated with crime data in order to identify patterns and show the relationship between a crime incident and the attributes of the location where it occurred?
3. How should the data be stored for easy update, integration and access?

4. How can GIS data and crime data be integrated in an interface that allows visualisation and interaction with data?
5. How can crime mapping be implemented using existing and available technologies?
6. How can crime mapping fit into the current organisation and practices at NamPol?

2.3 Scope and Delimitation

In general, the focus of this study is directed towards the design and development of a crime mapping tool. The research only focused on Windhoek as the study area. This was done in order to reduce expenses in terms of travel as well as time. Since the researcher was based in Windhoek, it was relatively easy to access data from the police as well as from the City of Windhoek and from the National Planning Commission. It is hypothesised however that most of the results will be generalizable to other urban and rural areas.

In this proposed tool, crime data and GIS data are stored in a geo-database for accessibility and visualisation. The Windhoek City Police are actively involved in crime fighting within the city but the research focuses only on NamPol. Web-access for public, community policing and ePolicing services are not included.

A prototype with limited functionality is developed to answer the research questions and not a fully integrated system however the prototype provides a very solid blueprint for a complete system. No real crime data will be used due to sensitivity and privacy issues but the random data created will be based on real crime data structures obtained from the police.

The experimentation is limited due to time constraints. NamPol is a busy organisation so their sample of test users will be limited to availability within the time frame.

2.4 Significance of the Study

Socio-economic significance

It is envisaged that the tool will lead to the reduction in crime as well as more efficient deployments of resources.

Technological significance

The proposed tool will introduce crime mapping and GIS to police operations in Namibia. The result of this study is beneficial to the following:

- NamPol - The proposed tool will display crime data on interactive maps making it easier to analyse and make operational and strategic decisions.
- Police Officers - The proposed tool will make it efficient and effective for officers to be deployed on patrols and investigate cases.
- Future Researchers - This will benefit other researchers who wish to conduct related studies as they can use this as a branching point.

This study is ground breaking in Namibia and thus the results can inform government and police officials on whether to pursue a crime mapping solution.

Chapter 3: Research Design and Methodology

This chapter outlines the applied research design and methods of research used. It discusses the techniques used from the feasibility study up to the prototype design. This complements a section on the data gathering tools and analytical tools used.

3.1 Research Design

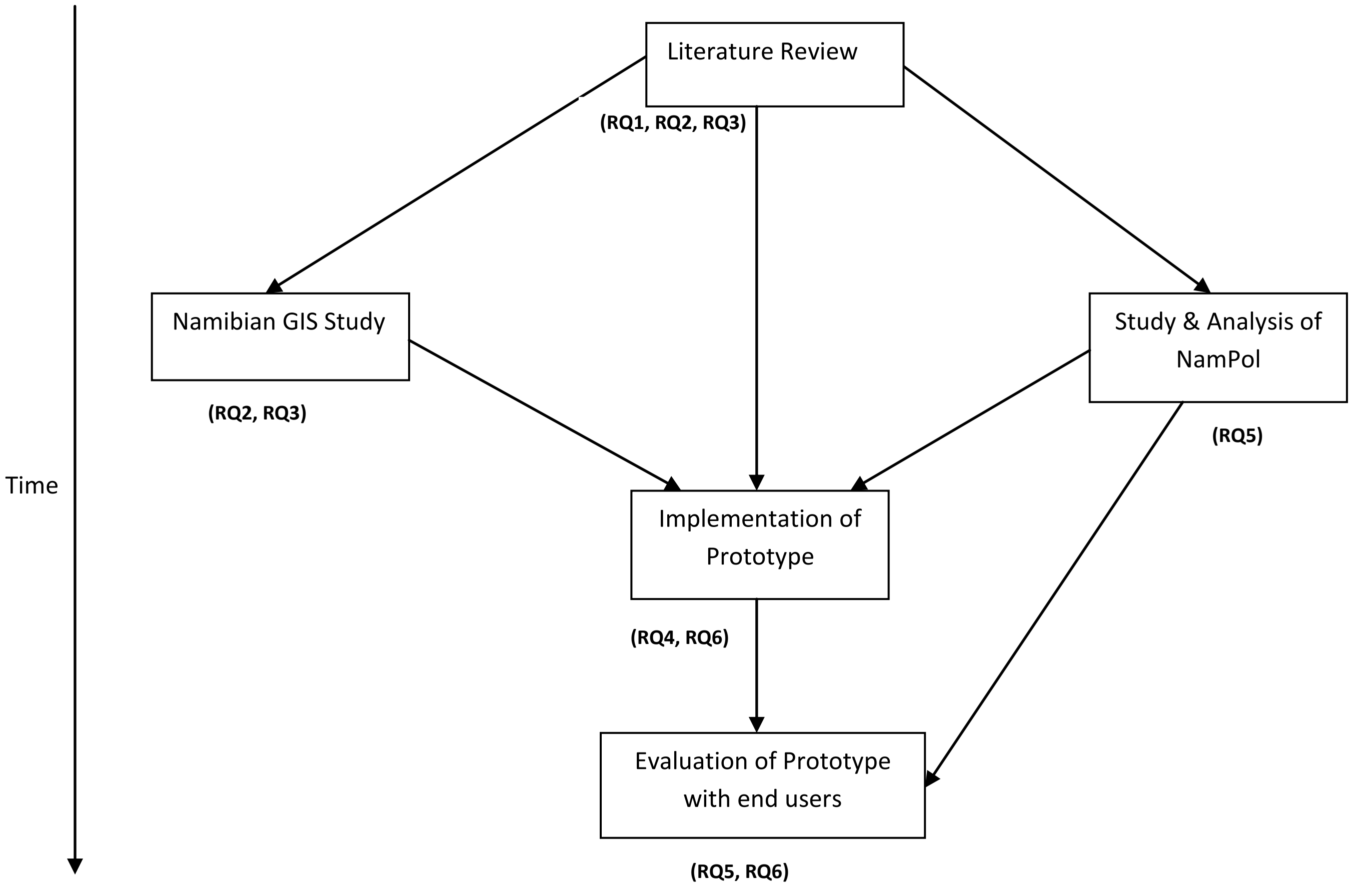


Fig. 3.1: Components of Research Design

In order to successfully carry out the research, the activities were broken down into five components as shown in Fig. 3.1 above. Fig 3.1 also shows how the results of each activity influence further research and how the results map to answering the research questions. A description of each activity and its role is given below.

3.1.1 Literature review

As a first step, an extensive literature review was carried out. This was done in order to gain an in-depth knowledge of crime mapping and underlying technologies as well as existing research on its use. Several cases of crime mapping implementation from the industrialised countries were identified and evaluated. The absence of crime mapping implementation in Africa then became apparent hence justifying the need to investigate and implement it in Namibia.

Geographical Information Systems and data storage technologies are reviewed and their application to crime visualisation and analysis are explored. The literature review attempts to answer the research questions number 1, 2 and 3 by looking at how best crime mapping can be implemented in terms of what data is required for successful mapping of crime and how the data should be stored.

3.1.2 Analysis of Existing Practices in NamPol

Interviews were carried out with police officers from various units within NamPol. The aim of the interviews was to find out the systems that NamPol has in place pertaining to data storage and visualisation as well as investigating the procedures and practices at NamPol with regard to crime reporting and solving.

Focus was on finding out which units of NamPol would benefit from the use of crime mapping and how it can be incorporated into the existing procedures hence answering research question number 5. From this information, system requirements were then derived contributing to the design of the crime mapping tool. Recorded information included the description, analysis and the presentation of the existing system, processes and procedures therein.

3.1.3 GIS Information in Namibia

An exploratory study was done to investigate how the crime mapping tool can integrate other spatial data with crime data for a more in-depth analysis of the crimes. This stage of the research involved identifying which spatial information can be used in analysing crime and what information sources are available. The format that the data is available in influences how the data should be stored in the prototype. The information gathered therefore answers the research questions 2 and 3.

The potential sources of spatial information were then approached and requests for the information were submitted. The received data was analysed to determine its suitability for the prototype.

3.1.4 Prototype Design and Implementation

The information gathered in the three preceding steps is then used in designing the system. With the knowledge of the available technologies, decisions are taken as to which technologies should be used to successfully implement crime mapping and to effectively integrate the crime data with other GIS data thus answering research question number 4 and 6. A system flow chart, context diagram and data flow diagram were developed. This then led to the implementation of the prototype as a proof of concept.

3.1.5 End User Evaluation

Prototype testing then followed whereby the use of the prototype was demonstrated to selected officers. The officers were then given an opportunity to interact with the system followed by a structured interview and a questionnaire.

The prototype was then evaluated in terms of:

a) Conceptual validity, to ascertain whether the prototype can display the crime locations alongside other GIS data in a map and whether it makes sense from the point of view of the Namibian police.
b) Technical capability, to determine if the data storage component of the prototype is linked with the visualisation components.
c) Interaction/interface, besides displaying the data on a map, does the interface properly allow the selection of different layers to be displayed? Does it allow customised querying of the data?
d) Is it perceived as useful and usable?

The information gathered at this stage answer the research questions number 5 and 6. Other issues to be considered during the evaluation included efficiency, speed and usability. Qualitative data was obtained from the structured interview while quantitative data was obtained from the questionnaire using the Likert scale. This is further discussed in the following sections.

3.2 Data Collection Methods

Three methods were used for data collection in this investigation: informal interviews, structured interviews and questionnaires. The following sections discuss the choice of methods and the implications for the research. Interviews were conducted with officers from various segments of the police force. This was done in order to get a clear picture of the operations of the Namibian police force with special emphasis on who collects data at crime scenes, how is the data collected, what data is collected and how is that data stored. It was also intended to find out what reports are generated within the police force, what the emphasis of the reports is and who the intended audience encompasses. Sampling is further discussed in section 3.5.

The questionnaire gave an insight into the potential users' view of the prototype. Meetings were set up with pairs of officers from various units to introduce them to crime mapping and to demonstrate the proposed solution and record their reactions and comments on the proposed solution. Each interactive demonstration was followed by a structured interview and of a questionnaire.

3.2.1 Interviews

Interviews played an important role in several phases of the research. The Association of Qualitative Research, (2004), defines an interview as “the collection of data by asking people questions and following up or probing their answers”. An interview may be conducted with just one respondent (depth interview), with pairs (paired depths), small groups (mini groups), or group discussions of between 5 and 8 participants.

Frey and Oishi (1995) define it as “a purposeful conversation in which one person asks prepared questions (interviewer) and another answers them (respondent)”. This is done to gain information on a particular topic or area to be researched.

Maheshwari, 2001, defines an interview as “a two-way systematic conversation between an investigator and an informant, initiated for obtaining information relevant to a specific study. Interviewing involves not only conversation, but also learning from the respondents’ gestures, facial expressions and pauses, together with their environment”. These can be recorded either by using a video camera or by having a dedicated observer in addition to the interviewer. This requires a personal sensitivity and adaptability as well as the ability to stay within the bounds of the designed protocol.

The paired depth method is preferred in this study since it offers a small manageable group to the interviewer while at the same time offering comfort in numbers to the interviewees. The pairs were interviewed in their own premises so that they would be relaxed during the interviews since they would be in their usual surroundings.

3.2.1.1 Informal interviews

An informal interview was conducted with Inspector S. A. Nuuyi of NamPol’s Public Relations Division. This was done as a way of finding out the general structure of NamPol as well as how the organisation operates. The outcome of the interview is attached in Appendix D.

Informal interviews are unstructured conversations between researcher and respondent, where the respondent has as much influence over the course of the interview as the researcher. No predetermined questions are asked, in order to remain as open and adaptable as possible to the interviewee’s nature and priorities. During the interview, the interviewer “goes with the flow” (Hannan, 2007). This method was used in the early phase where the researcher had very limited knowledge of the organisation.

3.2.1.2 Formal Interviews

Two formal Interviews were conducted. The first one was with Inspector Kumangamanga and Warrant Officer Sinombe, both of the Crime Statistics Sub-division. The second one was with Warrant Officer Owoseb of the Geo-Policing Unit.

The interview with the Crime Statistics Sub-division aimed to gain an in depth knowledge of what data is collected by the police, how is it stored, what reports are frequently generated and who are the main consumers of these reports?

An appointment was sought in advance with each of the respondents in order to conduct the interviews at their convenience. The purpose of the interview and line of questioning were preluded to during the setting up of the appointment in order to ensure that the respondents had a clear view of what to expect. The main objectives of the study were also explained in order for the respondents to understand what was being investigated and the possible impact the resultant solution would have on police operations.

Formal interviews use the guided approach with the intention of ensuring that the same general areas of information are collected from each interviewee. The question items for discussion are structured and experts are allotted different areas and questions to be asked, a very little degree of freedom and adaptability is allowed (McNamara, 2012).

3.3 Paired Depth Interviews

The paired depth interviews were used for the evaluation of the prototype. Eight participants were identified for these interviews. These consisted of two officers from the crime scene unit, two from the crime statistics subdivision, two station commanders and two from the crime investigation unit.

The paired depth interviews were designed such that a demonstration on the use of the prototype was conducted then the participants were given a chance to explore the prototype. After the demonstration, the interview was conducted. The participants would all be asked to sign a consent form before the session started and a voice recorder was used to record the sessions.

Due to the varying schedules of the officers, getting them all in one place at the same time proved to be a challenge hence four sessions were conducted instead on separate days. It proved more feasible to work with smaller numbers at a time hence the meetings were scheduled with pairs of participants. Some of the initially identified participants had to be replaced and some like the Geo-Policing unit officers, proved difficult to meet due to their busy schedule.

The sessions were independent of each other and the first meeting was conducted with officers from the crime statistics subdivision and the second one with the scene of crime unit. The third one was with the Windhoek Police station commander and the fourth one was with the Criminal Investigation unit officers. For consistency, the same questions and methods were used for all sessions.

3.4 Questionnaires

A questionnaire was used to obtain quantitative data about the applicability, the usability and performance of the prototype of the crime mapping tool.

A Likert Scale with five options was used meaning that statements were used in the questionnaire instead of questions. The users were then asked to state how much they agree with the statement. These options varied from Strongly Disagree to Strongly Agree. Five options were chosen to produce variability of responses. Variability in responses is introduced in order to reduce the uncertainty about why we asked the question and what we learnt from the information. It also gives respondents enough room to more closely portray their thoughts than yes/no questions.

The questionnaire was kept short and had only 13 statements. This was done deliberately since long questionnaires generally get fewer responses and fatigue the participants. Clear and concise instructions on how to complete the questionnaire were included.

McLean, 2012, defines a questionnaire as “A set of carefully designed questions given in exactly the same form to a group of people in order to collect data about some topic(s) in which the researcher is interested”. Dornyei and Taguchi, 2010, give further details in their definition of questionnaire by further stating that “many questionnaires do not contain any or many real questions ending with a question mark”. They elaborate further by saying that a questionnaire serves four basic purposes namely to collect the appropriate data, to make data comparable and amenable to analysis, to minimize bias in formulating and asking question, and to make questions engaging and varied.

3.4.1 Likert Scale

McDaniel and Gates, 1998, define a Likert Scale as “a scale in which the respondent specifies a level of agreement or disagreement with statements that express a favourable or unfavourable attitude towards the concept under study”. The respondents indicate their attitude using a numerical score.

The Likert scale was used in this research since having quantified responses to questions means there is little or no scope for the researcher to misinterpret the meaning of answers and it could be uniformly assessed across units.

3.5 Population and Sampling

It is hypothesised that a crime mapping and analysis tool would be beneficial to all the police stations throughout all the cities, towns and villages in Namibia. These police stations form the population of the study. Population is a precise group of people or objects that possesses the characteristic that is questioned in a study (Castillo, 2009). The police stations all have to deal with crime and would benefit from a tool that would enable their teams to understand the crime patterns in their areas better.

“Stratified sampling is a method of polling that separates the population into groups with commonalities and then polls members of each group” (stratifiedsampling.net, 2012). “A stratified sample is made up of different 'layers' of the population, for example, selecting samples from different age groups” (BBC, 2012). NamPol consists of different units and each unit is treated as a layer (strata). Stratified sampling is therefore used to get representative participants from the Crime Statistics Sub-Division, the Crime Scene Unit, Station Commanders and from the Crime Investigation Unit. Only four units were identified. This was due to time constraints and as stated in section 2.3, the availability of officers also played a very significant role.

Snowball sampling was used in finding more respondents. This type of sampling technique works like chain referral. After interviewing one respondent, the researcher asks for assistance from the respondent to help identify people who can provide further information (Lund, 2010). The interview with the Public Relations Unit led to the identification of the Crime Statistics Sub-Division as a suitable unit. This in turn led to the interviewing of the Geo-policing unit.

Chapter 4: Literature Review

The following sections will present and discuss the core aspects of crime mapping tools and the technology needed to realise it. Each section will lead to conclusions that inform the prototype development and research of this thesis. The main sections are:

- ePolicing
- Crime Mapping
- Geographical Information Systems
- Geo-spatial Data Storage
- Data Dissemination and Visualisation

4.1 ePolicing

In general one could define ePolicing as the use of Information and Communication Technologies in the full spectrum of policing. This would include the acquisition, storage and in the dissemination of information. Most police websites surveyed during the carrying out of this research, like the one for The Royal Canadian Mounted Police, show heavy leaning towards the transaction of services and information between the police and citizens via the Internet. ePolicing expands the channels of communication since members of the public can report incidents via the internet and the Police would then react to these reports as soon as resources become available. The police would also use their websites to communicate crime information to the public. This two way communication between the public and the police enables easier publicising of crime prevention initiatives and also contributes to better strategic planning by the police.

Crime mapping can therefore be implemented as part of a comprehensive ePolicing initiative. It would enable police organisations to show exactly where crimes are taking place in a particular neighbourhood.

There are very few visible ePolicing efforts in Africa. The Nigerian Police Force (NPF) describes ePolicing as ways of bringing policing to the internet. They encourage members of the public to sign up to receive email newsletters, crime trends and other important information. They also encourage members of the public to also provide information about crime via email (Nigeria police Force, 2012). The ePolicing system that NamPol is in the process of implementing is expected to eventually avail computers at all the stations in the country.

Efforts are currently underway in Namibia to implement ePolicing and interviews conducted with officers from NamPol have confirmed this. In this regard, the Namibian Police is currently undergoing training for ePolicing to enhance crime prevention, detection and control (New Era, 2012).

As part of ePolicing, Jensen, Iipito, Mukumbira and Onwordi (2012) propose that mobile policing can be part of the ePolicing solution. We envision Namibia and other emerging economies surpassing the incremental technological development that many Western countries have gone through and leapfrogging to mobile technology platforms. Namibia can learn from the Western countries' experiences, particularly how organizations can move from paper-based systems to integrating the latest in ICT solutions. The efficiency and effectiveness of policing can be optimised by leveraging the emerging mobile platforms (Jensen et al, 2012).

We view mobile crime and accident reporting systems as technologies that are ready to be integrated with crime mapping systems used in developed countries to come up with state-of-the-art crime solving technologies for use in developing countries without the need for advanced infrastructures (Jensen et al, 2012).

For crime mapping to be implemented there is need for crime location data storage to be computerised. This research will therefore highlight crime mapping as one of the major components of a comprehensive ePolicing solution.

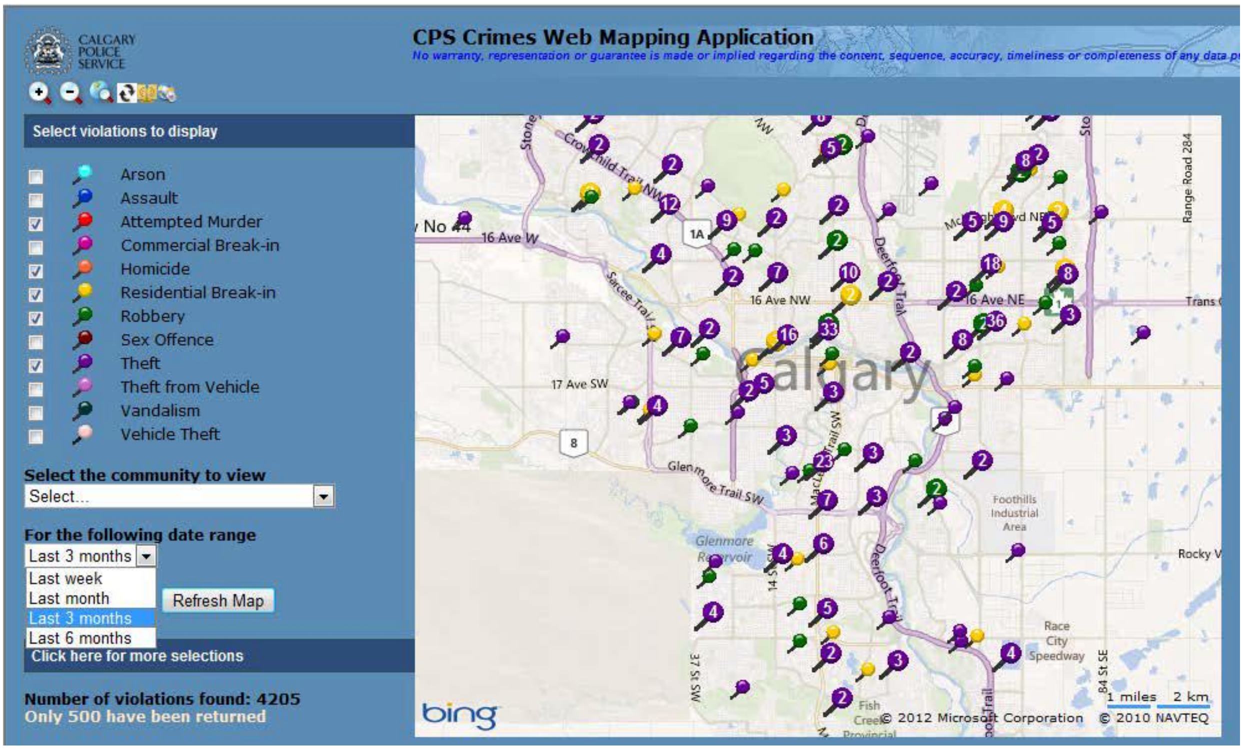


Fig. 4. 1: Screenshot from the CPS application which is managed by the Calgary Police Service (Calgary Police Service, 2012).

4.2 Crime Mapping

The author has not encountered any African implementation of crime mapping. However, numerous examples exist in the developed world e.g. the CPS system (Calgary Police Service, 2012) where crime mapping has been deployed in an ePolicing solution through a web application providing information to the public on the locations of certain crimes (figure 4.1). Using this web application the different crimes are displayed using unique colours to allow an easy overview. The information about the individual crime incidents is derived from a central server onto which crime data is stored. The end user has the choice of exactly which types of crimes s/he wants to see, from which area and for which period (Calgary Police Service, 2012)

An in-depth understanding of an area and its terrain can help law enforcement agents understand why a certain crime occurs at a particular place. The knowledge of features found at the place, the terrain, type of land use and population demographics help in planning intervention measures and in resource distribution.

The United States' National Institute of Justice championed the use of crime mapping in other countries like the United Kingdom, Australia, South Africa and across South America (Chainey & Ratcliffe, 2005). Applications of crime mapping include recording and mapping police activity, information dissemination in the police force, identifying hotspots, monitoring the impact of crime reduction initiatives and aiding decision making in resource allocation.

Developed countries have adopted Crime mapping as part of their overall set of crime fighting tools. The New South Wales Police Service in Sydney, Australia, projects maps of crime distribution onto a large screen for management and senior police executives to determine policing strategy (Ratcliffe, 2004). In the UK, the Crime and Disorder Act (Home Office 1998) makes it mandatory for every police service and local authority to produce a crime and disorder audit (Ratcliffe, 2004). This has had a significant role in bringing crime mapping to the fore in the crime and disorder arena.

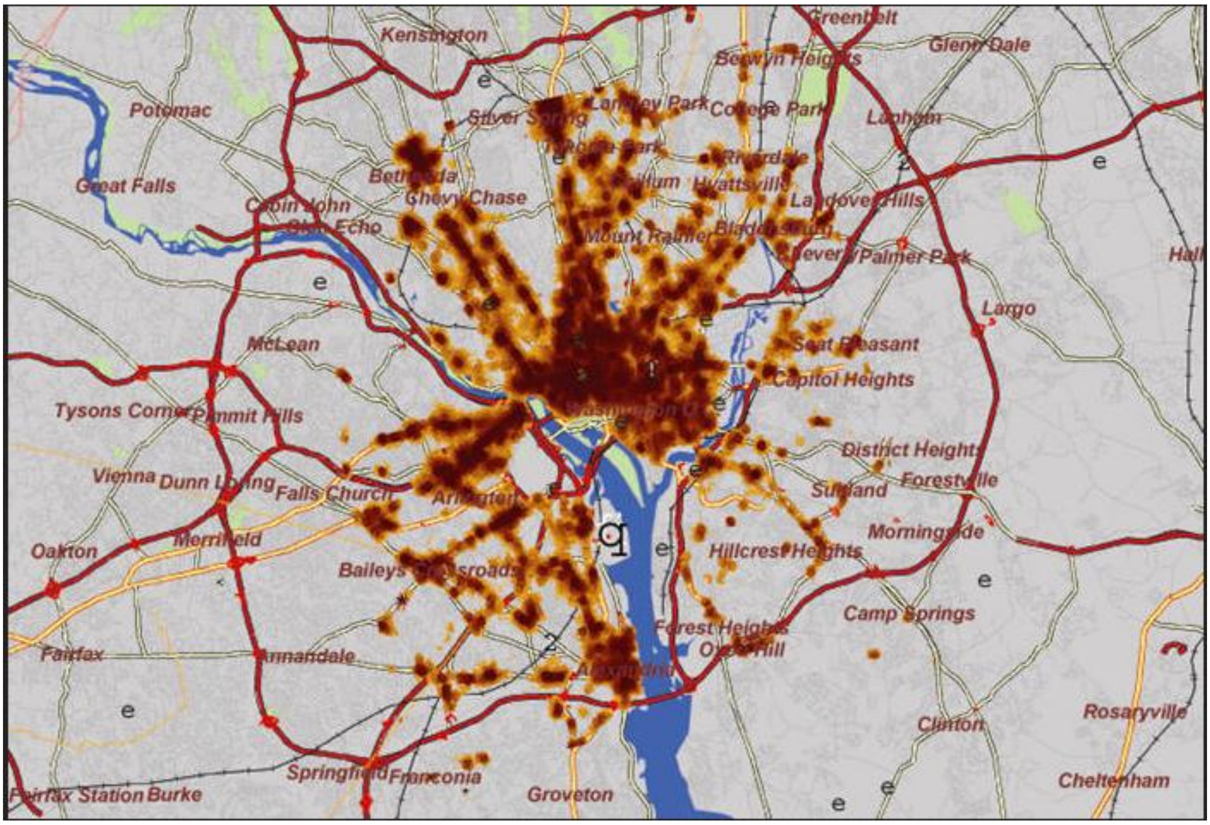


Fig. 4.2: SPADAC Signature Analysis for highest likelihood of ATM muggings in the Washington DC area, based on geoanalysis of the prior four years of crime data and other factors, such as lighting, stops signs vs. stop lights, proximity to gas (Dumas, 2007)

Figure 4.2 shows how crime mapping can also be used to predict crime.

Crime mapping is still at its infancy but it is hoped that once most of the police operations are computerised, crime mapping will then grow to become an integral part of NamPol operations. A crime mapping tool would enable NamPol to show the exact locations where crimes occur. Officers at various levels would then be able to integrate crime data with other geographical data in an attempt to understand why certain crimes are associated with certain places. This crime mapping tool would equip officers with enough visual information to predict to a certain extent, where criminals would strike next.

A crime mapping tool would enable decision makers to identify crime hotspots and hence put measures in place to militate against such trends. This tool can also be used in planning how the limited resources at NamPol's disposal can be utilised more efficiently in the fight against crime. The design of the crime mapping tool should involve as many police units as possible for the system to be usable and be able to add value to police operations.

4.2.1 Crime Location Data

When a crime occurs, it happens at a specific place. The place plays a vital role in understanding crime and how crime can be tackled. The place and the spatial dimension to crime began to be more fully explored during the late 1970s (Chainey & Ratcliffe, 2005).

By exploring the geographical components of crime, crime can be explained and understood in more depth. Techniques that can be used include identifying patterns and concentrations of crime, exploring the relationship between crime and the environment including socio-economic issues.

Block and Block address the relationships among individual (offender), specific place and area aspects of liquor-related crime, and argue that a combination of individual, place and area perspectives can yield better descriptions of the problem and a firmer foundation for the development of intervention strategies. The relationship between crime and place is neither uniform nor static (Block & Block, 2007). Extensive research has shown that occurrences of social disorder, crime and law enforcement activity tend not to be randomly scattered in space, but are clustered in certain areas (Block & Block, 2007).

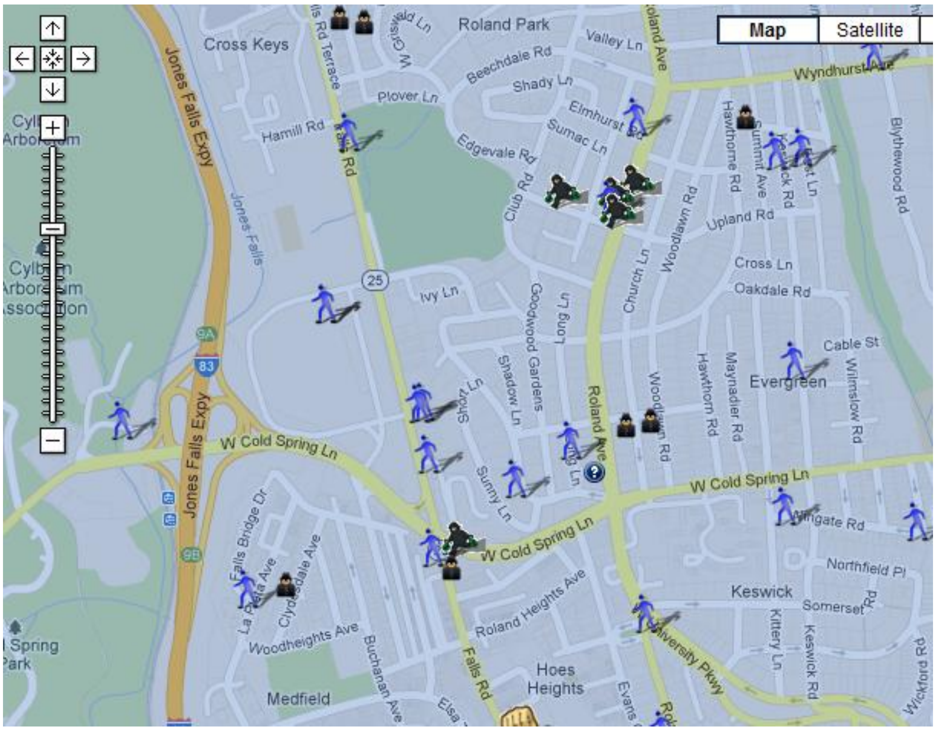


Fig. 4.3: Example of a crime map (Spotcrime, 2012).

Brantingham and Brantingham postulate that the analysis of individual criminal events and of individual persons, building or street victimization studies provides a starting point for fighting crime but for practical purposes individual criminal events must be aggregated in order to assess patterns and devise methods for addressing them. Crime analysis can be improved by mapping different measures of crime and comparing the results. Three different crime measures are suggested namely, the crime count, the crime rate, and the crime location quotient (LQC). The LQC is basically a method of measuring the relative mix of different types of crimes for a particular area compared to the mix in surrounding areas (2009).

The LQCs can then be used in conjunction with crime counts and crime rates, to offer a way of understanding how one area is different from another for purposes of research and deployment of prevention and control resources. Law enforcement units that specialise in certain crimes will then be located near areas where that particular crime is rife.

Analysing the relationship between crime and place is not a new phenomenon. In the 19th century, scholars focussed on the variation of crime in large administrative districts like provinces and countries. At the turn of the 20th century, a group of sociologists took the initiative to undertake new research on urban problems which centred in part on crime. Thus crime and place research was now focussing on comparisons within cities (Weisburd, Bernasco & Bruinsma, 2009).

Showing the locations where crime has taken place as in figure 4.3 can assist in the dissemination of information during awareness campaigns. This study therefore needs to come up with a solution for how to visualise local crime information on crime maps.

4.3 Geographical Information Systems (GIS)

A GIS is a system of hardware and software used for the storage, retrieval, mapping and analysis of geographical data. It is a tool for revealing what is otherwise invisible in geographical information (Longley, Goodchild, Maguire& Rhind, 2005). The computerization of police records has come with a realization that this material can be used for crime and intelligence (Ratcliffe, 2004). In order to recognize patterns of crime that police officers may not be necessarily aware of, GIS is employed to map crime.

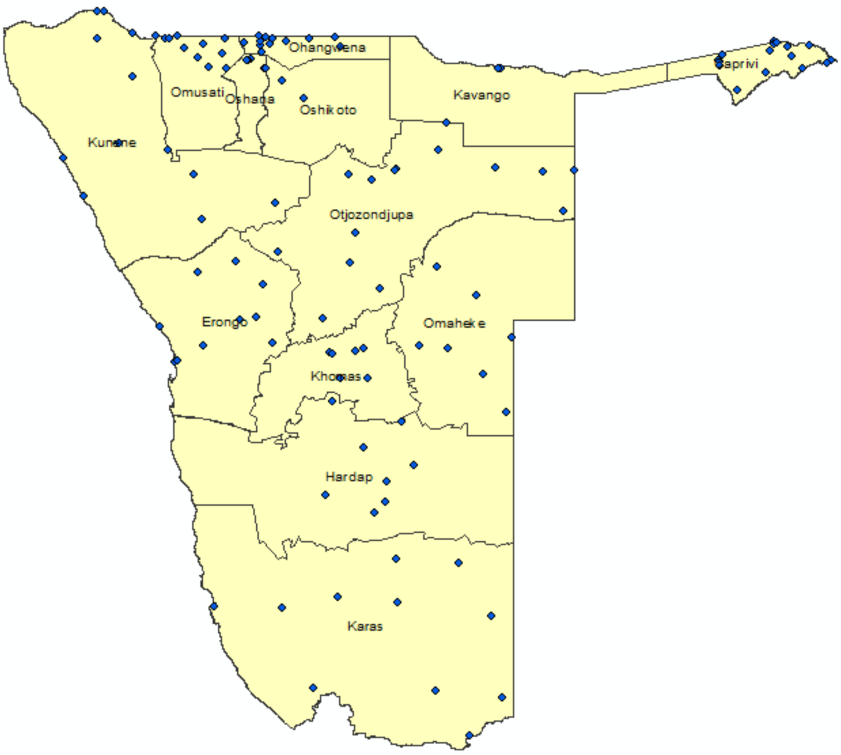


Fig. 4.4: Regional Boundaries of Namibia overlaid with Police Stations (from overlaying the regional boundaries layer with the police stations layer)

Law enforcement is a relative latecomer to the use of GIS (Chainey & Ratcliffe, 2005). Typical use entails using base map components such as streets, land parcels, and aerial photography. The addition of dispatch records, incident records, citations and intelligence reports would then follow. This will not only uncover the patterns in collected crime data and drive new ways to view the criminal justice system, it will also change the way many in criminal justice are doing business. Crime analysis is greatly advanced by having automated crime maps that are easily updated and mapped using customisable search algorithms which are tailored to the specific needs of a user (Chainey & Ratcliffe, 2005).

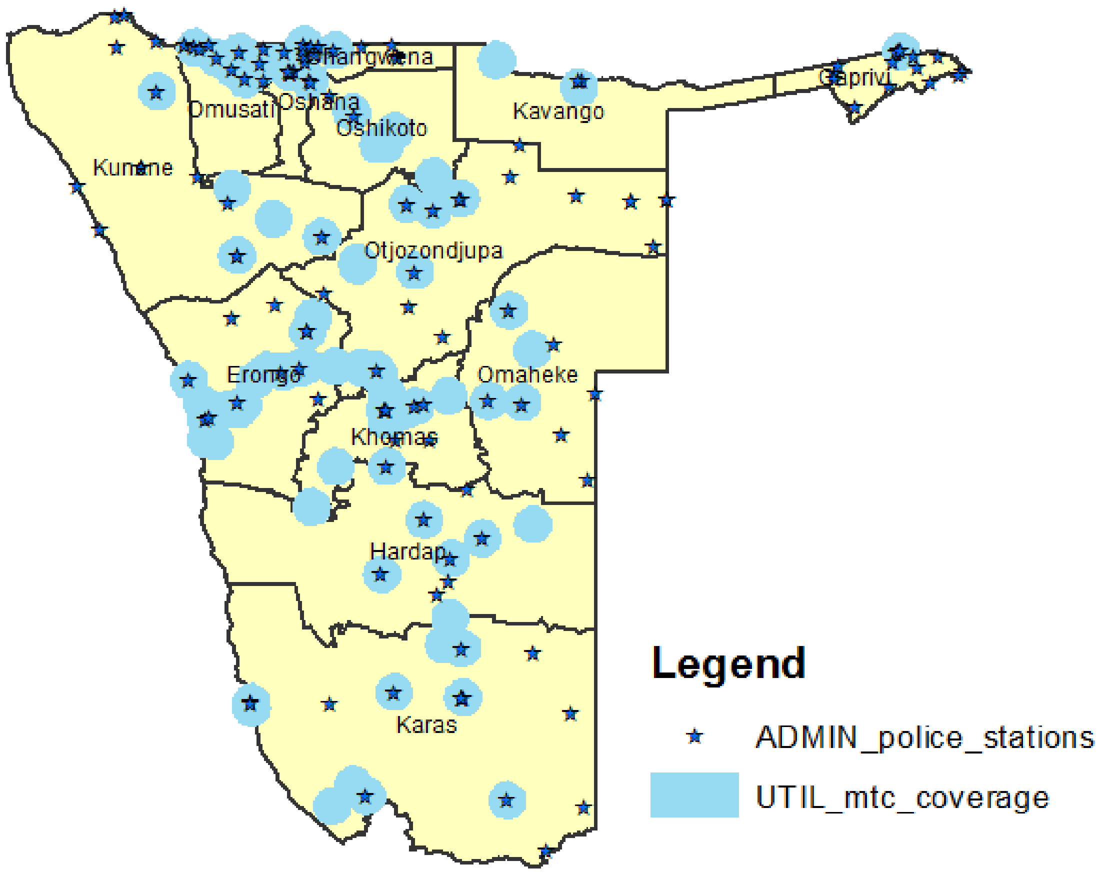


Fig. 4.5: Cell phone Coverage Areas Overlaid with Police Stations (from overlaying the regional boundaries, police stations and the MTC coverage layers)

The migration of GIS from mainframe to desktop computers provides the law enforcing agencies with a cost effective option for crime control since hardware and software prices have reduced drastically. Methods of data collection available to law enforcement agents include street investigations, informers and undercover operations. GIS would enhance the analysis of the collected data due to its ability to handle spatial data.

GIS allows effective integration and analysis of data leading to the identification, apprehension, and prosecution of suspects; it also helps the law enforcing agency to work against crime through effective allocation of resources (Sahu and Srivastava, 2004). Law enforcement agents would use GIS to visualise, analyse and explain the criminal activities in a spatial context. When analysing crime data, the effect of the physical layout of the areas, proximity to various services and land forms should be taken into account since these natural and man-made factors influence criminal behaviour.

Figures 4.3 and 4.5 demonstrate that various layers of data can be overlaid leading to deeper understanding of the areas being studied. GIS is important for crime mapping since it facilitates the integration of crime data and non-crime data leading to the better understating of why certain crimes occur in particular places.

4.3.1 WGS84 (the World Geodetic System of 1984)

The earth is not a regular sphere, neither is it a perfect ellipsoid. It is a geoid. In order to pinpoint a position on earth, coordinate systems are used. Each coordinate system is based on an estimation of the shape of the earth (datum). This could be a sphere or an ellipsoid. Several of these estimations exist and the most common nowadays is the WGS84 ellipsoid. Its popularity is partially credited to the fact that the Global Positioning System (GPS) is based on it. The WGS coordinate system gives coordinates (latitude and Longitude) based on the WGS84 ellipsoid (Longley, Goodchild, Maguire and Rhind, 2005).

Since the WGS84 coordinate system is used internationally, it is adopted in this research since it would allow the direct use of GPS data without first having to reproject it. It also makes the sharing of data with other international organisations easier.

4.4 Geo-Spatial Data Storage

For storage and management of geographic and attribute data, GIS software packages rely on an underlying Database management System (DBMS). Storage can also be directly controlled by the application (Rigaux, Scholl & Voisard, 2002).

Pure relational databases are not suitable for handling spatial data. This is due to a violation of the data independence principle since formulating queries on themes requires knowledge of the spatial objects' structure. Changing this structure implies a deep reorganisation of the database and changing the query formulation (Rigaux et. al. 2002).

Alternative data storage approaches would be to use either a loosely coupled approach where descriptive data is separated from spatial data or an integrated approach based on DBMS extensibility whereby the query language SQL is extended to manipulate spatial data as well as descriptive data (Rigaux et. al. 2002).

Most DBMS software vendors have released spatial extensions for their products. There is MySQL Spatial Extension, Oracle Spatial and OpenGIS Simple Features amongst the common ones. Microsoft SQL Server also supports spatial data since the 2008 version. The use of spatial databases would satisfy the need to manage geometric, geographic, or spatial data, which means data related to space. These databases can contain sets of objects in space rather than images or pictures of a space. The objects in space would have identity and well-defined extents, locations, and relationships (Guting, 1994).

Various definitions of spatial databases exist. A database can be defined as a structure that stores logically related data organised for easy retrieval and update. Guting (1994) defines a spatial database as first and foremost, a database; this database offers spatial data types in its data model and query language. It also supports spatial data types in its implementation, providing at least spatial indexing and efficient algorithms for spatial join.

In 2008, Microsoft released its SQL Server 2008 with support for new data types. Amongst the new data types supported was spatial data which can be stored in two ways namely as projected data and as geographic data. Geographic data in this case is based on the ellipsoidal model of the earth while projected data is based on a planar surface. For low budget organisations, SQL Server 2008 Express is available for free. It offers the same spatial capabilities as the Standard and Enterprise Edition of SQL Server 2008. Limitations are on the database size, mirroring and partitioning which do not affect spatial capabilities.

In response to the demand for Database Management Systems (DBMS) that can handle spatial data, Oracle came up with the separately licensed Oracle Spatial also simply known as Spatial. Oracle Spatial provides a SQL schema and functions that facilitate the storage, retrieval, update, and query of collections of spatial features in an Oracle database. Some of its components include a schema (MDSYS) that prescribes the storage, syntax, and semantics of supported geometric data types and a spatial indexing mechanism to make spatial attribute searches more efficient. It also has a set of operators and functions for performing area-of-interest queries, spatial join queries, and other spatial analysis operations as well as administrative utilities (Oracle, 2003).

For those organisations that find the price of Oracle Spatial an obstacle, Oracle Locator is available for free. It includes the data types, operators, and indexing capabilities of Oracle Spatial but lacks the advanced analysis capabilities like linear referencing, and Spatial Web services which are found in Oracle Spatial (Oracle, 2003).

Open source relational database systems have also started incorporating support for spatial data. They follow the guidelines published by the Open Geospatial Consortium (OGC) in 1997. The guide lines propose several conceptual ways for extending an SQL RDBMS to support spatial data. PostGIS was developed to add support for geographic objects to PostgreSQL. This enables PostgreSQL to be used as a backend spatial database for geographic information systems. PostGIS currently has basic topology support, data validation, coordinate transformation and current development includes full topology support, raster support, networks and routing, three dimensional surfaces, curves and splines (PostGIS, 2011).

MySQL is an open source database which makes it favourable in keeping the system costs down. It supports multiple user access which will enable the simultaneous updating of crime data from several officers. The MySQL Spatial Extension enhances the capability to handle spatial data. The SQL with Geometry Types environment is the one implemented by MySQL. It was also proposed by OGC. It refers to an SQL environment that has been extended with a set of geometry types. A geometry-valued SQL column is implemented as a column that has a geometry type. Geometry refers to geometric features that cartographers use to map the world. The feature can be an entity, a space or a definable location. The OGC specification describes a set of SQL geometry types, as well as functions on those types to create and analyze geometry values (MySQL, 1997).

IBM offers the DB2 Spatial Extender that enables one to store, manage and analyse spatial data in their DB2 Universal Database. With the DB2 Spatial Extender, spatial data is integrated with nonspatial data adding more capabilities. It follows the OGC specifications hence it has support from other industry tools like ESRI's ArcInfo and MapInfo MapExtreme.

In comparison, IBM's DB2 and Oracle Spatial are generally costly. Their free versions lack other capability and have limitations, for example, in terms of number of processors supported and size of database. DB2 is rich in terms of functionality and has unlimited database size but only supports up to 4GB of RAM.

Microsoft SQL Server is not free but its Express Edition is free and the spatial component is fully supported in the Express Edition. However, the Express Edition has a database size limit and only supports one processor. It would be ideal in scenarios where most of the applications in use are Windows based (Boston GIS, 2008).

Table 4.1 below compares the features of Microsoft SQL Server 2008, MySQL and PostGIS. These three were chosen because of their features and relatively lower initial cost of procurement.

Feature	SQL Server 2008 (RC0)	MySQL 5.1/6	PostgreSQL 8.3/PostGIS 1.3/1.4
OS	Windows XP, Windows Vista, Windows 2003, Windows 2008	Windows XP, Windows Vista, (haven't tested on 2008), Linux, Unix, Mac	Windows 2000+ (including Vista and 2003, haven't tested on 2008), Linux, Unix, Mac
Licensing	Commercial - Closed Source, Various levels of features based on version, Express version has full spatial support but limitation on database size and only use one processor.	Commercial Open Source (COSS), some parts GPL.	FLOSS (PostgreSQL is BSD, PostGIS is GPL Open Source - you can use for commercial apps but if you make changes to the core libraries of PostGIS, you need to give that back to the community)
Free GIS Data Loaders	shp dataloader for SQL Server 2008 developed by Morten Nielsen (doesn't yet work with RC0)	OGR2OGR, shp2mysql.pl script	included shp2pgsql, OGR2OGR, QuantumGIS SPIT, SHP loader for PostGIS also developed using SharpMap.NET various others
Commercial GIS Data Loaders	Manifold, Safe FME Objects, ESRI ArcGIS 9.3 (in a later service pack)	Safe FME Objects	Manifold, FME Objects, ESRI ArcGIS 9.3
Application drivers available specifically for spatial component	Not yet - SharpMap.NET eventually and probably built into new ADO.NET 3.5+	GDAL C++, SharpMap via OGR, AutoCAD FDO	SharpMap.Net, JDBC postgis.jar included with postgis, JTS etc. tons for Java, GDAL C++, AutoCad FDO beta support
Free Object/Relational Mapping	NHibernateSpatial (this is a .NET object relational spatial mapper) - beta support	Hibernate Spatial - this is a java object relational mapper	NHibernateSpatial and HibernateSpatial

Free Desktop Viewers and Editors	Will be built into SQL Manager, but not available in RC0 and only useful for viewing	GvSig	OpenJump, QuantumGIS, GvSig, uDig
Commercial Desktop Viewers and Editors	ESRI ArcGIS 9.3 Server SDE later service pack, Manifold, FME	FME	ESRI ArcGIS 9.3 Server, ZigGIS for desktop, Manifold, FME
Web Mapping ToolKits - it must be said things like OpenLayers and various other scripting frameworks that can accept GML will work with any of these databases and your favourite web scripting language	Manifold, MapDotNet, ArcGIS 9.3 (in later service pack), UMN MapServer see, MapGuide Open Source (using beta FDO driver)	UMN Mapserver, GeoServer, MapGuide Open Source	Manifold, MapDotNet, ArcGIS 9.3, UMN Mapserver, GeoServer, FeatureServer, MapGuide Open Source (using beta FDO driver)
Spatial Functions	Both OGC SFSQL MM and Geodetic custom (over 70 functions)	OGC mostly only MBR (bounding box functions) few true spatial relation functions, 2D only	Over 300 functions and operators, no geodetic support except for point-2-point non-indexed distance functions, custom PostGIS for 2D and some 3D, some MM support of circular strings and compound curves
Spatial Indexes (from reports Oracle also uses some sort of R-Tree indexing scheme and can use quadtree, IBM DB2 uses quadtree, Spherical Voronoi Tessalation, IBM Informix uses R-Tree. Note R-Tree indexes are self-tuning and do not require grid setup	Yes - 4 level Multi-Level grid hierarchy (BOL says its B-Tree based) with tessalation as described Isaac Kunene Multi-Level Grid requires defining an index grid for optimal performance	R-Tree quadratic splitting - indexes only exist for MyISAM	GIST - a variant of R-Tree

True Geodetic support - support for true measurement along a spherical coordinate (it must be noted Oracle and IBM provide geodetic support, although IBM Informix/DB2 have it as an additional Blade add-on in addition to standard spatial)	Yes - with caveats - must use Geography type which has the following constraints, no single geometry may overlap hemispheres, intersections, some operations are undefined for two geometries in separate hemispheres. SRID must be defined in spatial ref. Orientation of polygons is important in Geography. According to BOL - ST_Distance is only supported when one of the geography instances is a point (NOTE: Isaac Kunene says the BOL docs are wrong about ST_Distance and this restriction has been lifted) . Fewer spatial functions available for geography than geometry	No	No
Shared Hosting	Many	Many	Much fewer, but ramping up. It must be noted that if you have a dedicated Linux/Windows server, and aren't afraid to be your own admin (or to get a qualified consultant such as us), then your options are much wider.

Table 4.1: Comparison of Microsoft SQL Server 2008, MySQL and PostGIS. Source (Boston GIS, 2012)

Free Desktop Viewers and Editors are available to display and edit the spatial data stored in the Spatial Database Management Systems, SDBMS. Microsoft Server 2008 has an inbuilt viewer

(SqlSpatial Query Tool), while MySQL uses gvSig and PostGIS can use OpenJump, QuantumGIS, gvSig and uDig.

SqlSpatial Query Tool

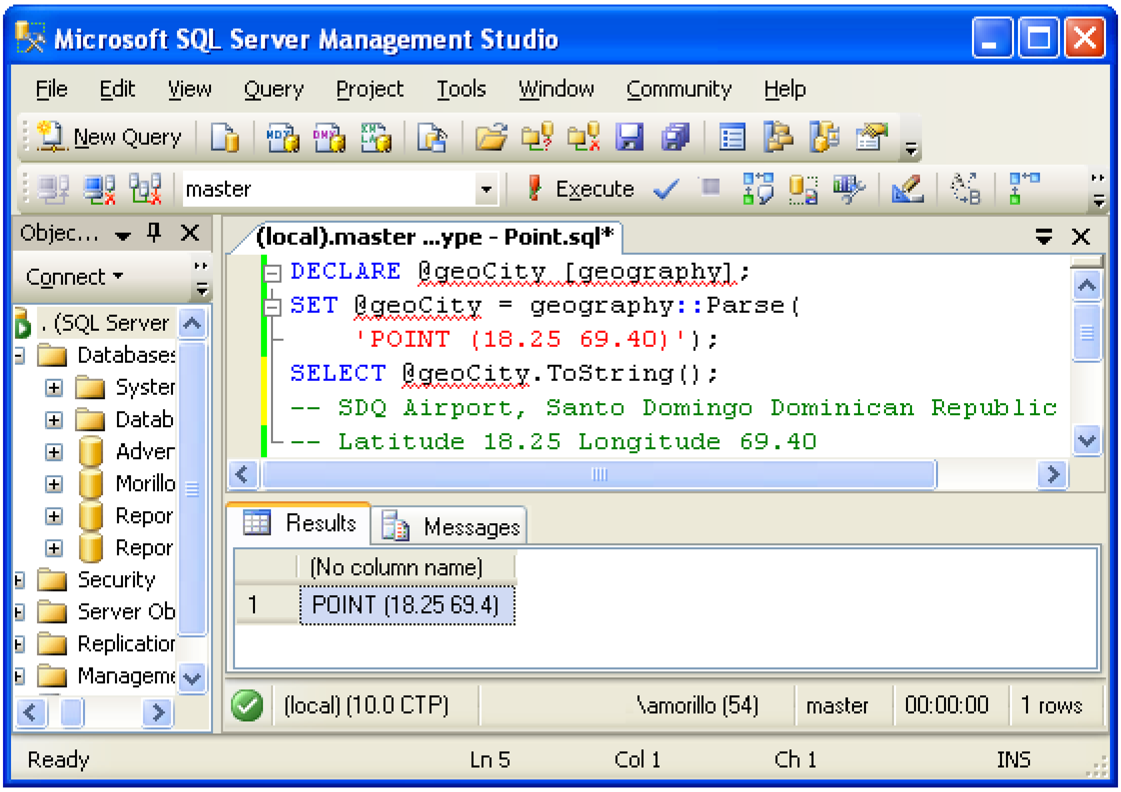


Fig. 4.6: SQL Server 2008 with support for spatial data (sqlcoffee.com, 2012)

The SqlSpatial Query Tool runs on Microsoft SQL Server 2008 and is used to run SQL queries and display the spatial results on a map. It supports both Geographic and Planar geometry types (Boston GIS, 2008). gvSIG can be used for capturing, storing, handling, analysing and deploying referenced geographic information. It can handle the common data formats, namely, vector and raster. Its other features include the ability to integrate in the same view both local and remote data through OGC standards. It is easily extendable, allowing continuous application enhancement, as well as enabling the development of tailor-made solutions. The GNU/GPL license, under which it falls allows its free use, distribution, study and improvement. It was developed using Java, and being available for Linux, Windows and Mac OS X platforms (OSGeo, 2011).

Openjump

Just like gvSIG, Openjump is a GIS that was developed using Java. It can display data retrieved from the World File Service, WFS and the World map Service, WMS web-services. It enables the editing of geometry and attribute data. However, OpenJUMP has limits in reading very large data files and has limited support for cartographic projections. QuantumGIS offers four applications with different capabilities. First there is QGIS Desktop which is a desktop application that offers functions for data viewing, editing, and analysis. Secondly there is QGIS Browser which is a data viewer for your local, network and online (WMS) data. Thirdly there is a WMS server in the form of QGIS Server. QGIS Client is a web front-end for web mapping needs based on OpenLayers and GeoExt.
uDig is an open source (LGPL) desktop application. It can be used as a stand-alone application or can be used as a plug-in in an existing RCP application.

Geocoding

Developing a geodatabase to contain the crime data is very important. The exact time and location information should be captured hence geocoding is vital. Geocoding is the task of converting locations, such as the addresses of burglary victims, into grid coordinates (Ratcliffe, 2004). Capturing the location information would enable the use of GIS software to come up with versatile electronic maps that use information from crime databases combined with digitised maps of the areas.

Through the analysis of collected data, crime hotspots can be identified and this would be used, for example, in deploying personnel for rapid response or in the establishment of police satellite stations.

This section shows that open source technologies are available that can store spatial information in databases. This helps in keeping the costs of the prototype low.

4.5 Data Dissemination and Visualisation

Police agents in developed countries have undergone organisational and technical changes in an attempt to improve the lines of communication and to smooth the flow of intelligence within the service. This has been necessitated by the need to have intelligence available for operational officers (Seddon and Napper, 1999).

A growing trend is for local area commanders to be shown maps of crime distribution in their area of command and for the individuals to be made responsible for the management of the identified pattern (Ratcliffe and McCullagh, 2001). Therefore a data dissemination method is necessary to ensure that different local area command centres receive up-to-date information round the clock. The ubiquitous internet provides a perfect platform to distribute these crime maps throughout the police force and also to members of the public. It enables all levels of society to not only access geo-spatial information but also provides a medium for processing geo-related information with no location restrictions. Moreover, disseminating spatial information on the internet improves the decision making processes since decision makers would have access to the data round the clock and from any location with internet access (Alesheikh et. al., 2002).

4.5.1 WebGIS

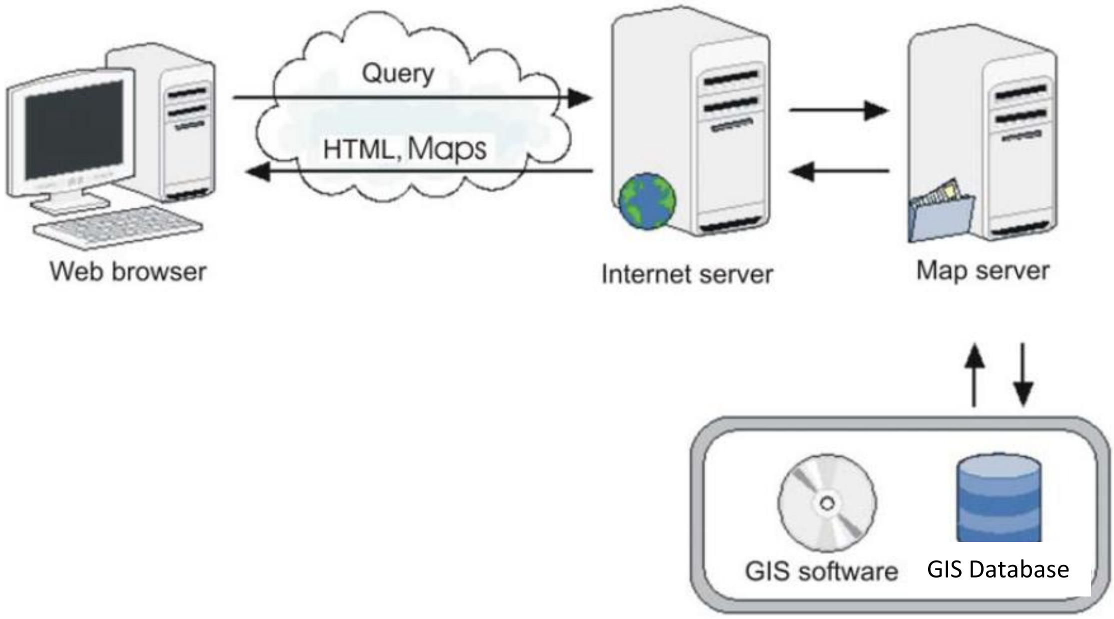


Figure 4.7: Traditional structure of Internet GIS (Adapted from Penev, 2012).

Not everyone has access to GIS applications, neither does everyone have the ability to spend the necessary time to use them efficiently. Web GIS therefore provides a cheap way to disseminate geospatial data and processing tools. Avraam defines web GIS as those Geographic Information Systems that use web technologies as a method of communication between the elements of a GIS (Avraam, 2009). The term web GIS is used interchangeably with internet GIS. Penev (2012) defines internet GIS as those systems and services which have the task of saving, analysing and visualising space related data. He equates internet GIS to ordinary GIS with the only difference being that access to ordinary GIS is not via the Internet.

The discussion of web GIS would not be complete without the mention of web mapping. Penev (2012) refers to web mapping and defines it at the creation, dissemination and use of maps via the internet. Web mapping is the designing, implementing, generating and delivering of maps on the World Wide Web and its product (http://www.ovguide.com). It is similar to web GIS with the exception that web GIS places emphasis on analysis, processing of project specific geodata and exploratory aspects. Ian Turton (2007), emphasises that when one talks about web mapping one means a map that you can interact with, zoom in and out, pan around and change what one is looking at.

Web GIS is not without its limitations. GIS uses graphics extensively and this impacts on the speed of both the visualisation and the processing. However, its elimination of the need for powerful computers, extensive training and expensive site licences makes it more preferable for site wide solutions over dedicated GIS programs. It also provides further incentives such as real-time maps, cheaper dissemination, more frequent and cheaper updates of data and software, personalized map content, distributed data sources and sharing of geographic information (Alesheikh et al., 2002).

The use of a web interface would reduce the training requirements needed for NamPol officers to utilise the tool. This would also reduce costs of proprietary GIS software licences.

4.5.2 Open Geospatial Consortium (OGC) Standards

The Open Geospatial Consortium was founded in 1994 in response to contained demand in the government and industry to address the issue of spatial data sharing and interoperability (Turton, 2007). As a result, the OGC has come up with 35 adopted standards (OGC, 2012). These international standards are essential for data sharing across organisations throughout the world. Cooperation amongst police forces from different countries, especially information sharing, is essential for Interpol operations. The most relevant standards to this project are outlined below.

4.5.2.1 WMS

The OpenGIS Web Map Service Interface Standard (WMS) provides maps in the form of images for display by a web client. This is possible since WMS provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The map is rendered on the server so the data provider determines how the map will be styled and presented. This map is sent to the client as a response to the request and is returned as JPEG, PNG, or any other format as defined by the data provider, which can be displayed in a browser application. The client has limited interactivity with the map, however the interface supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not (OGC, 2012).

4.5.2.2 WFS

Unlike the WMS which provides only the map as a picture, the Web Feature Service (WFS) provides map data to a web client. The client then decides whether to render the data for the user or to pass it through some local analysis before display. Therefore WFS affords the client much greater flexibility than the WMS as the client can choose the style and presentational details of how to display the data (Turton, 2007).

4.5.3 Mapserver

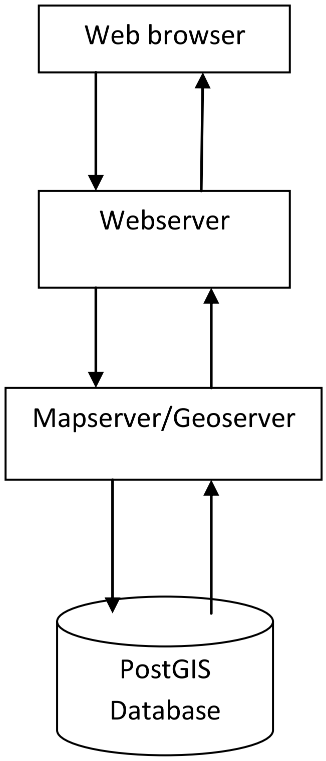


Fig. 4.8: Structure showing the Position of Mapserver and Geosever

Mapserver is an open source platform for publishing spatial data and interactive mapping applications on the web (http://mapserver.org). It can run as a CGI program or via Mapscript which supports several programming languages. It also supports popular OGC standards especially WMS and WFS (OSGeo, 2012).

Mapserver is required in order for spatial data to be displayed on web browsers as shown in fig. 4.8. It does not come with a configuration interface. Everything is done in text. It also doesn't have a built-in map interface.

4.5.4 Geoserver

An alternative to Mapserver is GeoServer is also an open source software server that allows users to share and edit geospatial data. Interoperability was also the main objective in designing Geoserver hence it publishes data from any major spatial data source using open standards. It is the reference implementation of OGC's WFS and WCS standards, as well as a high performance certified compliant WMS (http://geoserver.org).

Geoserver comes with a configuration interface which makes it easier to implement Geoserver. It also has a built-in map interface which makes it easier to visualise the spatial data in a web browser. This led to Geoserver being the preferred choice for this project.

4.5.5 OpenLayers

OpenLayers is viewed as a javascript library. Its primary use is for embedding spatial data in a web page. Since OpenLayers provides a rich javascript API, a great platform for displaying map tiles from a huge variety of sources and client-side overlays results from the use of OpenLayers. It has no server-side dependencies and it provides techniques for interactively editing vector data (DM Solutions, 2008).

When OpenLayers is compared to Google Maps and MSN Virtual Earth APIs, a lot of similarities are observed. One major and important difference is that it is Free Software, developed for and by the Open Source software community. OpenLayers' support for the OpenGIS Consortium's Web Mapping Service (WMS) and Web Feature Service (WFS) protocols makes it ideal for use in geographical data access over the web (DM Solutions, 2008). Openlayers provides flexibility in the presentation of the data. It also enables querying of the data hence its use in this project.

Since WMS offers limited interaction with the map, it shall be used only for those layers that just need to be displayed with no querying envisaged. WFS shall therefore be used for those layers where more analysis would need to be carried out before visualisation, since it provides more interaction with the map data. Mapserver does not come with a configuration interface while Geoserver does, so for easier configuration, Geoserver is preferred for this project over Mapserver.

4.6 Conclusion

It can be seen that despite crime mapping being an old concept in the developed world, it still has to be implemented in the developing world. This is emphasised by the lack of crime mapping examples in the developing world. Lessons and inspiration can be found in the existing systems, but the systems should be modified and re-designed for the Southern African context. It was found that PostgreSQL together with PostGIS provide the necessary storage facilities for crime and other GIS data and that Geoserver in conjunction with Openlayers provide a platform to develop interactive interfaces that can be used to display and interact with spatial data.

Chapter 5: Study of Existing Practices in NamPol

This study is based on available publications and interviews with key stakeholders in the police force as presented in Chapter 3 on page 8. The Namibia Police Force (NamPol) was established by act of parliament in 1990 (Scribd, 2012). In an endeavour to maintain law and order and to investigate and prevent crime, NamPol established the Criminal Investigations Directorate (Nakuta & Cloete, 2011).

Fig. 5.1: Namibian Police Logo (nampoltouristunit.com, 2012)

The Criminal Investigations Directorate's main focus is to conduct all investigations, and in particular criminal investigations. It comprises various sub-divisions, namely:

- The Commercial Crime Investigation Unit,
- The Drug Law Enforcement Unit,
- The International Police Unit,
- The National Central Bureau,
- The Motor Vehicle Theft Investigation Unit,
- The Namibian Police Criminal Records Centre,
- The Namibian Forensic Science Institute,
- The Protected Resources Unit,
- The Scenes of Crime Unit,
- The Serious Crime Investigation Unit,

- The Women and Child Protection Unit,
- The Crime Statistics Unit.

There are 92 police stations in Namibia and these are supported by sub-stations, satellite stations and border control posts (J. Kumangamanga, personal communication, October 31, 2012). These various divisions of NamPol are manned by a staff compliment of almost 15000 officers (O. Owoseb, personal communication, October 5, 2012).

5.1 Current Procedures within NamPol

If a crime is reported by phoning the nearest police station or the Police Communications Centre, officers will be dispatched to the scene by the authority who received the call. At the crime scene, the responding officer would seal off and control the movement of people at the scene before collecting statements from the victims and the witnesses. Additional police units can be called in depending on the nature of the crime, for example, if habit forming drugs are involved, the drugs squad would be called in. Notes written at crime scenes, photographs taken and any other collected information are kept in a docket. See fig. 1.1 on page 2 (S. Nuuyi, personal communication, February 3, 2012).

Each reported incident is recorded in a book known as the Occurrence Book. If the incident warrants investigation it is then recorded in the Crime Register and allocated a CR number e.g. CR 01/02/2012. This manual method of recording data is done at every police station. Each police station keeps its own Occurrence Book and crime register. There is also a book for recording deaths (Inquest Register) and a book for recording people under custody (Cell Register). Since the cell register is a book, situations have arisen where one officer is looking for a suspect who is actually in custody after being arrested for another crime. There is no central crime register (J. Kumangamanga, personal communication, October 31, 2012).

Each police station compiles its monthly statistics and records them on a form known as the Monthly Crime Return. This form is then faxed to the Crime Statistics Sub-Division by the 8th of each month. The Crime Statistics Sub-Division then compiles the statistics of the whole country with the help of a system known as Pol6. The monthly statistics for the country are then printed out and sent to the Inspector General, the Commissioner of CID and UNDP. These are mostly tables with figures, no crime maps are produced. Each crime is given a crime code for easier statistics compilation and reporting. For example Racial Discrimination is given the code 004 (J. Kumangamanga, personal communication, October 31, 2012). See Appendix H for part of a list of crime codes.

5.2 NamPol Geo-Policing Unit

The NamPol Geo-Policing Unit was initiated in 2010 with the aim of mapping crime, analysing it and identifying crime hotspots. With the commencement of the design of the e-Policing system in October 2011, Geo-policing is now under the umbrella of the e-Policing system. The implementation of the e-Policing system started in the Khomas region and will be rolled out to other regions in 2013, which marks the second year of the project. The border posts are now online. Namibia is the only country in Africa implementing this system (O. Owoseb, personal communication, October 5, 2012).

Police vehicles in the Khomas region have GPS devices mounted on them. These are used to collect the coordinates of the location of the crime. Having only mounted GPS devices impacts on the accuracy of crime scenes hence the use of portable devices would be more ideal. Smaller devices would be more suitable since officers may be required to chase suspects and to go to locations where cars cannot go. These coordinates are then recorded in the case docket on the e-Policing system. This then facilitates the automatic creation of maps showing crime locations. With the cooperation of the Ministry of lands and Resettlement, NamPol has in its possession, the Police station jurisdiction maps and the coordinates of the location of all police stations in the country (O. Owoseb, personal communication, October 5, 2012).

Currently, three directorates are earmarked for extensive use of the Geo-Policing component. These are the Crime Investigation Unit, the Organised Crime Division and the Internal Investigation Directorate. The Criminal Investigation Directorate will use the system for crime analysis, collecting statistics, investigations, crime scene visits and for statistical analysis. The Internal Investigation

Unit would use it at crime scenes involving police officers (O. Owoseb, personal communication, October 5, 2012).

5.3 Conclusion

This study has shown that most of the data acquisition, storage and dissemination is done manually in NamPol. This then provides a huge opportunity for improvement by incorporating the use of ICT's in all the three stages of data handling. Devices with voice recording capacity can be used to collect witness statements instead of notebooks. Instead of using the various books like the Crime Register, information can be directly recorded onto a central register which would be accessible from each police station. Information sharing would be improved as this would eliminate the need to fax Monthly Crime Returns to the Crime Statistics Sub-Division. Statistics would be compiled directly from the central register.

Reporting would be able to incorporate crime mapping leading to more informative reports which are faster to comprehend as compared to tables full of figures. The existing efforts in moving towards ePolicing show that new approaches are welcome in the organisation, which is positive for the system proposed in this thesis.

Chapter 6: GIS Information in Namibia

Information about a particular place can be made available to officers through GIS. This is spatial data which is available from various sources in Namibia and can be visualised using fully-fledged GIS applications or web based tools. If visualised together with crime data, many patterns would emerge which would help in the fight against crime. This information can be used in crime prediction.

Various spatial datasets are available in Namibia and the table below shows a list of identified datasets that can be integrated with crime data to enhance the operations of law enforcement agents. Telephonic requests were made for the data to the various organisations and the data was subsequently made available to the research on external hard disks.

GIS Data	**Source**
Household Income	National Household Income Survey
Zoning	City Town Planning Maps
Population Demographics	National Population Census
Street Maps	City Street Maps
Schools	City Street Maps
Home Ownership	City Valuation Roll
Street Lighting	City Street Maps
Sheebens	City Town Planning Map
Boundaries of Police Districts	Police District Maps
Public Open Spaces	City Town Planning Maps
Location of ATM's	Banks
Digital Terrain Models	Available for download from the internet

Table 6.1: GIS data and its Sources in Namibia (Jensen et al, 2012)

This spatial data listed in Table 6.1 above is also referred to as geospatial data which is positional data collected about geographical phenomena. Once a location component has been assigned to crime data officers will be able to overlay this crime data with base maps and other geographic data of the area where the crime data is associated (Chainey & Ratcliffe, 2005).

Of utmost importance amongst the geographical data would be the population demographics of the area. Kirch defines demographics as "population characteristics including race, gender, age, disabilities, mobility, home ownership, employment status, etc" (Kirch, 2008).

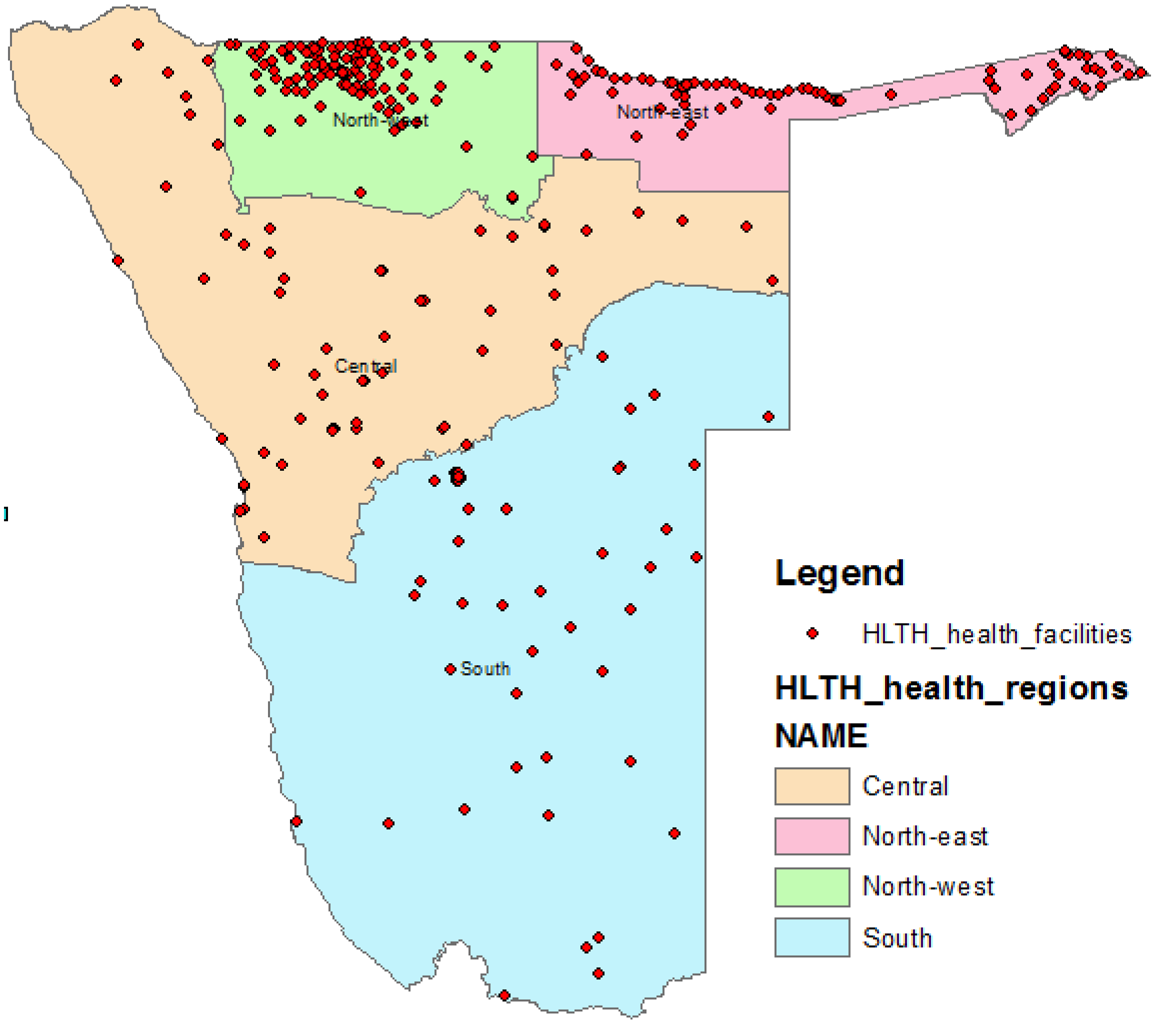


Fig. 6.1: Namibia's four Health Regions overlaid with Locations of Health Facilities (from overlaying the health facilities with the health regions layer).

"Using GIS, crime analysts can overlay other datasets such as census demographics, locations such as pawn shops, schools and industrial complexes to better understand the underlying causes of crime and help law enforcement administrators to devise strategies to deal with the problem. An example of an overlay is shown in Fig. 6.1. GIS is also useful for law enforcement operations, such as allocating police officers and dispatching to emergencies" (Rogers Park, 2007).

As part of the paper we published for SAICSIT 2012, the role of GIS data in the prototype was discussed. Some of the main points highlighted include the fact that Digital Terrain Models could be used in analysing the location of the crime in 3-D. Possible witness positions could be tested in order to be sure that the timing of events and lines of sight are consistent.

GIS data can also be used in geographic profiling. Geographic profiling is a criminal investigative methodology that relates the locations of a linked series of offenses to determine the most probable area an offender resides in. Coupled with both qualitative and quantitative methods, geographic profiling assists in understanding spatial behaviour of an offender and in focusing the investigation to a smaller area of the community. It also helps investigators to prioritize information in large-scale major crime investigations that often involve hundreds or thousands of suspects and tips.

Several fields of study focus on the relationship between crime and the location. This study borrows concepts from environmental criminology which focuses on criminal patterns within particular built environments and analyses the impacts of these external variables on people's cognitive behaviour.

6.1 Conclusion

Since various spatial data layers can be overlaid in coming up with a final map, using the technology outlined in chapter 4, this answers research question number two about integrating crime data with other spatial data. Since various datasets are available for use in creating maps, this could help in understanding why certain crimes are common in certain areas leading to the implementation of appropriate intervention programs. Importantly, a lot of GIS data was found to be both existent and available in Namibia, which can be integrated in the prototype system.

Chapter 7: System Implementation

7.1 System Requirements

Clearly defined system requirements help the developer to come up with a set of required goals against which they can measure the extent to which the developed system satisfies its objectives. Following the literature review, the Namibian GIS study and the study of existing procedures in NamPol, a list of system requirements was drawn up under three categories. These are storage, visualisation and interaction.

The requirements are:

- The system should be able to store spatial data in order to store the crime location information.
- The system should be able to display several layers of spatial data at a time in order to integrate other GIS data and crime data in the maps.
- The system should allow users to turn layers on and off as well as display only data that meets a given criteria in order to allow the querying of the data by the users.

Storage

Storage requirements can be met by the development of a geodatabase containing the crime data and other relevant spatial information that can be used in crime analysis answering research question number 3.

Visualisation

To meet the visualisation requirements for displaying the data stored, an interface has to be developed that allows the overlaying of various layers of geospatial data. This also answers research question number 3.

Interaction

In order for users to be able to add and remove layers to the display while also being able to select specific crime data, layer switching components and simple querying tools should be added to the interface. This answers research question number 4.

7.2 Methodology

This section will give an overview of the developed system. The utilised software development practices will be discussed and key implementations decisions taken will be identified and detailed as well.

Firstly a design phase of the project was conducted and its aims were to translate the user requirements into:

- A Geo-Database design consisting of database development, data manipulation and data storage and retrieval
- An Interface Design for the prototype, including the scope of the functions of the application.

This translation of user requirements into a fully functional system has been done according to established system development methodologies. The two methodologies, upon which the adopted hybrid method was based, are discussed in Appendix I. As this research is part of a large research effort with other developers and researchers involved, it was necessary to pay more attention to the development methods that support prototype development. The researcher will interact with other stakeholders in the larger project where the crime mapping will be integrated. See Appendix J for the paper published at the SAICSIT conference 2012.

7.2.1 Hybrid Model

The analysis of the methodologies in Appendix I shows that no single method is suitable for a particular project hence for this research a combination of features from the two methods was used. This was done in order to deliver the system in the shortest possible time. The aim of the hybrid model was to be able to deliver basic functionality quickly first then follow up with more functionality at regular intervals. The method used had to facilitate the incorporation of feedback from the users, that the system being developed is on the right track to fulfilling their requirements. Mostly the users were the police officers, but sometimes other researchers had their own requirements.

The stages included User requirement and System Specification, Design and Build iteration and Implementation.

7.2.2 Database Design

A properly designed database will provide access to up-to-date and accurate crime and other spatial information. It will enable the law enforcement agents to achieve their goals by meeting organisation needs while accommodating change. Designing a database involves three major steps, namely, conceptual design, logical schema design and physical database design. Conceptual design begins with the collection of requirements and results needed from the database (ER Diag.) while in logical schema design, a description of the structure of the database (Relational, Network, etc.) is produced. In physical schema design, a description of the implementation (programs, tables, dictionaries, catalogs is produced (Cleveland State University, 2012).

In this project a special type of database was required in order to accommodate spatial data, therefore, the three steps described above were incorporated into the major steps for creating a geo-database. Arctur and Zieler, 2004, propose a ten step approach to the design of a geodatabase. The first three steps lead to the identification and characterisation of each of the required thematic layers. Steps 4 to 7 look at the development of the representation specifications, relationships and geodatabase elements together with their properties. The last three steps then lead to the definition of data capture procedures, assignment of data collection responsibilities, testing and refinement of the design together with documentation.

For this research these steps were appropriated to the crime database and the GIS information as follows:

Step 1: identify the information products that will be produced with GIS

The database design was started with the end in mind. The sample final map products to be produced by the prototype were listed including the analytical models, the required reports, Web access, data flows and operational requirements. These were used in determining the data needs of the design.

Step 2: Identify the key thematic layers based on information requirements

A list of feature classes, tables, relationships, raster datasets and domains that would be needed was compiled. These would be used to produce the required map products leading to the effective analysis of the relationship between location and crime as well as to satisfy any other application and information requirements. For each theme, the visual representation (point, line, polygon and raster), the expected uses in GIS, the likely data sources, and the resolution were noted. Once these were noted, the specifications for their representation in the database were then developed (ESRI, 2012).

Use of a Computer Aided Software Engineering (CASE) design tool, Microsoft Visio was made for the documentation of the design.

Step 3: Specify the scale ranges and spatial representations for each thematic layer

Since feature representation changes between points, lines and polygons at larger scales, the scale at which the each layer was compiled is recorded as well as the limits to which the data can be zoomed in order to satisfy the modelling, query and or map product applications.

For example, the resolution of the aerial photo of Windhoek was noted together with the scale at which the Townships boundary layer was complied. This is done in order to avoid a scenario where boundary lines become blurry when a user zooms in on the aerial photo.

Step 4: Group representations into datasets

A feature dataset is a group of feature classes clustered together based on their sharing of the same spatial reference, relationship classes, geometric networks and geodatabase topologies. The relationships identified among the feature classes in a dataset help in generating information needed by problem stakeholders (Arctur & Zieler, 2004). Dataset are used to group feature classes that are edited simultaneously and are also used to group feature classes according to themes, for example, the theme Police Areas would have the location of police stations (points), the area covered by each police district (polygons) and the road network for that area (lines).

Step 5: Define the tabular database structure and behaviour for descriptive attributes

For each feature class, attribute fields are identified. The valid values and their ranges are also specified. Relationships between the different feature classes are created for referential integrity persistence, improving query and edit performance and also to optimise joins used in labelling and symbolisation.

Subtypes are applied to relevant feature classes to add selected behaviour to subsets of features in a feature classes. The crime feature class can have offences against the public peace and order, offences against the public health and morals, offences against the person and offences against property. Subtypes help to reduce the number of feature classes and improve performance. The use of subtypes results in a coarse-grained model, good for database performance, with finely discriminated object behaviour.

Step 6: Define the spatial properties of your datasets

For those connected features like roads, networks are composed. These help enforce referential integrity. Spatial relationships are ensured through the use of topology rules. The topology rules can be used to enforce spatial relationships such as how police districts nest into cities. Topology rules help to maintain the topological integrity of the data.

Step 7: Propose a geodatabase design

The set of geodatabase elements needed in the design are defined. These include how the features will be rendered and symbolised on maps, a specification of attributes that will be used to describe each feature and a specification on maintaining spatial relationships. This is done for each data theme.

Fig 7.1 below shows the specifications for the table Allcrimes.

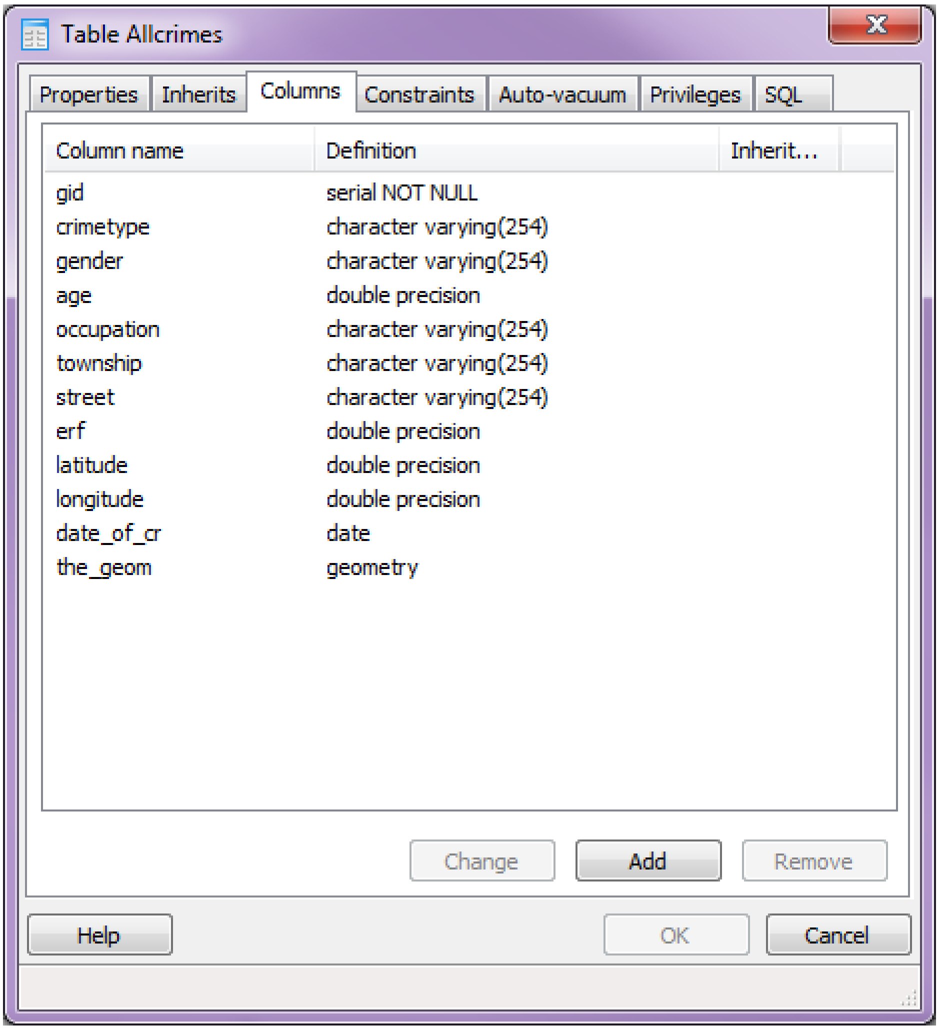


Fig. 7.1: Properties of the Allcrimes table (screenshot from prototype).

Step 8: Implement prototypes, review and refine your design

The prototype design was tested. This included building a sample geodatabase from the proposed design. Maps were then built, visualised, and editing operations performed to test the design's utility. The design was then revised based on the prototype test results to refine the design.

Step 9: Design workflows for building and maintaining each layer

Editing procedures and integrity rules (for example, all streets are split where they intersect other streets and street segments connect at endpoints) were defined. Display properties for maps were defined.

Step 10: Document your design using appropriate method.

Visio was then used to create a graphic representation of the geodatabase schema (Arctur & Zieler, 2004).

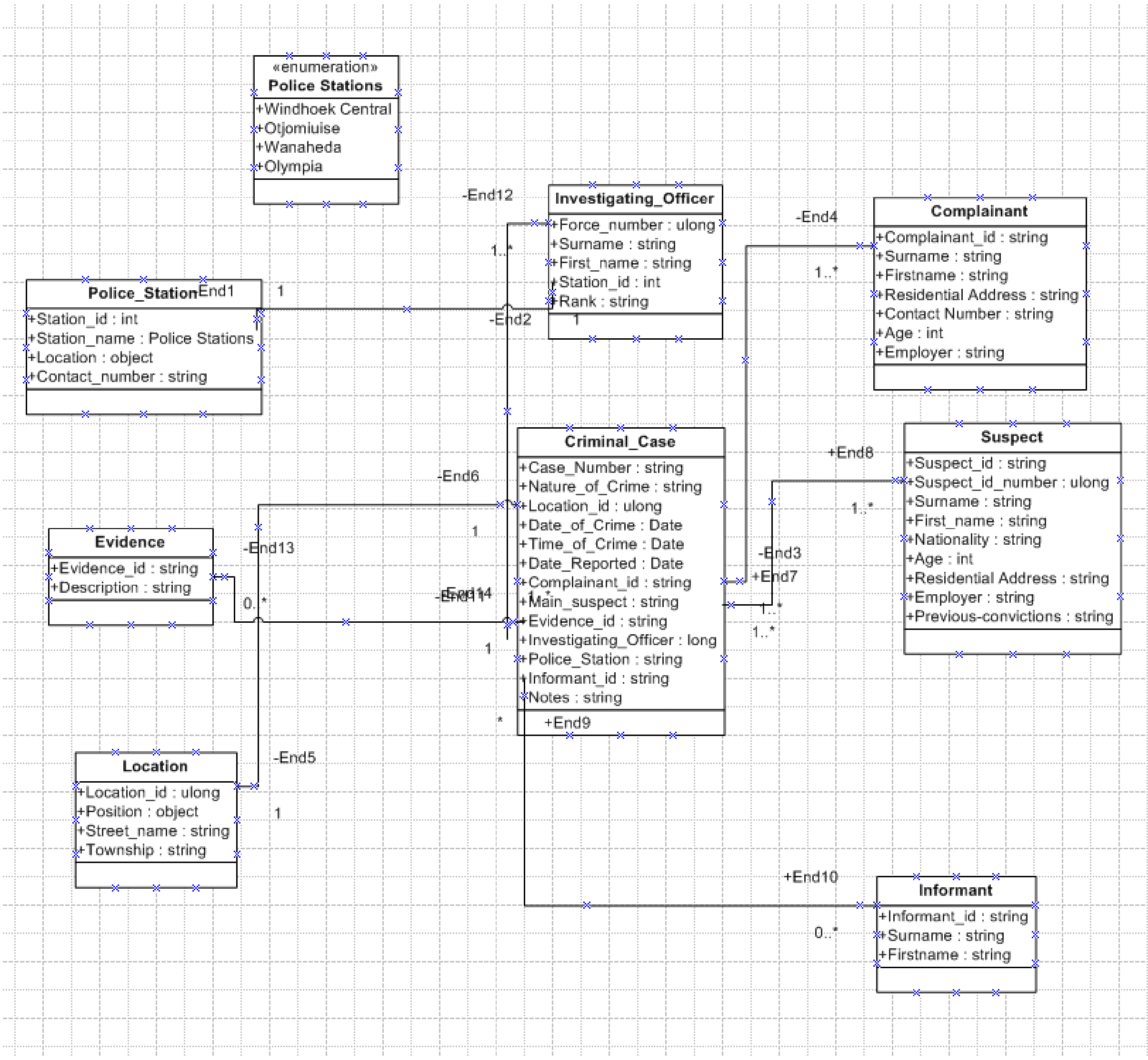


Fig. 7.2: Schema developed using Microsoft Visio

7.2.3 User Interface Design

Stone, Jarrett, Woodroffe and Minocha define a user interface as "that part of the computer system with which a user interacts in order to undertake his or her tasks and achieve his or her goals". They advocate for interfaces that provide an easy, natural and engaging interaction between a user and a system. Such interfaces can be achieved through good user interface design. "Depending on the design of the interface, a system will either be usable, i.e. easy to learn and easy to use, or problematic for users" (Stone, Jarrett, Woodroffe and Minocha, 2005).

User-centred design is one common approach to user interface design and development. It involves user participation throughout the design and development process. In this method it is important to understand the users of the system under development. Furthermore, an understanding of the tasks those users will perform with the system and the environment in which they will operate is very crucial (nextlab.mit.edu).

ISO, 1997 lists the four main principles of human centred design as:
"1. The active involvement of users
2. An appropriate allocation of function between user and system
3. The iteration of design solutions
4. Multidisciplinary design teams"

In this research, active user involvement was attempted and efforts were directed towards carrying out the four essential human centred design activities which ISO, 2007, lists as:
"1. Understand and specify the context of use.
2. Specify the user and organisational requirements.
3. Produce design solutions (prototypes)
4. Evaluate designs with users against requirements."

In as much as the four activities were not carried out to the book, there was extensive evaluation of the prototype with members of the police force.

Rubin and Chisnell (2008) detail a list of qualities that a good system should possess to be usable. These include:

Usefulness deals with how a system enables a user to achieve his or her goals. Can officers create crime maps with the system?

Efficiency deals with how fast a user's goal can be accomplished accurately and completely. How fast can an officer come up with a map showing all the information he/she requires?

Effectiveness to what extent does the system behave in the way that officers expect it to?

Learnability can the officers operate the system to some defined level of competence after being given a certain amount of training?

"S***atisfaction*** refers to the user's perceptions, feelings, and opinions of the product, usually captured through both written and oral questioning" (Rubin and Chisnell, 2008)

A user-centred approach of user interface design was used in this project. This entailed allowing users to explore the functionality of the prototype of the crime mapping tool which was created, apart from its use being demonstrated, tried out and discussed with the officers. The recommendations from the officers are to be incorporated into the next iteration of the system.

7.2.4 Creation of the System Prototype

In this phase, the system prototype was developed, the design of the database and user interface were implemented. The database was created using POSTGRESQL and POSTGIS. This was done on a Windows platform due to the researcher's familiarity with the Windows operating system but it can be done on any other common platform like Linux or OS. So this prototype is implemented using platform independent technologies which are outlined in the literature review.

7.2.5 Conclusion of Methodology

The purpose of this research is to develop a crime mapping tool which NamPol can use to show and analyse crime. The locations where crime occurred in Windhoek are pointed out on a map and this crime data can be integrated with other geographical data to better understand why crime occurs at a particular place.

The population of the research was Windhoek and test crime data was generated for test purposes. A hybrid software development method was selected and used in the design and implementation of the system.

7.3 Implementation

This section discusses the system architecture consisting of the geo-database, the connection between POSTGRESQL and POSTGIS and visualisation using Geoserver and OpenLayers as shown in Fig. 7.3 below. The system implementation stage involved phases where the system was installed, programmed, tested and modified to ensure that it satisfies the user requirements.

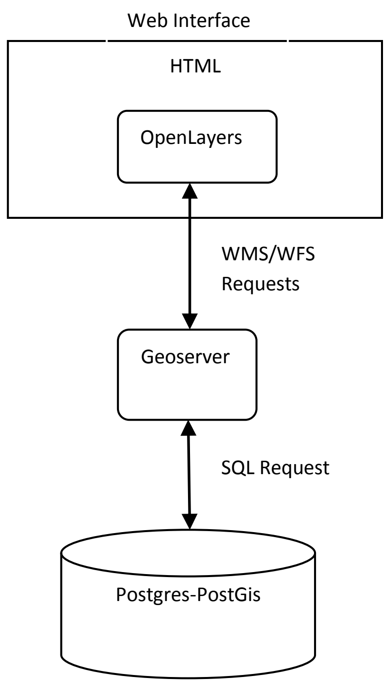


Fig. 7.3: Proposed System Architecture (Own Source)

7.3.1 The Geodatabase

Following the findings of the literature review pertaining to data storage, in order to store spatial data, PostgreSQL was implemented together with PostGIS.

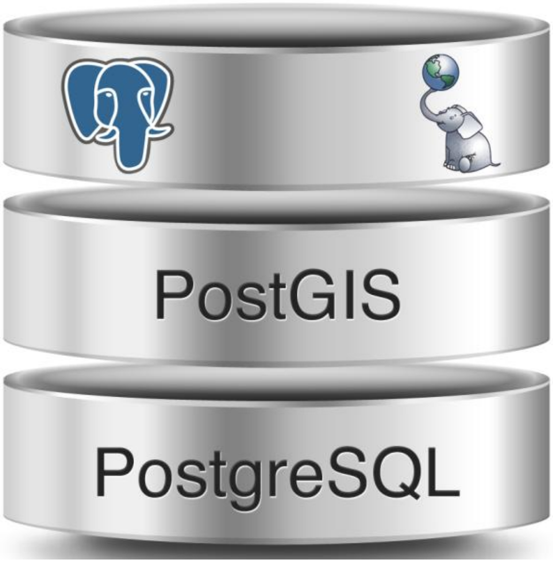


Fig. 7.4: PostGIS and PostgreSQL (pgday.postgresql.org.tr, 2012)

OpenGeo (2012) lists some of the features that a PostGIS database offers as:

- Support for big GIS objects – this would enable the storage of large datasets.
- Authentication services – in order to be able to update the database, the user must supply a username and password.

The browser sends a URL request that is translated into the appropriate PL/SQL call by GeoServer. The results that are relayed back to the browser as HTML after the database processes the PL/SQL are then formatted to be displayed as maps by OpenLayers, which is an opensource javascript library that loads, displays and renders maps from multiple sources onto web pages (Openlayer.org, 2012).

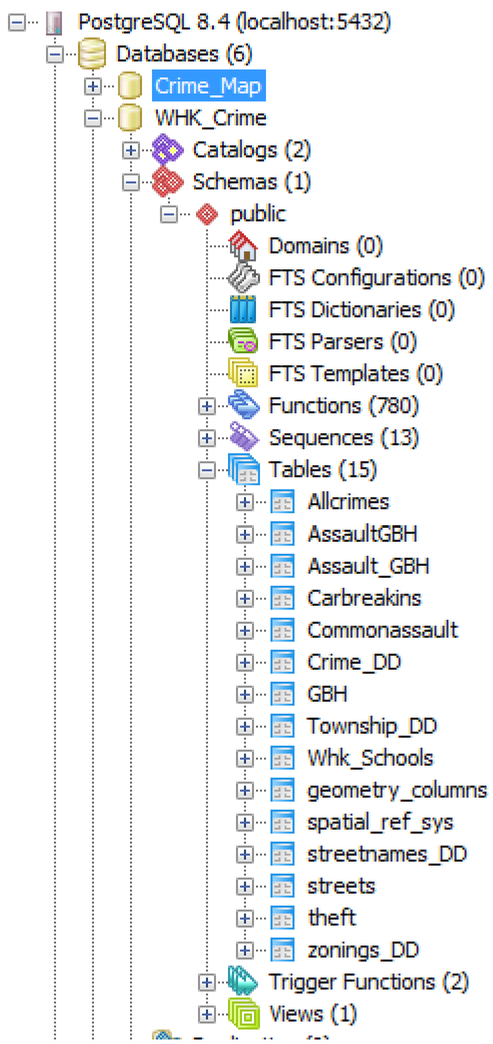


Fig. 7.5: Database Structure (screenshot from the prototype)

The database created was named *WHK_Crime* as shown in Fig. 8.3 above.

7.3.2 Crime Table and the Importing of Shape files

A table was created in WHK_Crimes and was named Allcrimes. This table contains crime information on incidents randomly generated for Windhoek based on crime types identified through interviews. Due to the sensitivity of crime information, real crime data could not be used hence the use of the randomly generated data. The incidents were given random dates starting from January 1, 2007 to October 20, 2012.

Edit Data - PostgreSQL 8.4 (localhost:5432) - WHK_Crime - Allcrimes

File Edit View Tools Help

No limit

	gid [PK] integer	crimetype character vai	gender character vai	age double precis	occupation character vai	township character vai	street character vai	erf double precis	latitude double precis	longitude double precis	date_of_cr date	the_geom geometry
9	9	Theft	male	52		Otjomuise	Nagashi	3952	-22.551774	17.024024	2010-07-28	0101000020E61
10	10	Theft	male	42		Otjomuise	Sandiego	3980	-22.551963	17.025548	2010-02-12	0101000020E61
11	11	theft out of mot	male	27		Otjomuise	Wesbarden	3983	-22.552085	17.025659	2009-12-21	0101000020E61
12	12	Theft	male	36		Otjomuise	SALZBURG	3873	-22.54657	17.02616	1997-01-31	0101000020E61
13	13	Theft	male	28		Otjomuise	Wesback	3865	-22.547656	17.0263	2007-05-31	0101000020E61
14	14	Theft	male	27		Otjomuise	Sadlago	1467	-22.551289	17.02645	2011-04-01	0101000020E61
15	15	House Breaking	male	32		Otjomuise	santa clara	1606	-22.55331	17.02668	2000-11-06	0101000020E61
16	16	Theft	female	27		Otjomuise	Wiebadnen	3887	-22.546678	17.026803	2010-03-26	0101000020E61
17	17	Assault GBH	FEMALE	31		Otjomuise	arusha street	3909	-22.54711	17.0269	2012-03-17	0101000020E61
18	18	Theft	male	24		Otjomuise	Westbarde	3901	-22.547439	17.027073	2000-03-05	0101000020E61
19	19	Theft	female	22		Otjomuise	Ansha	3915	-22.546736	17.027374	2010-09-21	0101000020E61
20	20	Theft	male	41		Otjomuise	Wiebadnen	3855	-22.547669	17.027458	2009-12-08	0101000020E61
21	21	House Breaking	female	26		Otjomuise	Linz	3044	-22.551302	17.027476	2010-09-24	0101000020E61
22	22	Assault Commor	male	33		Otjomuise	Kitchener	1998	-22.555142	17.027711	2010-07-02	0101000020E61
23	23	Theft	female	59		Otjomuise	Balzburg	2171	-22.54849	17.02793	1999-02-27	0101000020E61
24	24	Assault GBH	male	45		Otjomuise	Casssamba	3000	-22.550022	17.027986	2007-01-08	0101000020E61
25	25	Theft	female	37		Otjomuise	Osaka	3054	-22.551969	17.02803	2010-12-19	0101000020E61
26	26	theft	male	54		Otjomuise	Santa clra	1934	-22.554085	17.02833	2007-07-04	0101000020E61
27	27	theft	male	25		Otjomuise	Salburg	2956	-22.548634	17.028334	1998-11-11	0101000020E61
28	28	Assault Commor	female	51		Otjomuise	Amstendum	31	-22.546362	17.028432	2009-11-22	0101000020E61
29	29	Assault Commor	female	36		Otjomuise	Istanbul	33	-22.546546	17.028433	2010-04-10	0101000020E61
30	30	Assault Commor	male	55		Otjomuise	delhi square	0	-22.54767	17.02869	2008-12-22	0101000020E61
31	31	House Breaking	male	20		Otjomuise	Beijing	157	-22.549182	17.029059	2010-11-08	0101000020E61
32	32	theft out of mot	male	48		Otjomuise	Erdan	10	-22.546851	17.029142	2011-07-24	0101000020E61
33	33	House Breaking	male	31		Otjomuise	Delhi square	0	-22.54872	17.02915	2011-04-21	0101000020E61
34	34	Assault Commor	female	29		Otjomuise	Attawa	395	-22.549867	17.029214	2010-11-12	0101000020E61
35	35	Theft	male	54		Otjomuise	Amadams	19	-22.545764	17.029239	2011-02-02	0101000020E61
36	36	Theft	male	37		Otjomuise	Ottana	397	-22.549741	17.029364	2012-05-09	0101000020E61
37	37	Theft	female	35		Otjomuise	Delhi square	0	-22.54846	17.0295	2008-08-09	0101000020E61
38	38	House Breaking	male	31		Otjomuise	Delhi square	0	-22.54833	17.02957	2011-05-23	0101000020E61
39	39	Theft	female	36		Otjomuise	ottawa	440	-22.55026	17.02962	1998-05-07	0101000020E61
40	40	Theft	female	23		Wanaheda	Hwang Ho	1554	-22.521139	17.029675	2009-04-22	0101000020E61
41	41	House Breaking	male	18		Wanaheda	Tabeal	1588	-22.521893	17.02977	2011-11-15	0101000020E61
42	42	House Breaking	Male	47		Wanaheda	Tugela	1715	-22.516729	17.029801	2010-10-14	0101000020E61

Table 7.1: The Allcrimes table (screenshot from the prototype)

In table 7.1 above, the geographic coordinates of the crime location are given as latitude and longitude. This is based on the WGS84 coordinate system as explained in the literature review in section 4.4.1.

The column named the_geom is the geometry column to store the crime locations. It tells PostGIS what kind of geometry each feature has (points for crime locations). Other features could be lines or polygons. EPSG: 4326 is the code used to specify that the coordinates used are WGS84. The statement shown below is used to add the column to the table.

```
SELECT AddGeometryColumn ( 'Allcrimes', 'the_geom', 4326, 'POINT', 2);
```

To add a crime incident to the table *Allcrimes* a statement like the one shown below was used.

```
INSERT INTO Allcrimes (id, crime_type, gender, age, occupation, township, street,
erf, date-of_crime, the_geom VALUES (1995, burglary, male, 24, unemployed,
'Katutura', 'Munamava', 2345, ST_GeomFromText('POINT(-22.5257 17.0208)',4326));
```

The other geographic information such as schools and townships were available either as shapefiles or in CAD format especially the datasets from the City of Windhoek. The datasets available in CAD format such as the zonings were first converted to shape files in preparation for importing into the database.

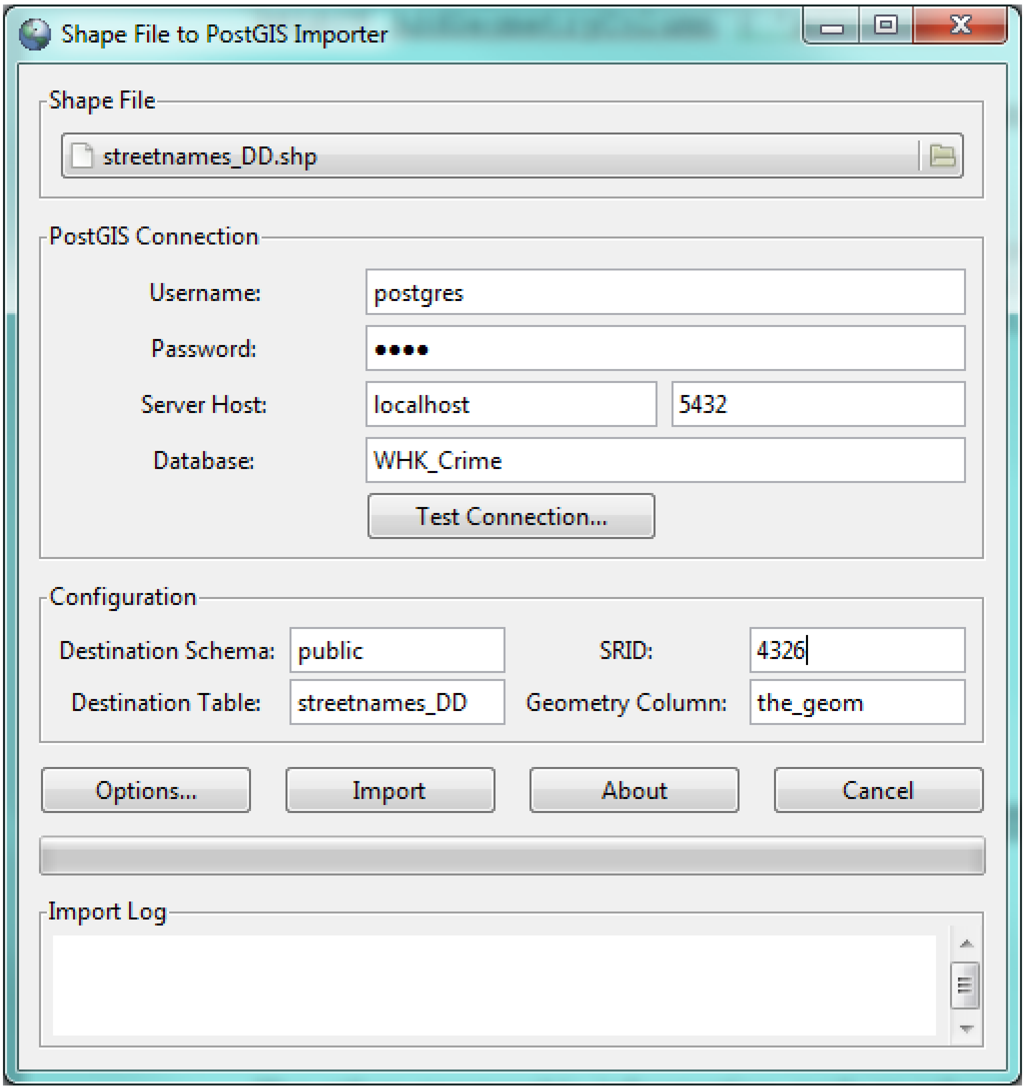


Fig.7.6: PostGIS Shapefile and DBF Loader (screenshot from the prototype)

Shapefiles can be imported directly into the geodatabase by using the PostGIS Shapefile and DBF Loader as shown in Fig7.6 above. This plugin was used to import all the shapefiles into the database. These shapefiles were sourced from various organisations as discussed in Chapter 6.

Shapefiles imported included:

- Townships

- Schools
- Streets
- Street names
- Zonings

7.3.3 Geoserver

Geoserver, enables the publishing of the geospatial data contained in the geodatabase.

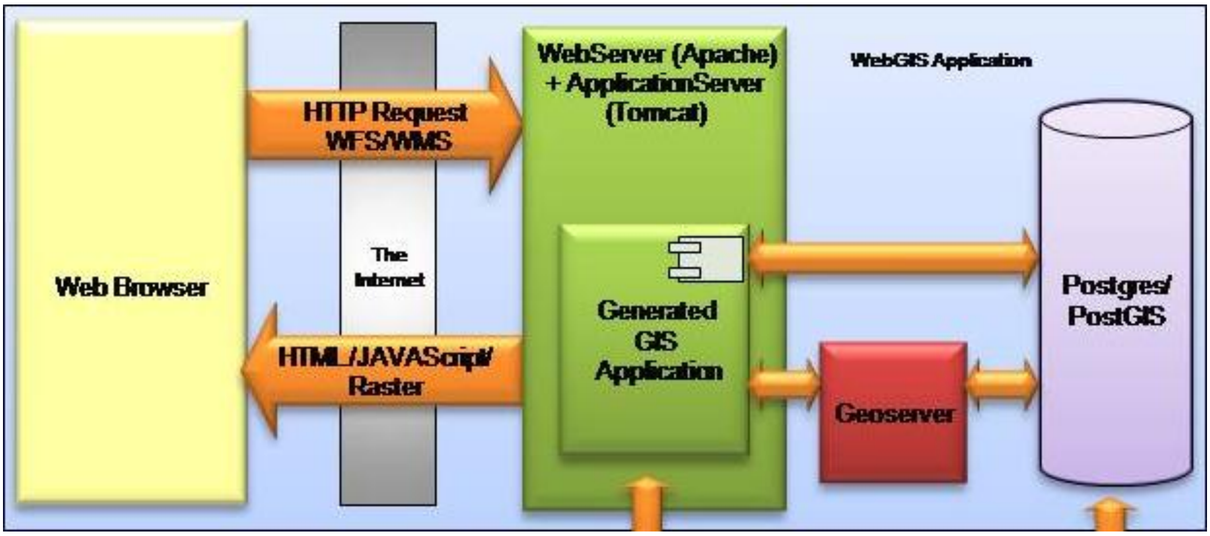


Fig. 7.7 WebGIS System Architecture (Adapted from Di Martino, 2007)

The figure above shows how requests from the web browser go via the webserver then through Geoserver to the PostGIS database. With that in mind, with the prototype developed, Apache Tomcat was first installed and the Geoserver was deployed via Tomcat.

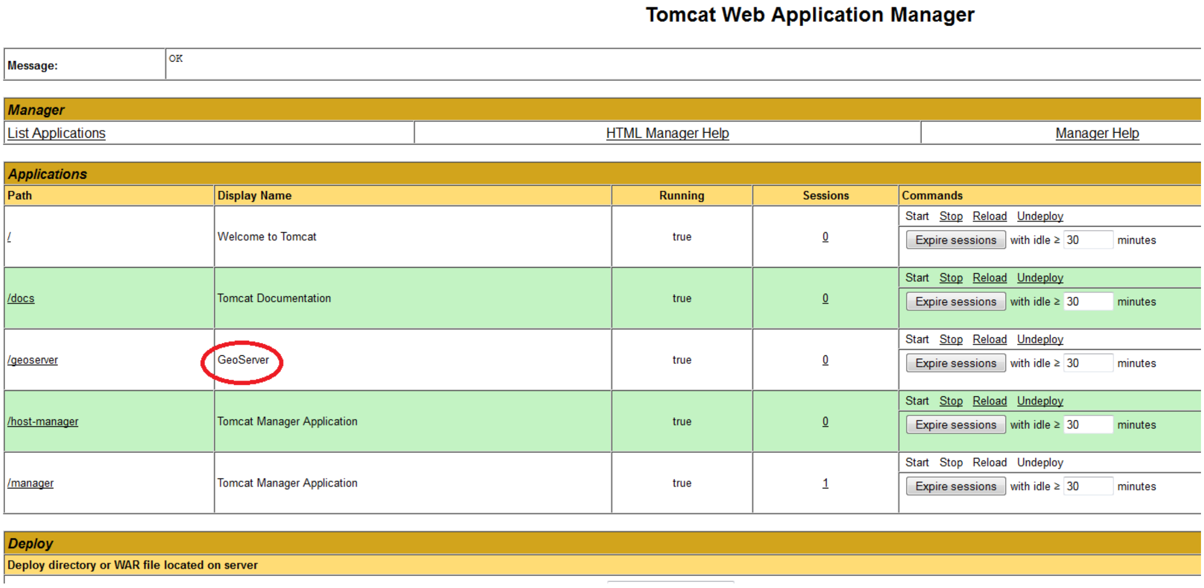


Fig. 7.8: Geoserver Deployed via Apache Tomcat

The next step was then to establish a connection between Geoserver and the WHK_Crime geodatabase created in PostGIS.

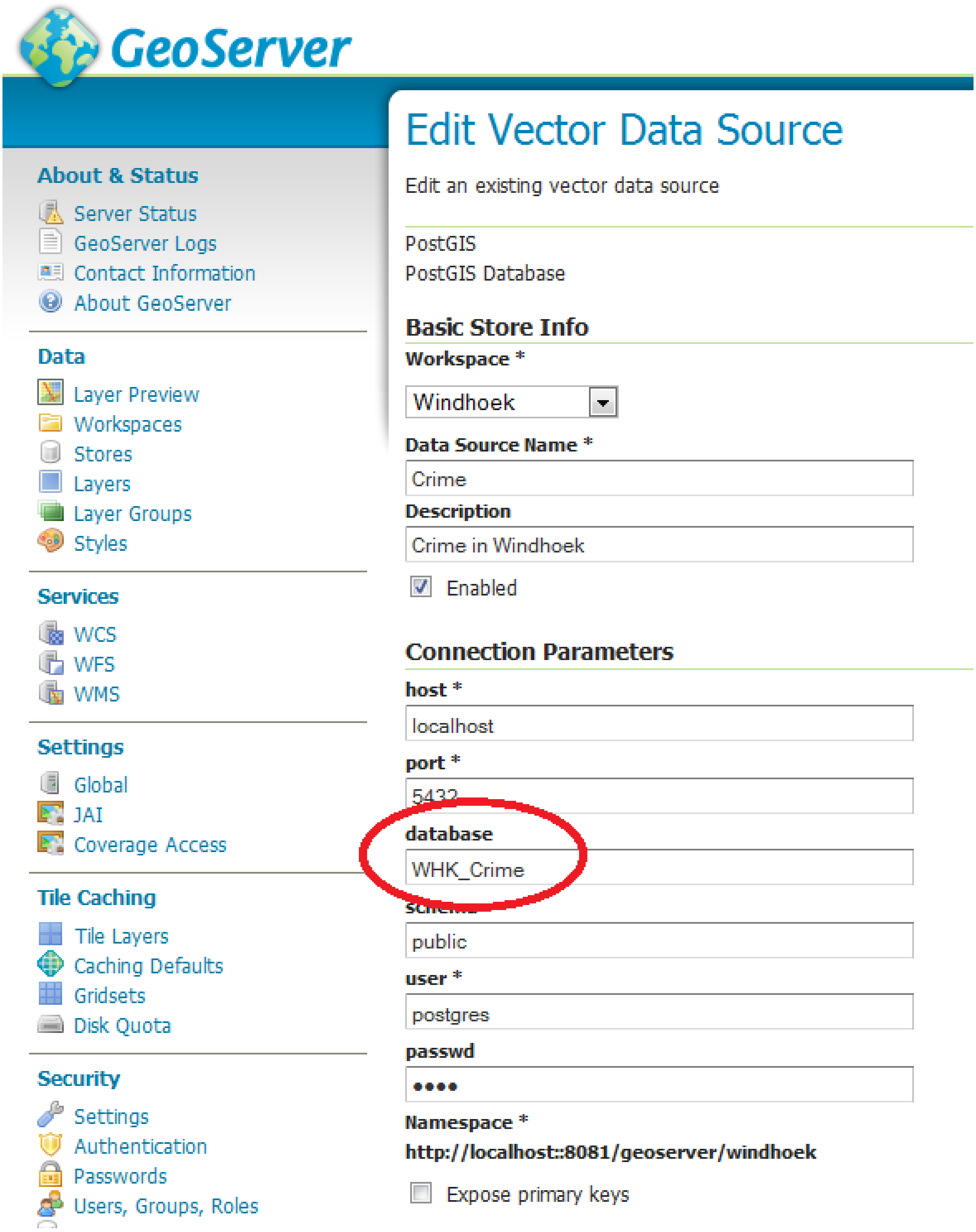


Fig. 7.9: Connecting Geoserver to Geodatabase (screenshot from the prototype)

The data contained in the geodatabase can be visualised using Geoserver's layer preview. Multiple layers can also be viewed after creating a layer group which would be consisting of the individual layers that one needs to visualise. For example, in Fig 7.10 below, shows incidents of car break-ins overlaid on the aerial photo of Windhoek.

Fig. 7.10: Car Break-ins in Katutura (screenshot from the prototype)

By editing the styles of the individual layers, icons depicting certain crimes were used to show the location of that particular crime. In the example shown in fig. 7.11 below, a fist is used to show the occurrence of assault.

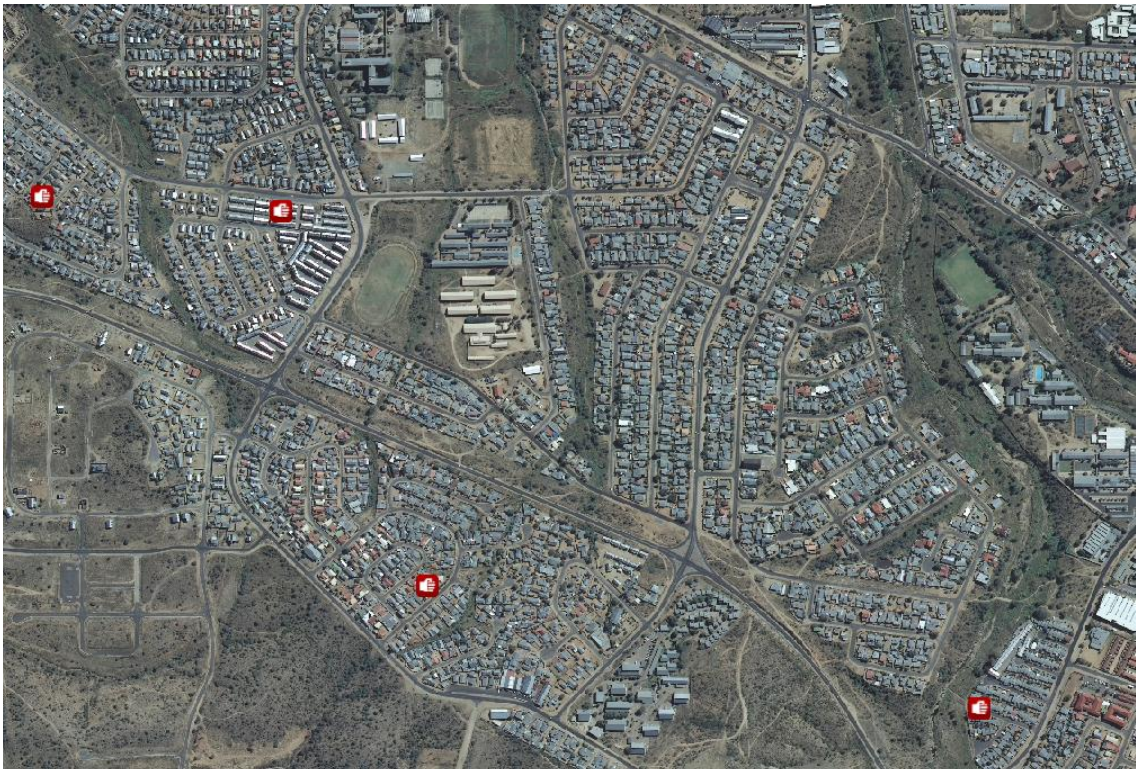


Fig. 7.11: Cases of Assault (screenshot from the prototype)

If more information is required about a particular incident, clicking on it would bring a table below the map with the information about that particular incident from the Allcrimes table as shown below in table 7.2.

Carbreakins

fid	crimetype	gender	age	occupation	township	street	erf	latitude	longitude	date_of_cr
Carbreakins.59	theft out of motor	Male	52.0		Katutura	Max Eixab street	624.0	-22.52592	17.06502	10/28/06 12:00 AM

Table 7.2: Further Information on a particular Crime Incident (Own Source)

7.3.4 OpenLayers

From the features of OpenLayers discussed in the literature review, section 4.11, OpenLayers was preferred since its makes it easy to put a dynamic map in any web page. The web pages can then be formatted to the developer's specifications. "OpenLayers is a pure JavaScript library for displaying map data in most modern web browsers, with no server-side dependencies. It implements a JavaScript API for building rich web-based geographic applications." (openlayers.org, 2012)

Several html files were developed to harness the power of OpenLayers. See Appendix G for code. Below, Fig. 7.12, is an output using OpenLayers, showing the layer selector on the top right hand corner and the zoom and panning tool on the top left hand corner.

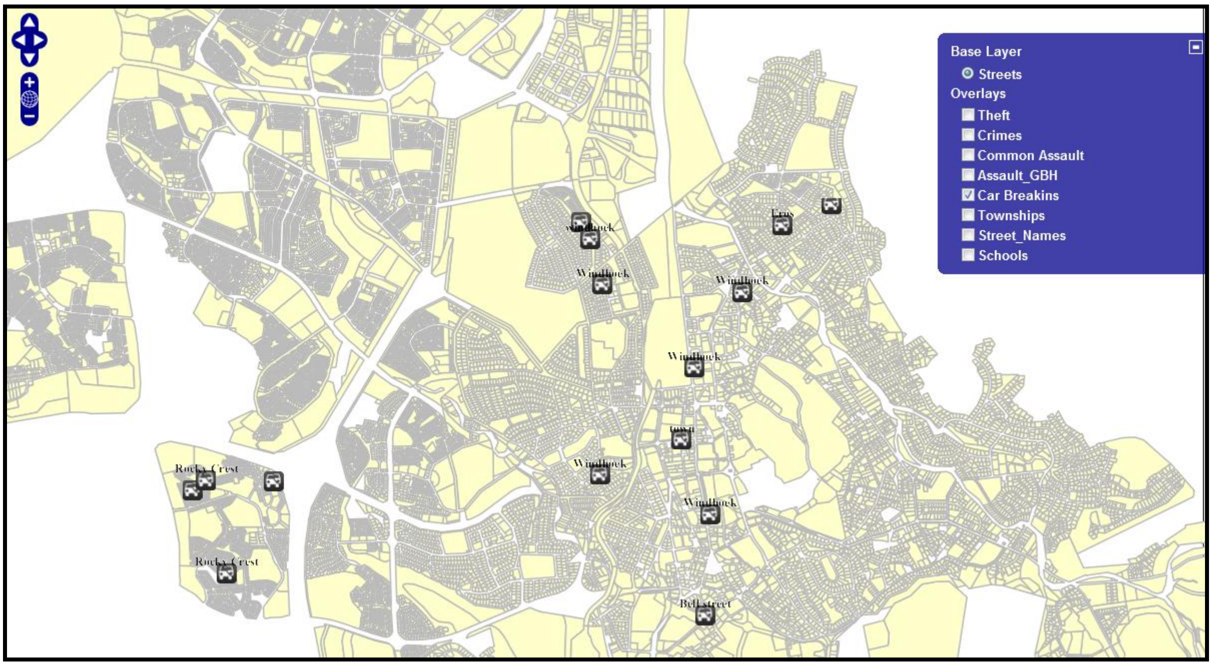


Fig. 7.12: OpenLayers Output (screenshot from the prototype)

Figure 7.13 below shows the location of schools and the locations where car break-ins were reported showing that crime data can be integrated with other spatial data.

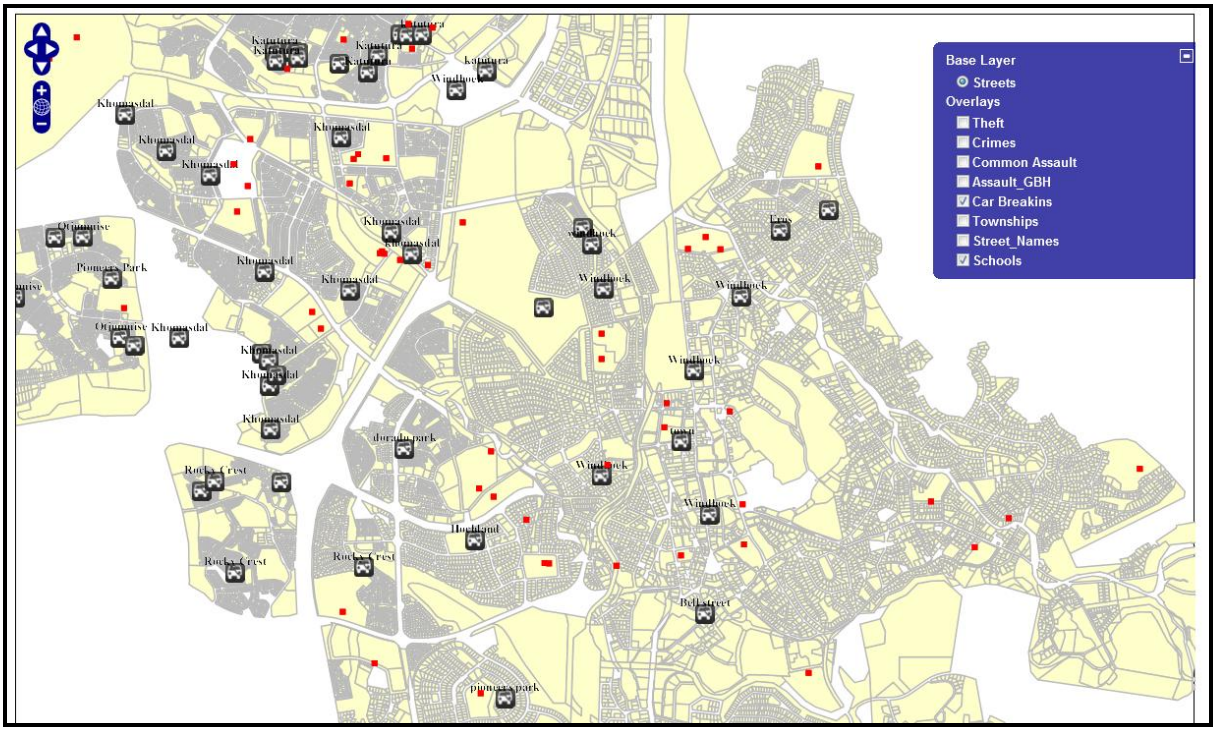


Fig. 7.13: integrating Schools Data with Car Break-ins (screenshot from the prototype)

7.4 Conclusion

This chapter has presented the construction and implementation of the prototype. The functionalities implemented are such that the location of crimes can be visualised on a map and the crime data can be integrated with other data to help in analysis and prediction. The prototype fulfils most of the system requirements. It provides the database for storage and provides an interactive interface for displaying the data. It can display crime locations and it can also overlay this information with other GIS data like schools, the aerial image of Windhoek, zoning information and township boundaries.

However, there are some limitations when it comes to the querying of the data. The prototype does not provide a tool that allows the querying of data, for example, a user cannot display only crimes committed in the past two weeks. However it has enough features necessary for the final evaluation as laid out in the methodology.

Chapter 8: Evaluation

The resultant prototype was evaluated in order to investigate the research questions i.e. whether it proves the concept that crime mapping would improve the operations of NamPol. It was evaluated in terms of usefulness, efficiency, effectiveness, learnability and user satisfaction.

8.1 Data acquisition

The evaluation involved collecting both qualitative and quantitative data as outlined in Chapter 3 section 3.2. The questionnaire employed the use of the Likert scale to collect quantitative data while qualitative data was collected via a structured interview.

As outlined in chapter 7, this evaluation was done with pairs of officers from the Statistics Sub-Division, the Crime Scene Unit, Station Commanders and the Crime Investigation unit. The evaluation consisted of the following activities:

- Introduction – besides introducing the researcher, the objectives of the research were outlined. The participants then signed consent forms (See Appendix A).
- Interactive Prototype Demonstration and test – The participants were shown how the prototype works and were also shown some of the maps produced by the prototype. They were then given a chance to use the prototype and get a feel of how it works.
- Structured Interview – After the demonstration, each pair of respondents was asked the same set of questions (see Appendix B) and their responses were noted.
- Questionnaire – The respondents were then given a questionnaire (see Appendix C) to fill in.

The focus of the evaluation was on the following criteria:

Proof of Concept:

- Can the prototype display crime data on maps?

- Can the crime data be integrated with other spatial data?

Technical Feasibility:

- Is the prototype development feasible within the limits of current technology?
- What required technology exists to build the prototype?
- Is the required technology available within given resource constraints for NamPol?

Usability

- Usefulness
- Efficiency
- Effectiveness
- Learnability
- Satisfaction

8.2 Results

This section presents the data gathered during the study, interpretation of the results from the conducted demonstration and the prototype analysis.

8.2.1 Demographic Profile of the Respondents

Age	Gender		Percentage		Age %
	M	F	M%	F%	
21 - 30					
31 - 40					
41 - 50	5	3	63%	38%	100%
51 - 60					
over 60					

Table 8.1: Age and Gender of Respondents

The table shows that all the respondents were in the 41 to 50 age category. This is due to the tradition of seniority within the police force. Only people above a certain rank are preferred to interact with members of the public. Having officers in this age bracket could influence results since these mature officers joined the force before computers were introduced. A group of younger respondents could have different opinions

8.2.2 Respondents' Length of Service

Years	No of Respondents	Percentage
<5		
5 to 10		
>10	8	100%

Table 8.2: Distribution of respondents according to years of service

Again, 100% of the respondents have more than 10 years of service in the force. Since promotion within the force is dependent on a number of factors including years of service, the data shows that the respondents are highly experienced since their ranks are high as well. Of the 8 respondents, only one was a sergeant, 3 were warrant officers, 3 were inspectors while one was a chief inspector. Having a group of respondent rich in experience is advantageous to the research since the respondents are well versed with the operations of various police units.

8.2.3 Respondents' Perception of the Prototype

	1	2	3	4	5
	Strongly Disagree	**Disagree**	**Neither Disagree nor Agree**	**Agree**	**Strongly Agree**
Crime maps will add value to our operations.				7	1
The crime mapping tool can be directly applied to our work.				4	4
It is easy to understand and use the tool			1	5	2
It is easy to learn the functionality of the tool.				8	
The tool was very fast and responsive.			2	6	
The information portrayed by the maps is clear, concise, and informative to the intended audience.				5	3
The information provided by each map encourages comparisons among locations or crimes.				5	3
The tool can be a useful resource in creating reports.				5	3
The tool provides information that can be useful in understanding reports.				5	3
The language and terminology in the maps is clear and is in line with the language used in the police force.			1	1	6
The program can be used by officers at all levels in the force?			1	6	1
The tool can be used to predict the occurrence of crime.			1	4	3

Table 8.3: Respondents' perception of the prototype

The table shows the responses of the participants to the prototype and their rating for each statement, where the scale of 5 means strongly agree while the scale 1 refers to strongly disagree.

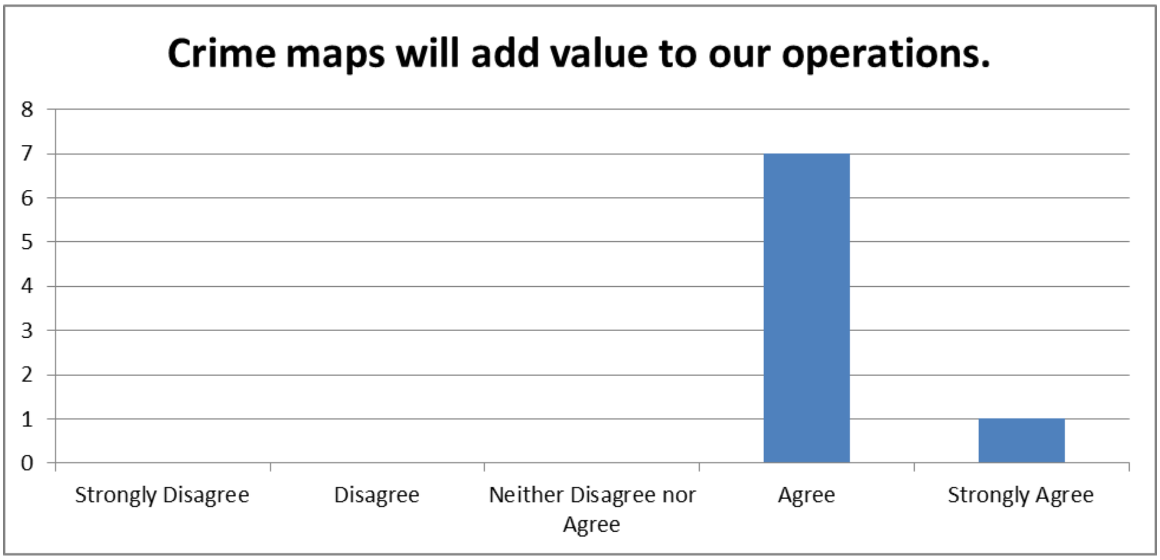


Fig. 8.1: Response to value addition capability of crime mapping

The majority (7 out of 8) of the total respondents strongly agree that crime maps will add value to police operations, the rest also agree. This is very good since it supports the hypothesis that says that crime mapping would add value to NamPol operations.

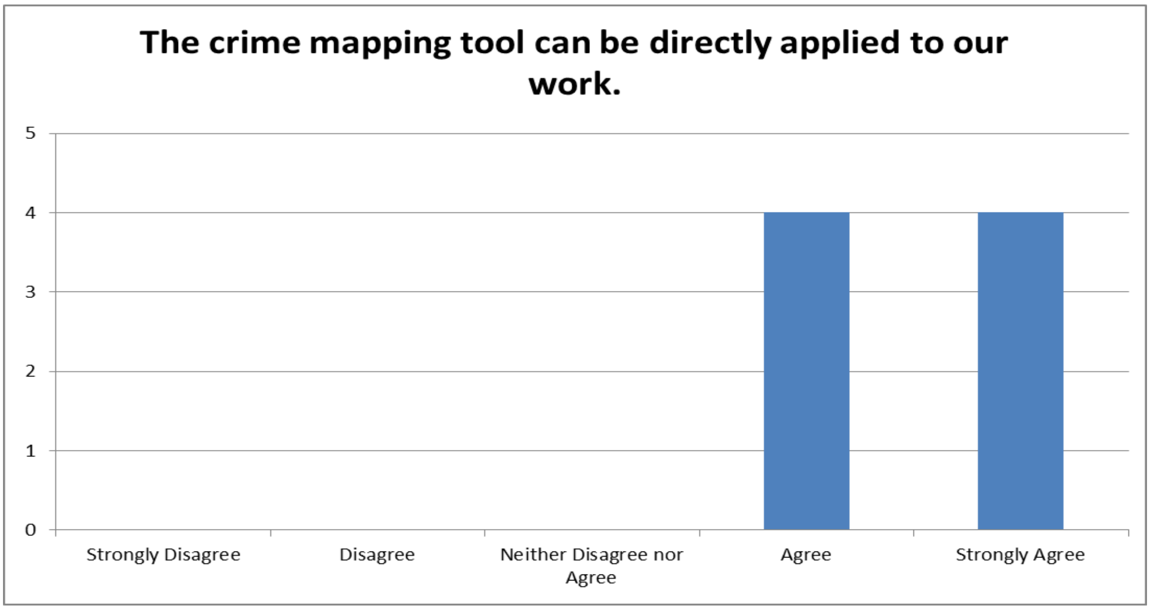


Fig. 8.2: Response to the applicability of the tool to NamPol

All of the respondents agree that the crime mapping tool can be directly applied to their work, 4 of the 8 agree strongly. This is important as it shows that the prototype represents directly usable technology.

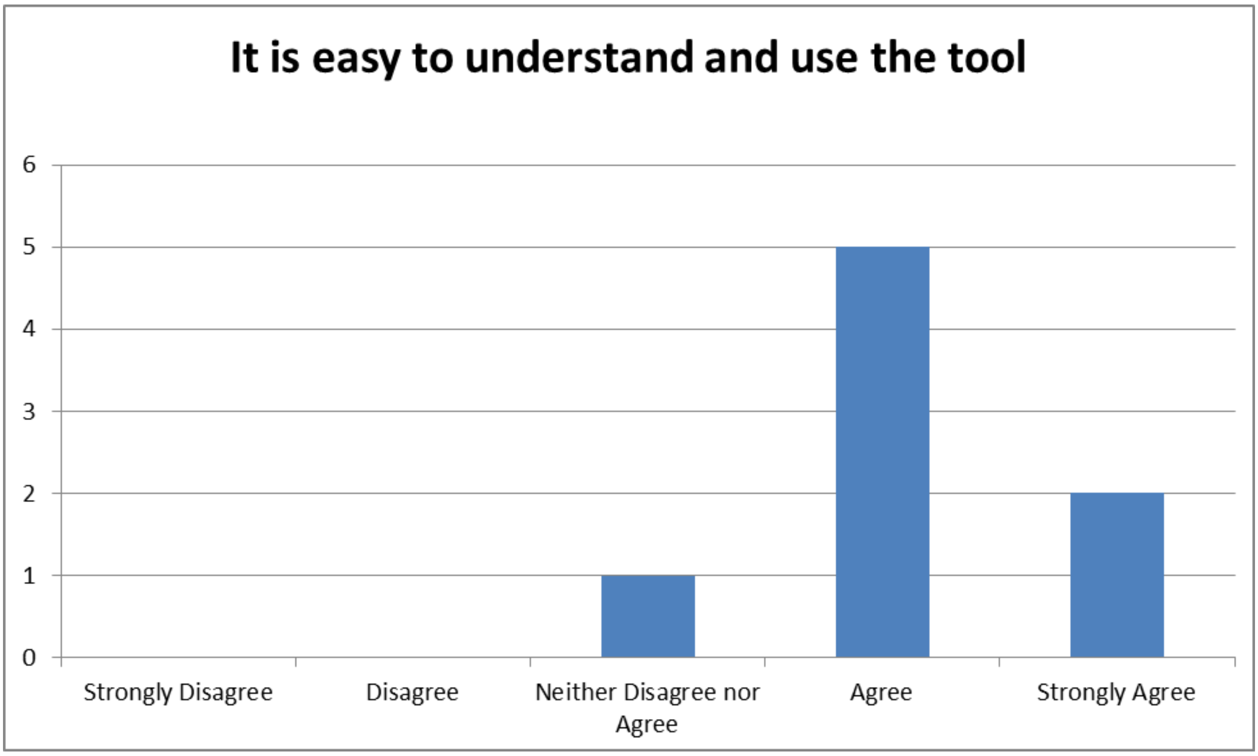


Fig. 8.3: Response to learnability

5 agree that the tool is easy to understand and use. 2 agree strongly while 1 neither agree nor disagree. This highlights that the tool would be usable within NamPol.

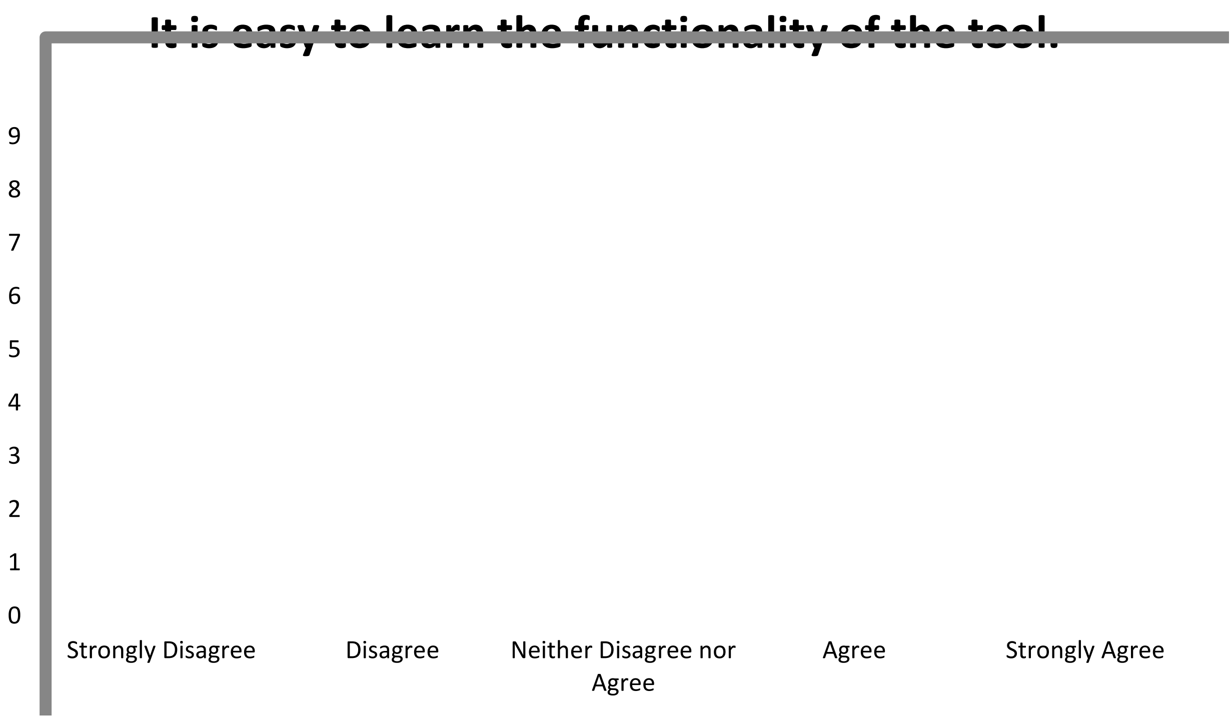


Fig. 8.4: Response to level of complexity of the tool

All the respondents agree that it is easy to learn the functionality of the tool. This advocates for the easy learnability of the tool which would imply easy implementation within NamPol.

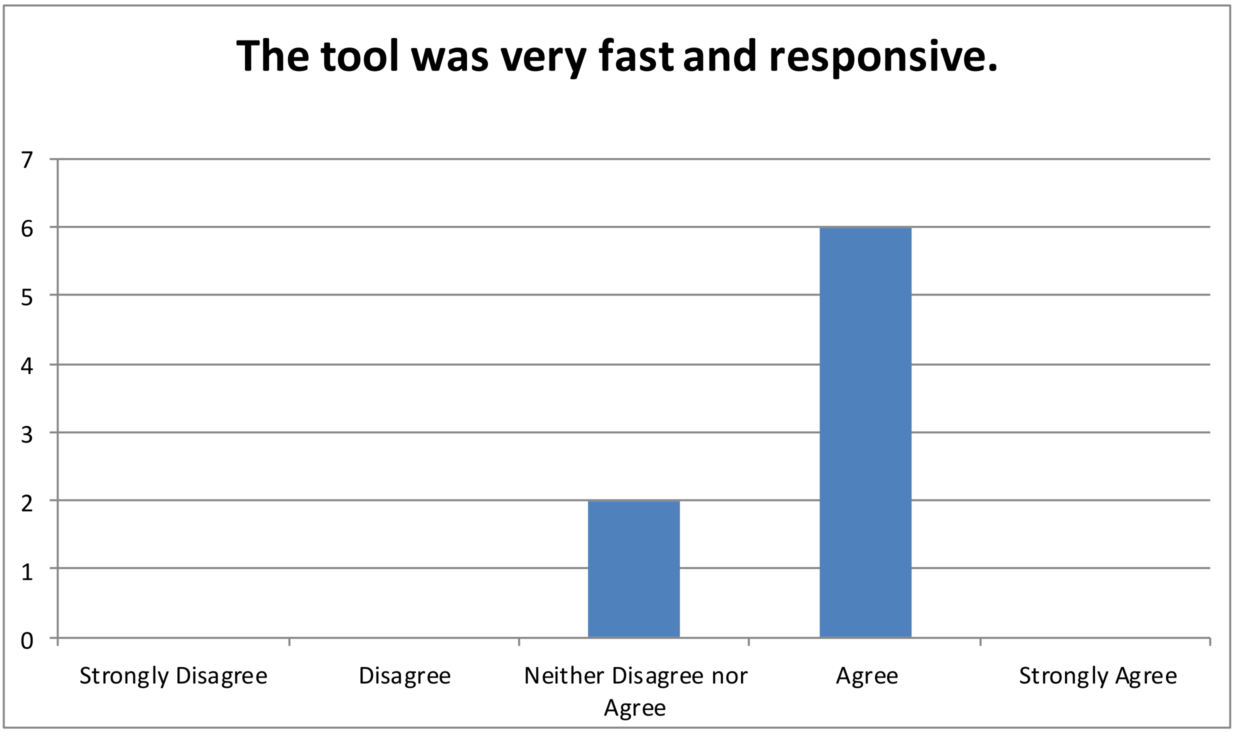


Fig. 8.5: Response to efficiency of the prototype

2 of the respondents neither agree nor disagree that the tool was fast and responsive. The rest only agree. The reason could be that the prototype was slow relative to acceptable standards. This was due to the large datasets displayed and the sub-optimal hardware that the prototype was running on.

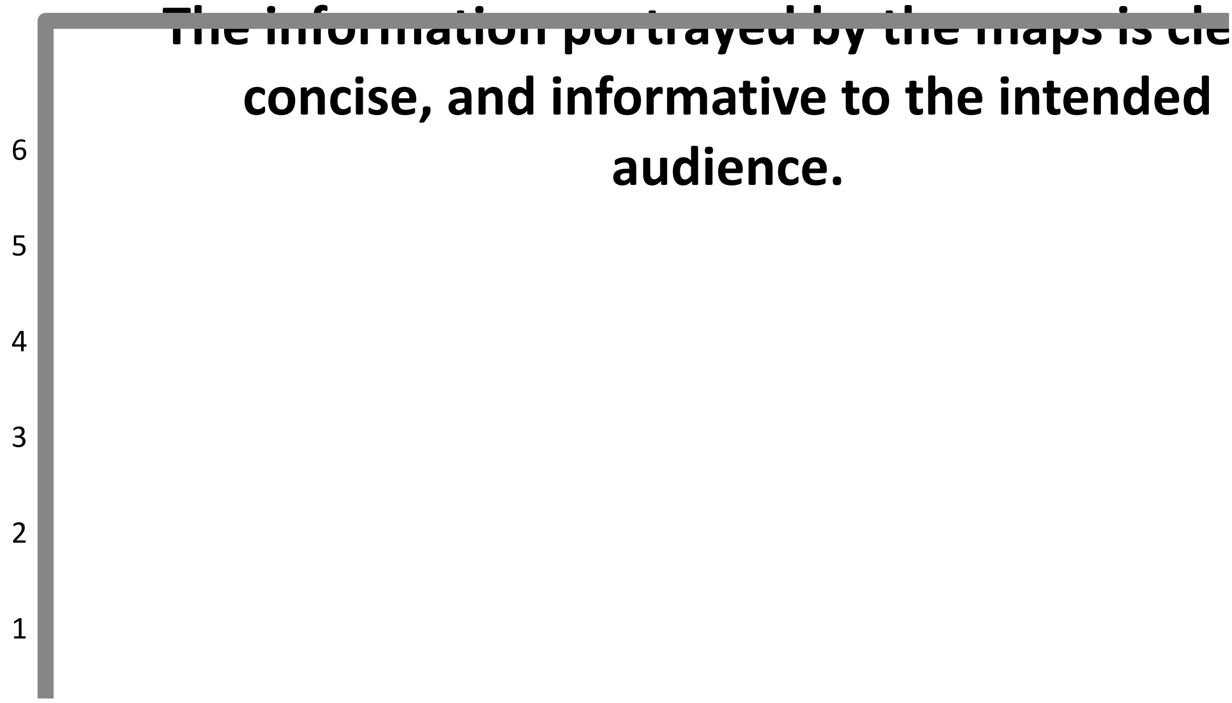


Fig. 8.6: Response to the effectiveness of the prototype

More than half (5) of the total respondents strongly agree that the information portrayed in the maps is clear and informative, 3 strongly so. This is important as it shows that the prototype is applicable to NamPol operations.

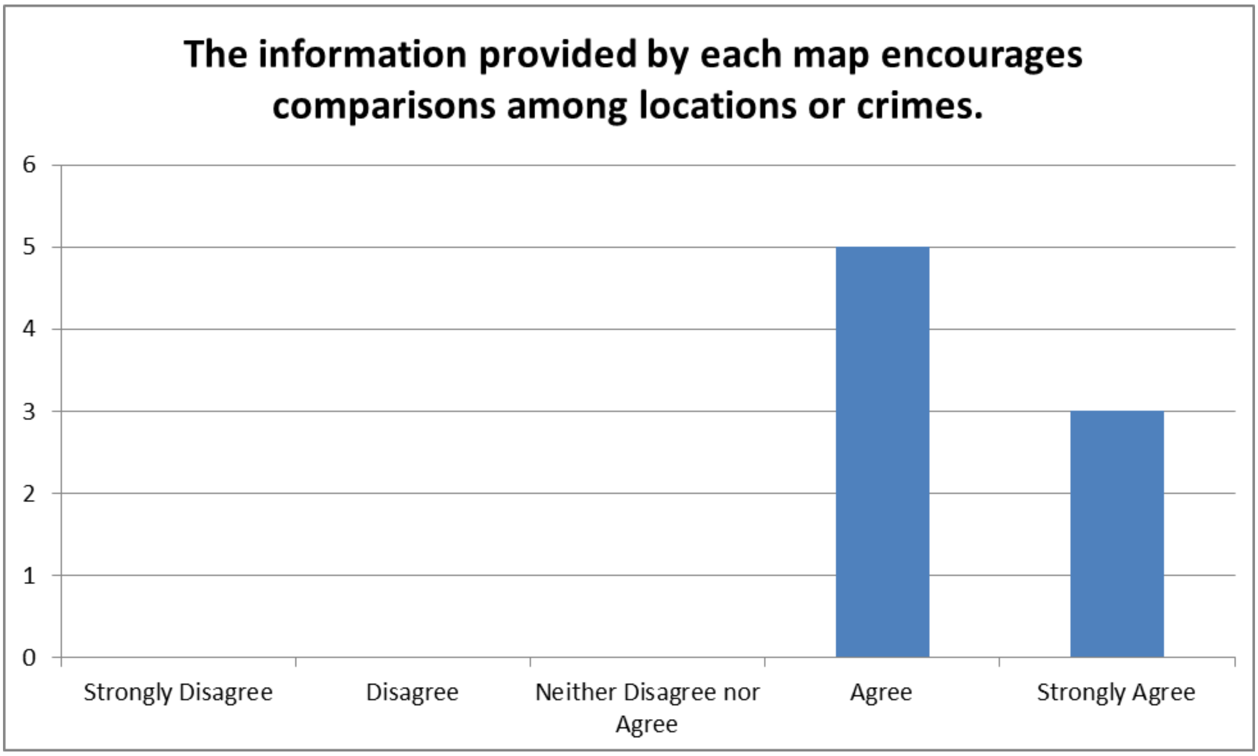


Fig. 8.7: Response to the usefulness of the prototype

Following a pattern of 63% to 37%, all the respondents agree or strongly agree that the maps encourage the comparison of crimes and their locations. This is important as it shows the usefulness of the system.

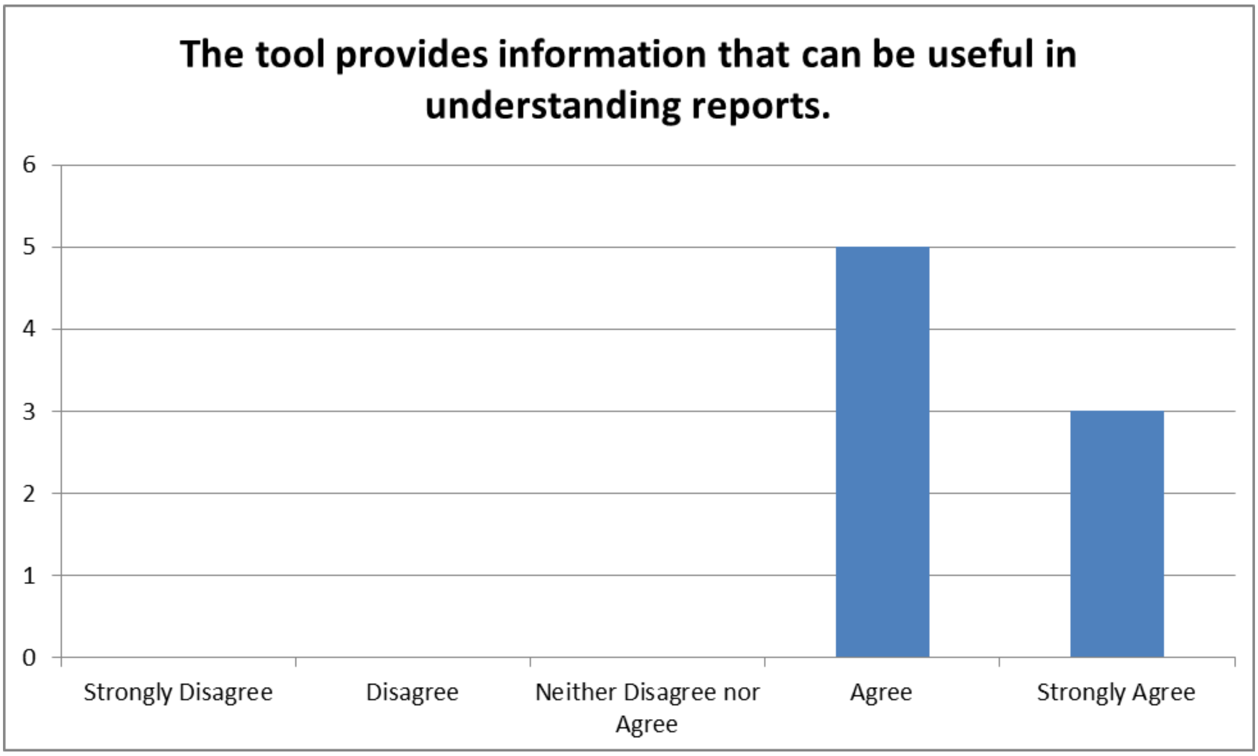


Fig. 8.8: Response to the usefulness of the prototype

A similar pattern emerges when it comes to the usefulness of the tool in create reports and when it comes to making reports easier to understand. This is good since it shows the usefulness of the system and also highlights that the users are satisfied with it.

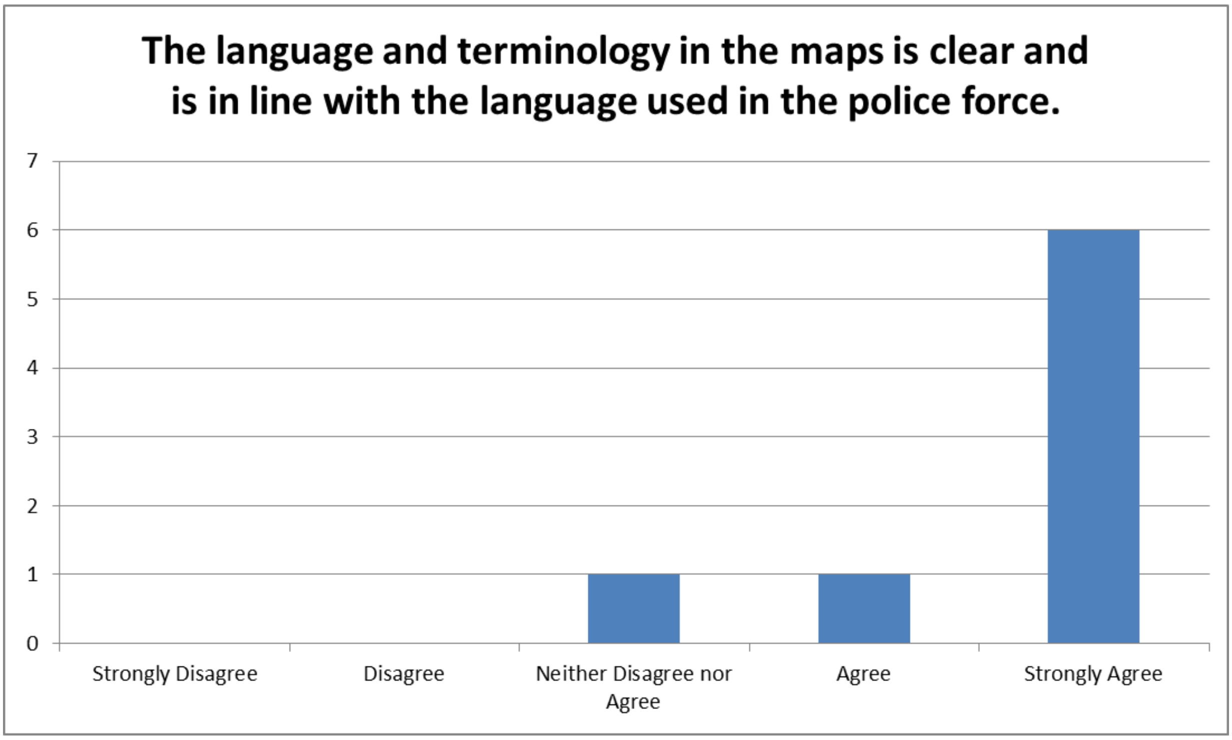


Fig. 8.9: Response to satisfaction capability of the prototype

A vast majority (6 out of 8) of the sample population strongly agree the language used is clear and in line with the language used in the police force. This is important as it shows that the prototype is user friendly.

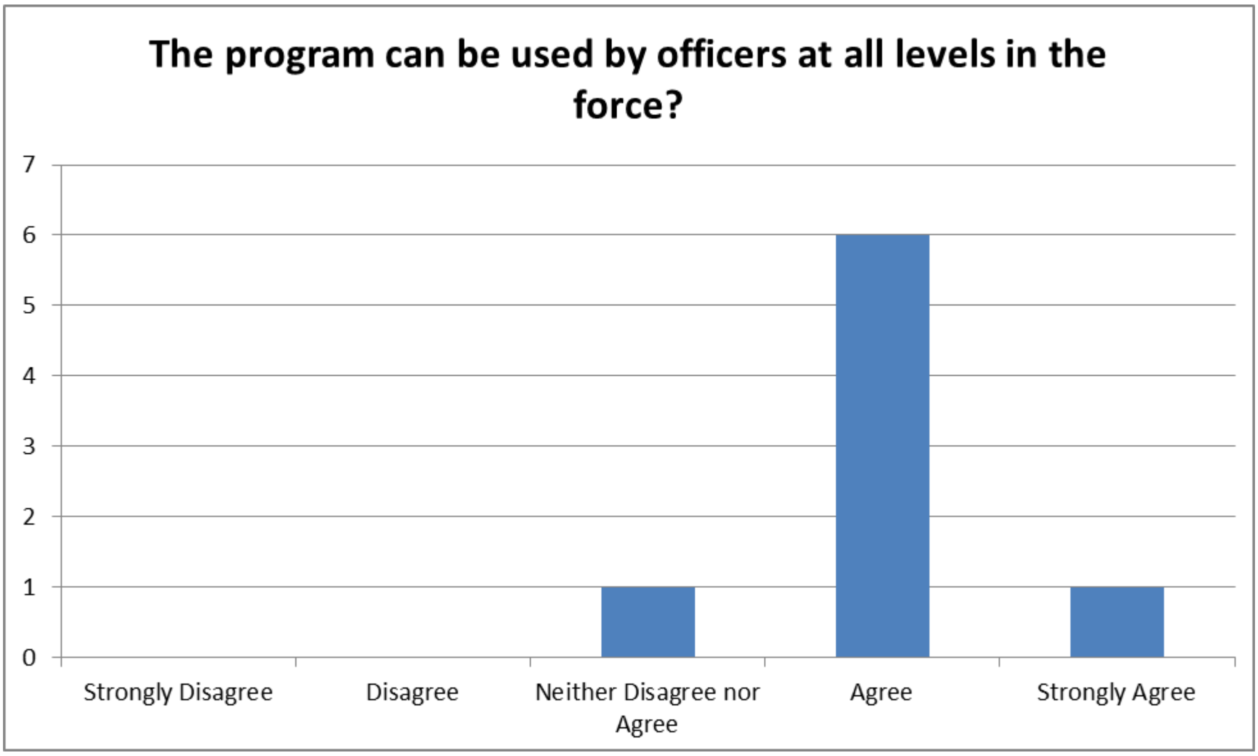


Fig. 8.10: Response to the learnability of the prototype

88% agree that the tool can be used by officers at all level of the force while only one neither agrees nor disagrees. This is important as it shows that it would be easy to teach the rest of the officers in NamPol how to use the system.

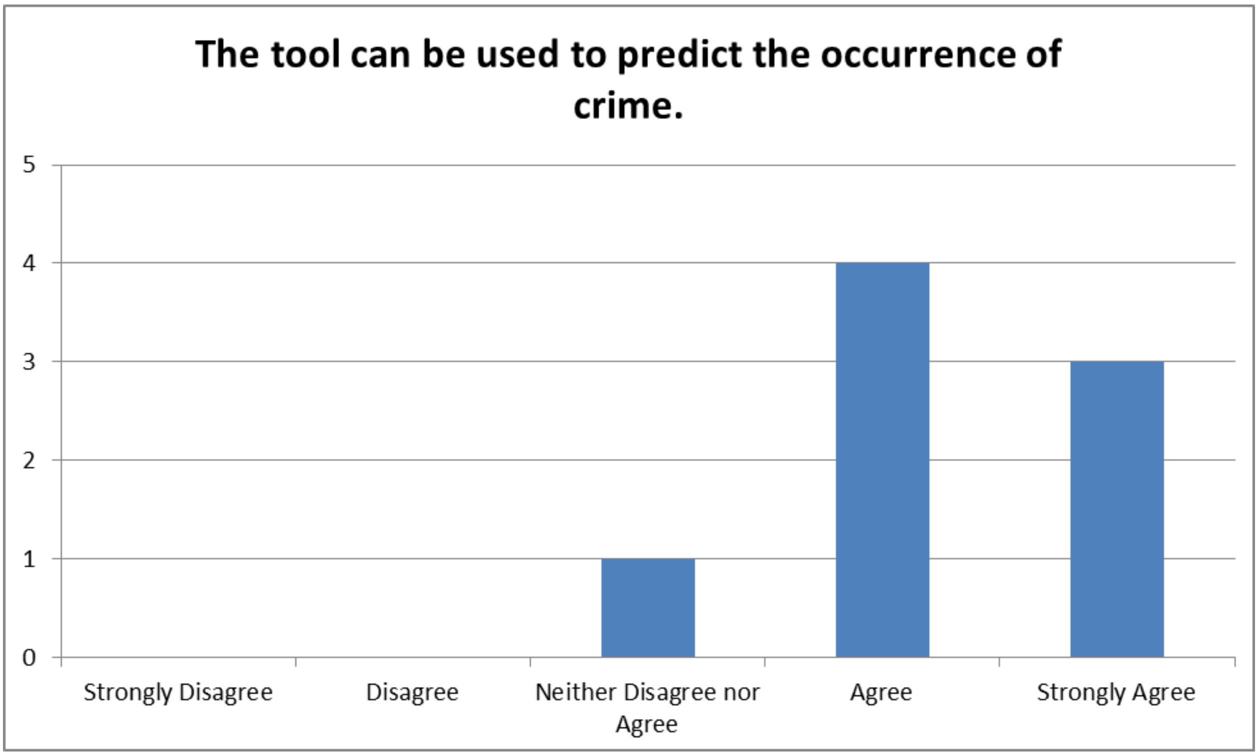


Fig. 8.11: Response to the usefulness of the prototype

Similarly, 88% agree that the tool can be used to predict crime. The rest neither agree nor disagree. This shows that the system would be useful in NamPol operations.

The tables clearly show that a vast majority of the respondents strongly agree to the usefulness of the crime mapping tool to analysing and predicting crime. This was also supported by the qualitative data collected through the interview.

8.2.3 Structured Interview Outcome

1. *How would you like the different crimes to be displayed on the map?*
To this question, the respondents from the Statistics Sub-Division and from the Scene of crime felt that the crime symbols were adequate. The Police commanders felt that colour coding the different crimes would be sufficient while the Crime Investigation Unit officers suggested a colour variation according to the number of cases.

2. *What information would you like to be displayed about a particular crime?*
The respondents want to see whether the offender is a juvenile or not. They also want to see what other crimes are linked to a particular suspect and also to see whether the suspect has been arrested or not. They also felt that witness information would be beneficial

3. *What other information besides crime would you like to see displayed on the map?*
The respondents expressed the need to see information about the type of businesses around a particular crime scene. The respondents also expressed the need to map accident scenes.

4. *What interaction do you think the Inspector General and the commanders would like to have with the map?*
The Statistics Sub-Division respondents suggested the displaying of statistics once a particular police district is clicked.
5. *What other uses do you think these maps can be put to?*

The respondents said that the maps can be used for presenting crime information to visiting delegates, for community policing especially during awareness campaigns.

From these findings, new features have been identified that would need to be added to the system to make it even more relevant to NamPol.

8.3 Conclusion

The chapter presented the criteria used in the evaluation of the system, which was done with the help of participants from four different units of the police. All the participants agreed that a crime mapping tool would be useful in NamPol operations. The evaluation proved that crime mapping can add value to police operations. This provides the confidence that when the prototype is fully developed in the future, it will add great value to the operations of NamPol.

The results support the main hypothesis of the study, namely that it is possible and feasible to implement and incorporate a crime mapping tool that would add value to NamPol operations.

Chapter 9: Discussion and Conclusion

From the literature review, it was shown that crime mapping has been successfully implemented in developed countries, and it is hypothesised that Namibia can also successfully implement it and reap the associated rewards. The purpose of this study was to develop a crime mapping tool which would enable the visualisation of crime data, integration of crime data with other spatial data and hence hotspot identification. Through the prototype development, it was shown that crime data can be integrated with other spatial data specific to an area which would help in identifying certain patterns associated with the incidents therein.

This chapter summarises the study and the development of the crime mapping tool and suggests several associated research areas that can be looked into.

To investigate the main hypothesis, the following research questions were put forward:

1. **What data is required to map the occurrence of crime in Windhoek?**
   It was found that the coordinates of the location where a crime has been committed need to be recorded when the rest of the details of the crime are being collected. This can be done with the use of a GPS or a smart mobile device. These coordinates will then be used to plot the crime location on a map. These points representing crime locations can be overlaid on an aerial photo of the area or any other base map.
2. **How can GIS data be integrated with crime data in order to identify patterns and show the relationship between a crime incident and the attributes of the location where it occurred?**
   It was found out that with the use of GIS, several layers of spatial data can be overlaid to produce the final map. For visualisation purposes, a fully-fledged GIS application is not required; tools like Geoserver and Mapserver facilitate the display of geographical data on web interfaces.
3. **How should the data be stored for easy update, integration and access?**
   It was found out that the use of geo-databases facilitates the storage of spatial data. There exists platform independent, open source database solutions (e.g. PostGRESQL) which can

be combined with other extensions (e.g. PostGIS) to give them spatial data handling capacity. So the inherent advantages of using databases like easy update, centralised security and multi user access are enjoyed.

4. **How can GIS data and crime data be integrated in an interface that allows visualisation and interaction with data?**

   Through the literature review, it was found out that there exists interface standards like the WFS which allow requests for geographical features across the web using platform-independent calls. WFS enables interaction with the data and spatial querying can be done. The WMS interface returns only an image, hence providing visualisation but the users cannot edit it or carry out any spatial analysis.

5. **How can crime mapping be implemented using existing and available technologies?**

   It was found out that by combining the available spatial database solutions and the visualisation standards like WFS and WMS, crime mapping can be successfully implemented.

6. **How can crime mapping fit into the current organisation and practices at NamPol?**

   The available literature and responses from interviews conducted with officers from NamPol revealed that several units would be able to use crime mapping for their day to day operations. For example, the Crime Statistics Sub-Division would include crime maps in their monthly reports while the Police Commanders would use crime maps when making resource allocation decisions.

In order to answer the first three research questions an extensive literature review was carried out. This resulted in a list of what data would be required to map crime, an understanding of how that data can be integrated with other non-crime data and how best the data can be stored for easier visualisation and update.

A study of the structure and procedures at NamPol was carried out in order to answer research question number 6. A study of the available spatial data in Namibia and the possible sources was carried out leading to the answering of research questions number 2 and 3. A prototype which displays crime locations and adds other spatial data like schools was then developed. Its use was then demonstrated to pairs of participants from four police units, namely the Statistics Sub-

Division, Crime Investigation, Crime Scene and Station Commanders, as part of evaluating the prototype hence answering research questions 5 and 6. The demonstrations were followed by a structured interview and the filling in of the questionnaire to get the opinions of the respondents on the concept and functionality of the prototype.

9.1 Validity

Based on the rank and experience of the participants of the prototype demonstrations, the results are perceived to be reliable. The police officers had no interest in just liking the prototype hence their responses are taken to be reliable. However the social desirability bias cannot be completely eliminated since the questionnaires were filled in in the presence of the researcher.

The 8 respondents were enough to get a mosaic on how they perceive the idea of crime mapping and the prototype itself. This gives credibility to the results.

9.2 Generalizability

The results cannot be generalised to all police units. There are some police units who would not need crime mapping like the police mortuary unit. These results also cannot be generalised to police forces in other Southern African countries like Botswana and Zimbabwe, even though it is likely that they would also find it useful. These would have to be looked at in their own contexts; however the technical aspects can be applied.

9.3 The Developed System

The proposed design of the tool included a database that can store geographic information coupled with that is a web interface that should be able to display this data and allow interaction with the data without requiring the users to be conversant with GIS. With this in mind, a combination of

Postgresql and PostGIS was used to create the geodatabase. A table to contain the crime data was then created and populated with fictitious crime data. This was then followed by the importing of various shapefiles into the geodatabase. Geoserver then responds to data requests coming from the browser, using Openlayers. The system is able to display crime locations and also allows the integration of the crime data with the other spatial data for further analysis.

9.4 Limitations

The size of the sample was relatively small due to limited time in terms of data collection. Hence focus was only on Windhoek. It was decided to go into depth with fewer participants instead of having a larger more shallow study.

Some of the challenges encountered during the project include:

- Having to write formal letters requesting for data and interviews. This on its own is not a challenge but the long periods of waiting and constant follow ups associated with it were taxing. Having to await clearance from superiors first before certain information was made available was a bit cumbersome. However this is understandable considering the nature of police operations.

- A planned second meeting to demonstrate the system to the Geo-Policing Unit officers did not materialise due to their busy schedule.

9.5 Future Work

During this study, the system was only shown to four police units. More police units can be identified and have the system demonstrated to them as well to gather their inputs. This would be important for a full scale system as it would need to work across the whole organisation.

The issue of data security needs to be explored further. Crime data is sensitive data hence a study into the appropriate security needs of the crime mapping tool would be beneficial.

This study only focused on proving that crime mapping is beneficial. Limited attention was paid to the quality of maps produced by the prototype. Further work can be undertaken by improving the quality of maps in conjunction with NamPol and cartographers.

The findings of the interview and questionnaire show that the all participants agree that the crime mapping tool would add value to their operations. The participants also suggested other police units whom they feel could also benefit from crime mapping.

Certain new functionality was suggested for future prototyping:

- They would like to see colour variations signifying the number of cases of a particular crime. They commended the use of symbols to represent crimes and even suggested the use of an image of a cell phone to identify cell phone theft.

- According to Inspector Nandapo, Station commander at Windhoek Police Station, the priority crimes are house breaking, theft, fraud and theft from motor vehicles. Maps showings colour variations based on the number of cases for a certain period of time of the crimes would be beneficial. There was also a request for viewing whether the suspect was a juvenile or not.

- "Since suspects can be arrested on a certain charge which can then be changed in court, for example when an attempted murder victim dies, the charge changes from attempted murder to murder, the system should be able to handle such changes" (Chief Inspector Shiimi, Crime Scene Unit, personal communication, November 8, 2012).

The use of mobile technology should also be investigated further. One can investigate how officers with smart phones can connect to the database and have the maps displayed on smartphones in the field.

9.4 Publications

Part of this work was published in the paper entitled "***Toward an mPolicing Solution for Namibia: Leveraging Emerging Mobile Platforms and Crime Mapping***" which was presented at the conference of the South African Institute for Computer Scientists and Information Technologists which was held in October 2012. See Appendix J for a draft of the paper.

9.5 Conclusion

It is important to equip law enforcement agencies with the technology to be able to fight crime effectively and also efficiently. This project provides a crime mapping tool that police units can use to show crime locations and also in decision making especially where resource allocation is concerned. This will also enhance data sharing across the different police units to make crime fighting more efficient.

Through this study, it has not been proven that this particular system will work. However the study has shown that it is possible and feasible to implement crime mapping in Nampol and that such a system will add value to the organisation given the feedback from the senior police officers that evaluated the system.

This study was exploratory and ground breaking in Namibia as no other studies have been conducted and based on the results the concept has been validated. The prototype was not perfect but many avenues for further research and development have been identified.

As shown in the literature review, the implications of implementing crime mapping are many; especially efficiency, better use of resources and more effective crime fighting through both analysis and prediction of crime behaviour through a spatial lens.

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Appendix A

Participant Details and Consent form

<table>
<tr><th colspan="3">Crime Mapping Focus Group Participant Demographics</th></tr>
<tr><td colspan="2">Name:</td><td>Unit</td></tr>
<tr><td>Date:</td><td>Time:</td><td>Place:</td></tr>
<tr><td>What is your rank:
o Constable
o Sergeant
o Warrant Officer
o Inspector
o Chief Inspector
Other: ……………………………………</td><td>How long have you been in the Police force?
o Less than 5 years
o 5 to 10 years
o More than 10 years</td><td>Which other police units were you attached to before the current unit you are in?<table><tr><th>Unit</th><th>Years served</th></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr></table></td></tr>
<tr><td>Your Age:
o 21 to 30
o 31 to 40
o 41 to 50
o 51 to 60
o Over 60</td><td>Your gender:
o Male
o Female</td><td></td></tr>
</table>

Consent to Participate in Focus Group

You have been asked to participate in a focus group for the Mobile Policing Research Projects at the Polytechnic of Namibia. The purpose of the group is to try and find out the best way of disseminating crime data using crime maps. The information learned in the focus groups will be used to improve the design of the crime mapping tool intended for use by various police units in showing where crime is occurring.

You can choose whether or not to participate in the focus group and stop at any time. You are free to withhold any information which you feel might be sensitive. Although the focus group will be recorded, your responses will remain anonymous and no names will be mentioned in the report. The responses made by all participants will be kept confidential.

I understand this information and agree to participate fully under the conditions stated above:

Signed:____ Date:____________________

Appendix B

Structured Interview Questions

1. How would you like the different crimes to be displayed on the map?

2. What information would you like to be displayed about a particular crime?

3. What other information besides crime would you like to see displayed on the map?

4. What interaction do you think the Inspector General and the commanders would like to have with the map?

5. What other uses do you think these maps can be put to?

Appendices C

NamPol Questionnaire

Introduction

This questionnaire is part of the research project titled: "***Development of a Crime Mapping, Analysis and Prediction Tool for Windhoek"*** for a Master Thesis at the Polytechnic of Namibia. The aim of this questionnaire is to collect user sentiments about the prototype of the tool. The questionnaire is to be filled in after the prototype has been demonstrated to the participants. The responses will then be used in the improvement of the design of the crime mapping tool. The tool can be used by Police officers in analysing the occurrence of crime and in identifying factors contributing to the identified patterns by combining crime location data with other data like the demographics of the area, average household income and proximity to certain services like schools and liquor outlets.

The information you provide is entirely confidential and your name will be kept totally anonymous on the report. The questionnaire will take about 10 to 15 minutes to be filled.

Instruction:

Please put a tick on the appropriate box to state how much you agree with the following statements.

1. Name:_________________________________ Unit:________________________________

2. Crime maps will add value to our operations.

   1 2 3 4 5

   ☐ ☐ ☐ ☐ ☐

   Comments:____
   ____
   ____

3. The crime mapping tool can be directly applied to our work.

   1 2 3 4 5

   ☐ ☐ ☐ ☐ ☐

Comments:____

4. It is easy to understand and use the tool.

1 2 3 4 5

Comments:

5. It is easy to learn the functionality of the tool.

1 2 3 4 5

Comments:

6. The tool was very fast and responsive.

1 2 3 4 5

Comments:

7. The information portrayed by the maps is clear, concise, and informative to the intended audience.

1 2 3 4 5

Comments:

8. The information provided by each map encourages comparisons among locations or crimes.

1 2 3 4 5

Comments:____

____

____

9. The tool can be a useful resource in creating reports.

1 2 3 4 5

Comments:____

____

____

10. The tool provides information that can be useful in understanding reports.

1 2 3 4 5

Comments:____

____

____

11. The language and terminology in the maps is clear and is in line with the language used in the police force.

1 2 3 4 5

Comments:____
____
____

12. The program can be used by officers at all levels in the force?

1 2 3 4 5

Comments:____
____
____

13. The tool can be used to predict the occurrence of crime.

1 2 3 4 5

Comments:____
____
____

Any other comments:
………
………
………
………
………
………
………
………
……………………………………………………

Thank you very much for your participation.

Appendix D

Police Public Relations Interview

Summary of Informal Interview held with Inspector Nuuyi on the 3rd of February 2012

Below are summary points of the informal interview held with Inspector Nuuyi of the Public Relations Division of Nampol on the 3rd of February 2012 in his office at the Nampol Public Relations Building.

Resources are not enough for every officer to have a pc.

- Crime occurs anywhere and everywhere
- It occurs anytime'
- For example there are break-ins in business and in residential areas as well.
- Some crimes are common in areas with common characteristics for example robberies may be common in dark areas, riverbeds and business areas. Assault with Grievous Bodily Harm may be common in shebeens and in homes as well
- Some crimes only occur in certain areas, for example stock theft in rural and farm areas.
- Victims and the public in general can report any crime by phoning the nearest police station or the Police Communications Centre.
- The police station or the Communications Centre will then dispatch officers to the scene.
- At the crime scene, the responding officer would seal the scene off and control the movement of people at the scene before collecting statements from the victim and witnesses as well.
- The officer has to gather what happened, where it happened, when it happened, through whom and how.
- The statement is recorded on a standard form or in the officer' notebook for later transfer to the form or the occurrence book
- The statement contains: the preamble - who is making the statement, I.D. number, Address and contact number, age and workplace. It also dwells on when, where, what, how and the circumstances.
- Each police station keeps its own register of crimes (occurrence book).
- The CR number has the format CR 01/02/2012.

Appendix E

Crime Statistics Sub-Division Interview

Outcome of the Interview held with the Crime Statistics Sub-Division of NamPol

(Inspector Kumangamanga & Warrant Officer (2) Sinombe)

There are currently 92 Police Stations in Namibia excluding Sub-Stations, Satellite stations, etc. By the 8th of each month, every station should have faxed its Monthly Crime Return (POL 6) and Inquest Return forms (compiled from crimes and inquest cases recorded during the previous month and also crimes carried over from previous months) to the Crime Statistics Sub-Division. It will then take a minimum of 2 weeks for the statistics to be processed. Currently we are using E-Policing System but the stations outside Windhoek are not yet connected, once they will be connected then GPS coordinates of the crime scene, the nature of crime committed together with the date and time will be available.

If a crime is reported at a station, it is first recorded in the Crime Register where details are added. In addition to the crime register, each station also has a Cell Register, and an Inquest Register. Each station then compiles its statistics on a (POL 6), (accidents also have a crime code but minor accidents are only recorded on a POL 66). Suicide statistics are indicated on the POL 6 in the space provided. These are then forwarded to the Crime Statistics Sub-Division.

Some of the columns on the POL 6 include crime codes, reported cases, brought forward cases from previous month, cases to court, cases on hand, arrests, victims, etc. Each crime is given a code, for example 004 for Racial Discrimination. A legend of crime codes is available. (Inspector Kumangamanga to seek clearance on whether to avail the legend or not).

The main consumers of the crime statistics are the Inspector General, Commissioner of CID and UNDP. Regional Commanders can request data directly from the Crime Statistics Sub-Division, with regard to their specific regions only. All other requests for statistics have to be addressed to the Inspector General.

At a crime scene there could be different Police Officers from different units depending on the crime committed. These could be Scene of Crime (for photographs and fingerprints), Protected Resources, Police Mortuary, Drug Law Enforcement, etc. All data from one crime scene and various charges are recorded in a docket to which a CR number is allocated.

The program used by the Crime Statistics Sub-Division is called the POL 6 program. It was compiled by the IT Department at the Office of the Prime Minister during 2000.

NB: THE CRIME CODE LIST REQUESTED BY YOU CAN BE OBTAINED FROM THIS OFFICE.

Reviewed on 31/10/2012

Appendix F

Geo-Policing Unit Interview

Outcome of meeting held with Warrant Officer Owoseb of the Geo-Policing System, NamPol

Geo-Policing was initiated in 2010 with the aim of mapping crime, analysing it and identifying crime hotspots. With the commencement of the design of the e-Policing system in October 2011, Geo-policing is now part of the umbrella e-Policing system.

With the cooperation of the Ministry of lands and Resettlement, the Police station jurisdiction maps have been compiled and the coordinates of the location of all police stations in the country have been recorded.

Current Implementation

Police vehicles in the Khomas region have GPS devices mounted on them. These are used to collect the coordinates of the location of the crime. These coordinates are then recorded in the case docket on the e-Policing system. This then facilitates the automatic creation of maps showing crime locations.

These maps and crime statistics are then used to advise gatekeepers like Station Commanders on areas that need special attention in terms crime prevention and maintenance of Law and Order. Having only mounted GPS devices impacts on accuracy hence the use of portable devices would be more ideal. Smaller devices would be more suitable since officers may be required to chase suspects. Smart phones would enable the officers to collect data and also access data from the server while still at the crime scene.

Introducing smart phones would require training of the officers and implementation. Acquisition costs have to be factored in. Low cost modules like the Samsung Galaxy Ace are to be considered.

Currently, three directorates are earmarked for extensive use of the Geo-Policing component. These are the Crime Investigation, the Organised Crime Division and the Internal Investigation Directorate. The Criminal Investigation Directorate will use the system for crime analysis, collecting statistics, investigations, crime scene visits and for statistical analysis. The Internal Investigation Unit would use it at crime scenes involving police officers.

Implementation of the e-Policing system started in Khomas and will be rolled out to other regions in the second year of the project. The border posts are now online. Namibia is the only country in Africa implementing this system.

Expansion

Plans are in place to expand the capacity the officers responsible for Geo-Policing to enable them to create their own maps. For example, in order to support traffic operations, the officers should be able to come up with maps showing certain stretches of road together with feeder roads and possible by-pass routes.

It would be valuable to link ePolicing with eNatis for traffic operations.

Highlights of Benefits of e-Policing

Time saving especially where large reports are concerned

Value addition through graphics

Ease of use

Reduce time of investigation

Data sharing

Crime Analysis

Linkage of a suspect across various crimes (through fingerprints, modus operandi, et al)

Development of Crime Statistics

Bottlenecks and Challenges

The Prosecutor General’s office is not yet computerised hence they still require dockets on hard copy. This has led to a parallel system being run in Windhoek to encompass e-Policing and also accommodate the manual system.

Some challenges encountered so far include resistance to change from within the force, low computer literacy especially among the older officers, high costs of software and hardware and chiefly the lack of human resources to effectively manage the program. Currently the Geo-Policing team only consists of a manager and two trainers. These are faced with training +- 15000 other officers who make up the Namibian Police force.

Further Requirements

The current trainers need further training in GIS and Cartography. There is need for a system manager to verify data collected by the officers. Data Security has to be fortified to prevent abuse.

Possible Cooperation with the Polytechnic

In the short term, The Polytechnic is to organise workshops on GIS and Cartography for officers. The Nampol Geo-Policing Manager is to facilitate visits for the Polytechnic research team to crime scenes for first-hand experience on Police operations.

Appendix G

HTML files

Crimeswmsforms:

```
<html xmlns="http://www.w3.org/1999/xhtml">

  <head>

    <style type="text/css">

        #map {

            width: 1200px;

            height: 900px;

            border: 1px solid black;

        }

    </style>

    <script src="C:/Program Files/OpenLayers-2.7/OpenLayers.js"></script>

      <script type="text/javascript">


            var map, layer;


            function init(){



                  map = new OpenLayers.Map( 'map' )



                  //layer = new OpenLayers.Layer.WMS(

                  //"Imagery",
"http://localhost:8081/geoserver/wms?service=WMS&layers=Windhoek:WHK_IMG",

            //{layer: 'WHK_IMG'});
```

```
        // map.addLayer(layer);


            layer1 = new OpenLayers.Layer.WMS(
            "Theft",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:theft",
            {layer: 'theft', transparent: "true", format: "image/png"},
            {isBaseLayer: false,
            visibility: false});
            map.addLayer(layer1);


           layer4 = new OpenLayers.Layer.WMS(
            "Crimes",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Allcrimes",
            {layer: 'Allcrimes', transparent: "true", format:
"image/png"},
            {isBaseLayer: false,
            visibility: false});
            map.addLayer(layer4);


           layer2 = new OpenLayers.Layer.WMS(
            "Common Assault",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Commonassault",
            {layer: 'Commonassault', transparent: "true", format:
"image/png"},
            {isBaseLayer: false,
            visibility: false});
            map.addLayer(layer2);


         layer3 = new OpenLayers.Layer.WMS(
```

```
                  "Assault_GBH",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Assault_GBH",

                  {layer: 'Assault_GBH', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer3);


            layer5 = new OpenLayers.Layer.WMS(

                  "Streets",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Streets",

                  {layer: 'Streets', transparent: "true", format: "image/png"},

                  {isBaseLayer: true,

                  visibility: true});

                  map.addLayer(layer5);


                  layer6 = new OpenLayers.Layer.WMS(

                  "Car Breakins",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Carbreakins",

                  {layer: 'Carbreakins', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer6);


                  layer7 = new OpenLayers.Layer.WMS(

                  "Townships",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Township_DD",

                  {layer: 'Townships_DD', transparent: "true", format:
"image/png"},
```

```
                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer7);


                  layer8 = new OpenLayers.Layer.WMS(

                  "Street_Names",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:streetnames_DD"
,

                  {layer: 'streetnames_DD', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer8);


            map.addControl(new OpenLayers.Control.ScaleLine());     <!--Add a
scale bar-->


            map.addControl(new OpenLayers.Control.MousePosition());     <!--Adds
coordinates of mouse position-->


            map.setCenter(
            <!--Add map center-->

        new OpenLayers.LonLat(17.077148, -22.565906).transform( <!--Specify
coordinates-->

        new OpenLayers.Projection("EPSG:4326"),                         <!--
Specify EPSG code-->

        map.getProjectionObject()

        ), 14
            <!--Specify zoom level -->

        );

        map.addControl(new OpenLayers.Control.LayerSwitcher());} <!--Adds a
layer switcher-->
```

```
    </script>

  </head>

  <body onload="init()">

    <div id="map"></div>

      form method="post" action="" id="form1" style="height: 100%">

<div class="aspNetHidden">

<input type="hidden" name="__VIEWSTATE" id="__VIEWSTATE"
value="/wEPDwUKLTQ5ODA4NDg2N2RkDoFAD7jydycRhyKzWf25IZRH+mcxpvmYMrNw0qXyRsk=" />

</div>


    <div id="silverlightControlHost">

        <object data="data:application/x-silverlight-2," type="application/x-
silverlight-2"

            width="100%" height="100%">

            <param name="source" value="ClientBin/PublicIncidents.xap" />

            <param name="onError" value="onSilverlightError" />

            <param name="background" value="white" />

            <param name="minRuntimeVersion" value="4.0.50826.0" />

            <param name="autoUpgrade" value="true" />

            <a
href="http://go.microsoft.com/fwlink/?LinkID=149156&v=4.0.50826.0" style="text-
decoration: none">

                <img src="http://go.microsoft.com/fwlink/?LinkId=161376"
alt="Get Microsoft Silverlight"

                    style="border-style: none" />

            </a>

        </object>

        <iframe id="_sl_historyFrame" style="visibility: hidden; height: 0px;
width: 0px;

            border: 0px"></iframe>
```

```
    </div>

    </form>

  </body>

</html>
```

Crimeswithschools

```
<html xmlns="http://www.w3.org/1999/xhtml">

  <head>

    <style type="text/css">

        #map {

            width: 1200px;

            height: 900px;

            border: 1px solid black;

        }

    </style>

    <script src="C:/Program Files/OpenLayers-2.7/OpenLayers.js"></script>

      <script type="text/javascript">


            var map, layer;


            function init(){



                  map = new OpenLayers.Map( 'map' )



                  //layer = new OpenLayers.Layer.WMS(
```

```
                  //"Imagery",
"http://localhost:8081/geoserver/wms?service=WMS&layers=Windhoek:WHK_IMG",

            //{layer: 'WHK_IMG'});

           // map.addLayer(layer);


                  layer1 = new OpenLayers.Layer.WMS(

                  "Theft",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:theft",

                  {layer: 'theft', transparent: "true", format: "image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer1);


                layer4 = new OpenLayers.Layer.WMS(

                  "Crimes",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Allcrimes",

                  {layer: 'Allcrimes', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer4);


                layer2 = new OpenLayers.Layer.WMS(

                  "Common Assault",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Commonassault",

                  {layer: 'Commonassault', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer2);
```

```
            layer3 = new OpenLayers.Layer.WMS(
                  "Assault_GBH",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Assault_GBH",
                  {layer: 'Assault_GBH', transparent: "true", format:
"image/png"},
                  {isBaseLayer: false,
                  visibility: false});
                  map.addLayer(layer3);

            layer5 = new OpenLayers.Layer.WMS(
                  "Streets",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Streets",
                  {layer: 'Streets', transparent: "true", format: "image/png"},
                  {isBaseLayer: true,
                  visibility: true});
                  map.addLayer(layer5);

                  layer6 = new OpenLayers.Layer.WMS(
                  "Car Breakins",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Carbreakins",
                  {layer: 'Carbreakins', transparent: "true", format:
"image/png"},
                  {isBaseLayer: false,
                  visibility: false});
                  map.addLayer(layer6);

                  layer7 = new OpenLayers.Layer.WMS(
                  "Townships",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Township_DD",
```

```
                  {layer: 'Townships_DD', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer7);


                  layer8 = new OpenLayers.Layer.WMS(

                  "Street_Names",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:streetnames_DD"
,

                  {layer: 'streetnames_DD', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer8);


                  layer9 = new OpenLayers.Layer.WMS(

                  "Schools",
"http://localhost:8080/geoserver/wms?service=WMS&layers=Windhoek:Whk_Schools",

                  {layer: 'Whk_Schools', transparent: "true", format:
"image/png"},

                  {isBaseLayer: false,

                  visibility: false});

                  map.addLayer(layer9);


            map.addControl(new OpenLayers.Control.ScaleLine());     <!--Add a
scale bar-->


            map.addControl(new OpenLayers.Control.MousePosition());     <!--Adds
coordinates of mouse position-->
```

```
            map.setCenter(
            <!--Add map center-->

        new OpenLayers.LonLat(17.077148, -22.565906).transform( <!--Specify
coordinates-->

        new OpenLayers.Projection("EPSG:4326"),                        <!--
Specify EPSG code-->

        map.getProjectionObject()

        ), 14
            <!--Specify zoom level -->

        );

        map.addControl(new OpenLayers.Control.LayerSwitcher());} <!--Adds a
layer switcher-->

    </script>

  </head>

  <body onload="init()">

    <div id="map"></div>

      form method="post" action="" id="form1" style="height: 100%">

<div class="aspNetHidden">

<input type="hidden" name="__VIEWSTATE" id="__VIEWSTATE"
value="/wEPDwUKLTQ5ODA4NDg2N2RkDoFAD7jydycRhyKzWf25IZRH+mcxpvmYMrNw0qXyRsk=" />

</div>


    <div id="silverlightControlHost">

        <object data="data:application/x-silverlight-2," type="application/x-
silverlight-2"

            width="100%" height="100%">

            <param name="source" value="ClientBin/PublicIncidents.xap" />

            <param name="onError" value="onSilverlightError" />

            <param name="background" value="white" />

            <param name="minRuntimeVersion" value="4.0.50826.0" />
```

```
            <param name="autoUpgrade" value="true" />
            <a
href="http://go.microsoft.com/fwlink/?LinkID=149156&v=4.0.50826.0" style="text-
decoration: none">
                <img src="http://go.microsoft.com/fwlink/?LinkId=161376"
alt="Get Microsoft Silverlight"
                    style="border-style: none" />
            </a>
        </object>
        <iframe id="_sl_historyFrame" style="visibility: hidden; height: 0px;
width: 0px;
            border: 0px"></iframe>
    </div>
    </form>
  </body>
</html>
```

Appendix H

Part of list of Crime Codes

CRIME CODE LIST

CODE	OFFENCE	COMMENTS
CLASS A - GOVERNMENT AUTHORITY AND GOOD ORDER		
A1 - STATE SECURITY		
001	Sedition.	Unlawfully gathering together with a number of people with the intention of impairing the majestas of the state by defying or subverting the authority of its Government, but without the intention of overthrowing or coercing that Government.
002	High Treason.	Consists of any act unlawfully committed by a person owning allegiance to the state possessing majestas who intends to impair that majestas by overthrowing or coercing the Government of that State.
003	Protection of Information Act, 84/1982.	See AG Proclamation 29/1985.
A2 - ORDER AND PEACE		
004	Racial Discrimination Prohibition Act, 26/1991.	
005	Unlawful and/or riotous assemblies: Public gatherings Proclamation.	Proc AG 23/1989. Excluding strikes. Riotous Assemblies Act, 17/1956 as amended by AG Proc. 14/1989.
006	Unlawful strikes and similar behaviour.	Labour Act, 6/1992.
007	Breach of the peace and riotous behaviour.	Excluding transgressions of by-law of local Authorities.
008	Public violence.	
009	Supplying of firearms and ammunition to unauthorised persons.	Arms and Ammunition Act, 7/1996.
010	Unauthorised possession of firearms and ammunition.	Arms and Ammunition Act, 7/1996.
011	Arms and Ammunition Act, 7/1996.	Excluding codes 009 and 010.
012	Possession and supplying of explosives.	Explosives Act, 26/1959.
A3 - ADMINISTRATION OF JUSTICE		
021	Bribery.	Bribery (as a briber) consists of unlawfully and intentionally offering to or agreeing with a State official to give consideration in return for action or inaction by him/her in an official capacity.
022	Prevention of Corruption Act, 6/1958 and other statutory provisions relating to bribery.	Act 21/1985 and Ord. 2/1928.
023	Escaping from custody and assisting in escaping under Common law as well as Statutory law.	Criminal Procedure Act, 51/1977. Prisons Act, 17/1998.
024	Inciting to commit an offence.	
025	Compounding (concealing) a crime.	Unlawfully and intentionally agreeing for reward not to prosecute a crime which is punishable otherwise than by fine only.
026	Defeating the Course of Justice.	Doing any act, whereby the due administration of justice is defeated or obstructed, with intent so to defeat or obstruct.
027	Contempt of Court.	Magistrate's Court Act, 32/1944.
028	Perjury and subornation of perjury, under Common Law and Statutory Law. Criminal Procedure Act, 51/1977 section 101.	A person who wilfully, and upon oath or a form allowed by law to be substituted for an oath, makes, in the course of a judicial proceedings before an authority of competent jurisdiction, a statement of fact which he/she knows to be false or does not know or believe to be true.
029	Obstruction of messenger of Court.	Magistrate's Court Act, 32/1944 section 107.
030	Resisting, obstructing or assaulting Police Officers in the execution of their duties.	Police Act, 19/1990 section 35, amended by Act 3/1999.
031	Impersonation of a Police Officer.	Police Act, 19/1990 section 33 and 34, amended by Act 3/1999.
032	Impersonation of other than Police.	For example Traffic Officer, Health Inspector.
033	Crimes Prevention Ordinance and police offence laws prior to 1910.	Excluding persons found by night under suspicious circumstances.
034	Anatomical Donations and Post Mortem Examinations Act, 24/1970.	
035	Ombudsman Act, 7/1990.	
A4 - FINANCE		
037	South African Mint and Coinage Act, 78/1964.	
038	Income Tax Act, 24/1981.	Amended by: Proc AG 10 /1985 and Acts: 8/1987, 1/1989, 3/1991, 8/1991, 12/1991, 25/1992, 10/1993, 17/1994, 22/1995, 12/1996, 5/1997, 13/1998, 7/1999 and 21/1999.
039	Stamp Duties Act, 15/1993.	Amended by Act 12/1994.
040	Customs and Excise Act, 91/1964.	Amended by Act 20/1998.
041	Import and Export Control Act, 45/1963.	
042	Agricultural Credits Act, 28/1966 and Land Bank Act, 13/1944.	Amended by Acts 15/1992 and 27/1991.
043	Estate Agents Act, 12/1976.	
044	Inspection of Financial Institutions Act, 68/1962.	
045	Financial Institutions (Investments of Funds) Act, 56/1964.	
046	Prevention of Counterfeiting of Currency Act, 16/1965. Read with Act 8/1990.	
047	Building Societies Act, 2/1986.	Amended by Acts 8/1992 and 25/1994.

September 2010 1.

Appendix I

System Development Methodologies

Daemons Software Systems, (2012) define software (or system) development methodology as the framework that is used to structure, plan, and control the process of developing an information system. Many system development methodologies have evolved over the years. Each of these methodologies has its own recognized strengths and weaknesses hence there is no single methodology suitable for use in all projects (CMS, 2008).

A number of technical, organizational, project and team considerations have to be taken into account when choosing the most appropriate methodology for a particular project. After a review of the major prescribed methodologies in context with the crime mapping tool, a combination of linear and iterative methodologies was deemed as appropriate for this project. The review of the methodologies is outlined below.

7.2.1 The Waterfall Method

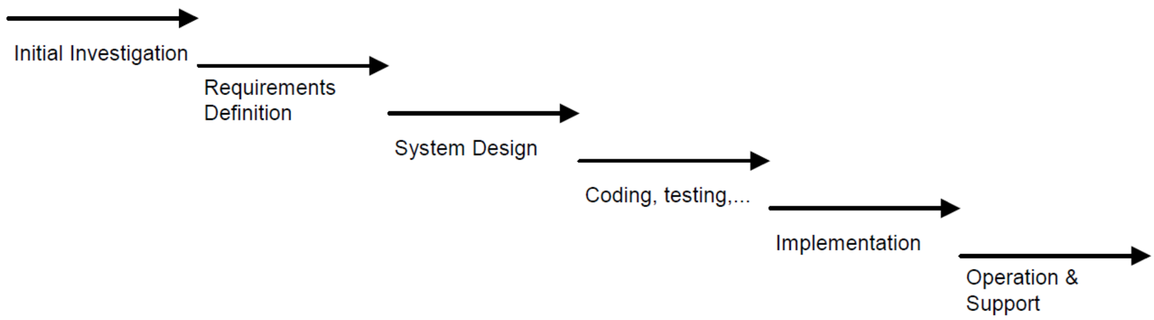

Fig. 4.1: The Waterfall Method (CMS, 2008).

Pune University defines the waterfall method "as a sequential design process, often used in software development processes, in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of Conception, Initiation, Analysis, Design, Construction, Testing, Production/Implementation and Maintenance". This waterfall method is a classic example of a linear and sequential method of software development. Once a phase of development is completed, the development proceeds to the next phase and there is no moving back to the previous phase.

Some highlights of the principles of the waterfall method include the division of a project into sequential phases. These phases have very little overlap and some splash back is acceptable between them. This method's emphasis is on planning, time schedules, target dates, budgets and implementation of an entire system at one time. Tight control should be maintained over the life of the project through the use of extensive written documentation, as well as through formal reviews and approval/signoff by the user and information technology management occurring at the end of most phases before beginning the next phase (CMS, 2008).

Strengths of the Waterfall Method

CMS (2008), points out the strengths of the waterfall method as:

"1. Ideal for supporting less experienced project teams and project managers, or project teams whose composition fluctuates.
2. The orderly sequence of development steps and strict controls for ensuring the adequacy of documentation and design reviews helps ensure the quality, reliability, and maintainability of the developed software.
3. Progress of system development is measurable.
4. Conserves resources."

Weaknesses of the Waterfall method

The Waterfall method is not without weaknesses and CMS (2008) lists them as:

"1. Inflexible, slow, costly and cumbersome due to significant structure and tight controls.
2. Project progresses forward, with only slight movement backward.
3. Little room for use of iteration, which can reduce manageability if used.
4. It depends upon early identification and specification of requirements, yet users may not be able to clearly define what they need early in the project.
5. Requirements inconsistencies, missing system components, and unexpected development needs are often discovered during design and coding.
6. Problems are often not discovered until system testing.
7. System performance cannot be tested until the system is almost fully coded, and under-capacity may be difficult to correct.

8. Difficult to respond to changes. Changes that occur later in the life cycle are more costly and are thus discouraged.
9. Produces excessive documentation and keeping it updated as the project progresses is time-consuming.
10. Written specifications are often difficult for users to read and thoroughly appreciate.
11. Promotes the gap between users and developers with clear division of responsibility.”

Situations where most appropriate:

According to CMS (2008) the use of the waterfall model is most ideal where the:

“1. Project is for development of a mainframe-based or transaction-oriented batch system.
2. Project is large, expensive, and complicated.
3. Project has clear objectives and solution.
4. Pressure does not exist for immediate implementation.
5. Project requirements can be stated unambiguously and comprehensively.
6. Project requirements are stable or unchanging during the system development life cycle.
7. User community is fully knowledgeable in the business and application.
8. Team members may be inexperienced.
9. Team composition is unstable and expected to fluctuate.
10. Project manager may not be fully experienced.
11. Resources need to be conserved.
12. Strict requirement exists for formal approvals at designated milestones.”

Situations where least appropriate:

However, under the following scenarios, the waterfall method would not be ideal (CMS, 2008):

“1. Large projects where the requirements are not well understood or are changing for any reasons such as external changes, changing expectations, budget changes or rapidly changing technology.
2. Web Information Systems (WIS) primarily due to the pressure of implementing a WIS project quickly; the continual evolution of the project requirements; the need for experienced, flexible

team members drawn from multiple disciplines; and the inability to make assumptions regarding the users' knowledge level.

3. Real-time systems.
4. Event-driven systems.
5. Leading-edge applications."

7.2.2 Iterative

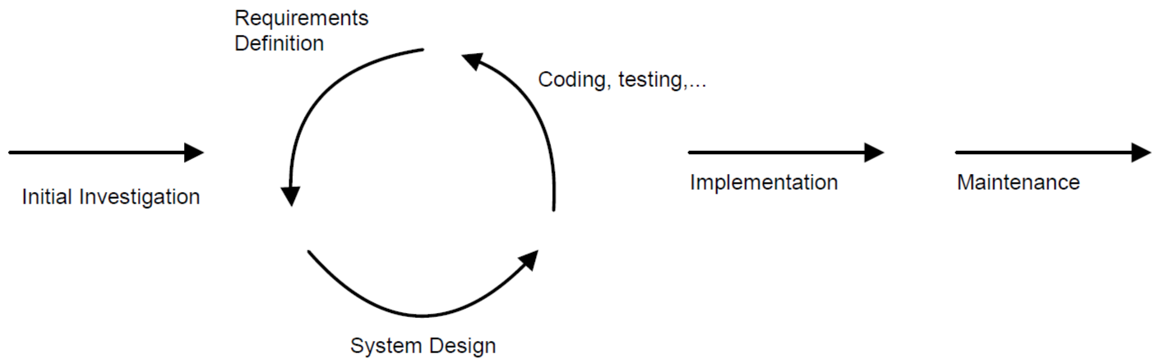

Fig. 4.2: Prototyping (CMS, 2008)

According to CMS (2008), prototyping is a method whereby small-scale mock-ups of the system are developed following an iterative modification process until the prototype evolves to meet the users' requirements.

Advantages of Prototyping

The following are the advantages as described by Freetutes website (Freetutes, The tutorial website, n.d.).:

- "Users are actively involved in the development;
- It provides a better system to users, as users have natural tendency to change their mind in specifying requirements and this method of developing systems supports this user tendency.
- Since in this method a working model of the system is provided, the users get a better understanding of the system being developed.
- Errors can be detected much earlier as the system is mode side by side.
- Quicker user feedback is available leading to better solutions."

The productdevelop.blogpost.com has identified the following as advantages of prototyping model:

- “It is good for developing software for users who are not IT-literate;
- Quicker user feedback is available leading to better solutions;
- Reduces time and costs;
- A system requirement specification will be frozen after obtaining the feedback from the user, this is to make sure the new requirement is considered and incorporated;
- The prototyping model is useful in situation where requirements and user’s need are not clear or poorly specified. It benefit is that it helps in specifying the requirement and it can also incorporate new technologies that are identified during the project. The model provides the system is a short time and reduce the cost needed for the project.”

Disadvantaged of Prototyping

The following are the disadvantages as described by (Freetutes, The tutorial website, n.d.).:

- “The method leads to implementing and then repairing way of building systems;
- Practically this methodology may increase complexity of the system as scope of the system may expand beyond original plans.”

The productdevelop.blogspot.com has described the following disadvantages of prototyping development model.

- “That customers (users) could believe the prototype as the working version;
- Users can begin to think that a prototype, intended to be thrown away, is actually a final system that merely need to be finished or polished;
- Excessive development time of the prototype: this happens if the developers lose sight of the fact that prototyping is supposed to be done quickly, and they try to develop a prototype that is too complex;
- Expenses of implementing prototyping- that the start-up costs of building a development team focused on prototyping may be high.”

When using prototyping one runs a risk of the users thinking the prototype is the final system that merely needs to be finished of polished. This misconception can lead to users expecting the prototype to accurately model the performance of the final system when this is not the intention of the developers.

Prototyping has been found to be very effective in the analysis and design of online-systems, especially for transaction processing, where the user screen dialogs is much more in evidence. The greater the interaction between the computer and the user the greater the benefit is that can be obtained from building a quick system and letting the user play with it. However, prototyping has been found unsuitable for the development of systems with little user interactions, such as batch processing or systems that mostly do calculations. This is because sometimes the coding needed to perform the system functions may be too intensive and the potentials gains that prototyping could provide are too small (Crinnion, 1991).

Appendix J

SAICSIT PAPER (PRE PRINT)

Toward an mPolicing Solution for Namibia: Leveraging Emerging Mobile Platforms and Crime Mapping

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ABSTRACT

In this paper we present a system designed for the Namibian Police to empower officers to create and maintain crime and accident reports more effectively and more efficiently by improving the current paper based procedures. Beyond the digitalization of existing forms, the activity of creating new reports in the field is enhanced through a mobile application that utilizes built-in sensors in mobile devices such as tablet computers and smartphones to capture location and other contextual information together with rich media such as pictures and videos. A central repository is used to allow fast and easy access for relevant stakeholders, and we demonstrate how this repository can be used together with GIS data to create powerful crime mapping tools. While still in the early phases we demonstrate the feasibility of the proposed solution through implementation of prototypes and isolated studies of core modules in the architecture and a first iteration of the interface design based on interviews with stakeholders in the organization and analysis of the current workflows.

Categories and Subject Descriptors

H.2.8 Database Applications: *Spatial databases and GIS.* H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Human Factors.

Keywords

Mobile, context-aware, crime and accident reporting, mobile data capture, crime mapping, ePolicing, ICT4D, HCI4D.

INTRODUCTION

Extensive use of ICTs in police work is common in developed countries and is also finding its way into developing contexts such as many African countries. Often this is manifested in integrated solutions that aim to streamline and support the workflows of the police force through digitalization of knowledge and information with regards to police matters and procedures. Ideally this enables more effective and efficient police work through optimized access to relevant information with regard to each case and facilitating communication among relevant stakeholders. Sometimes such solutions further extends into what is commonly (yet ambiguously) referred to as "ePolicing" or electronic policing. Often so-called ePolicing systems include citizen information and services. For instance, the LAPD (Los Angeles police Department) in California has implemented a website onto which citizens can sign up to receive e-mails with new police information such as newsletters, crime trends as well as crime mapping 0. Thus, ePolicing in the broader sense has many dimensions including community involvement and public dissemination of relevant information, but in this paper we mainly focus on a few of the core police activities, namely crime and accident reporting and how such reports can be tracked and used by different people in the organization. Specifically, we will discuss how systematic reporting directly from the field using mobile devices can be integrated with geo-spatial data through GIS system to provide timely overviews to decision-makers at various levels in the organization.

Crime and Accident Reporting

Crime and accident reporting is a basic function and starting point for many processes in police work They cover a wide range of case types such as burglary, theft, vandalism, assault, murder (crimes) and car crashes (accidents). Often this involves field officers arriving at the scene of the incident and collecting evidence such as materials, names and addresses of involved parties and statements from witnesses. This will often prompt a formal case to be opened and from this procedures will be followed to resolve the issues with the involved parties.

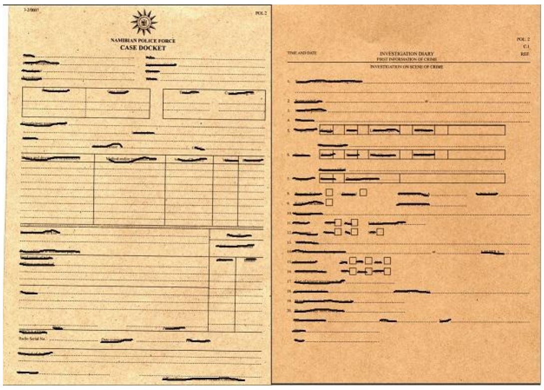
NAMIBIAN POLICE FORCE
CASE DOCKET
[redacted]
INVESTIGATION DIARY
[redacted]

Figure 1: Case Docket to be filled out during the start and processing of a crime report (fields anonymized).

Through formal and informal interviews with police officers at different levels and through analysis of template documents currently in use we have mapped out essential parts of the workflow of Police officers with regards to crime and accident reports.

The Namibian police currently collect crime data with the use of paper forms as illustrated in figure 1. These so-called 'dockets' are then circulated around to members of the police with the authority to validate the data as well as to make these data forms available to all stake holders, e.g. the lawyers, insurance companies and for the police statistics department to make summaries and reports. Afterwards, the data is then stored in central filing facility called the Crime Register.

ePolicing for Africa

To our knowledge, few large scale systems have been embraced by countries in Africa so far. As one of the few, Nigeria has implemented an ePolicing solution "as part of efforts to combat crime and meet up with world's standard of policing ... to enable the average policeman and Nigerians access its data base from any part of the country" 0. According to government officials, ePolicing in some form is currently in the process of being implemented in Namibia, and according to the same sources, the Namibian Police force is currently undergoing training for ePolicing to enhance crime prevention, detection and control 0. From our interactions with various stakeholders in the Namibian Police system there is generally is a positive attitude towards technology, and it is thus timely to investigate how such systems should be designed, implemented and deployed.

In this paper, we argue that Namibia and other emerging economies have a chance of leapfrogging the incremental technological development that many Western countries have gone through and learn from these experiences. Especially how organizations can move from paper-based systems towards more advanced ICT solutions to optimize the efficiency and effectiveness of policing by leveraging the emerging mobile platforms.

We look at crime mapping as an example of state-of-the-art crime solving technology used in the developed countries that can readily be implemented in developing countries together with a mobile crime and accident reporting system without the need for advanced infrastructures. To our knowledge crime mapping has not yet been implemented and used in Africa, but there are many other examples, e.g. the CPS system 0 where crime mapping has been deployed in an ePolicing solution through a web application providing information to the public on the locations of certain crimes. This web application is displaying the different crimes with unique colors to allow an easy overview. That information is derived from a central server onto which crime data is stored. The end user has the choice of choosing exactly which types of crimes s/he wants to see, from which area and for which period 0.

Crime Mapping

Both location and time play a vital role in understanding crime and how crime can be tackled. The urge to understand crime locations and their spatial dimensions to crime began to be more fully explored during the late 1970s 0. Geographic Information Systems (GIS) can be used as powerful tools for tracking crime trends and highlighting crime hotspots. Visual information in the form of maps overlaid with thematic data, are defining concepts of geographic information systems, making GIS a valuable tool for crime fighting 0. A GIS is a system of hardware and software used for the storage, retrieval, mapping and analysis of geographical data. It is a tool for revealing what is otherwise invisible in geographical information 0. In order to recognize patterns of crime that police officers may not necessarily be aware of, GIS is employed to map crime. GIS allows effective integration and analysis of data leading to the identification, apprehension, and prosecution of suspects; it also helps the law enforcing agency to work against crime through effective allocation of resources 0. Law enforcement agents would use GIS to visualise, analyse and explain the criminal activities in a spatial context. When analysing crime data, the effect of the physical layout of the areas, proximity to various services and land forms should be taken into account since these natural and manmade factors influence criminal behaviour.

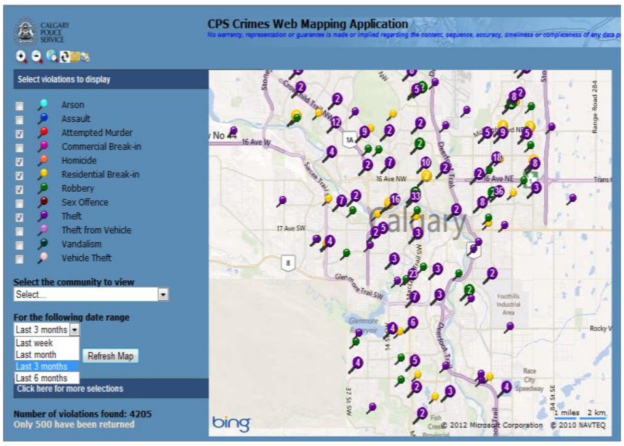

Figure 2: Screenshot from the CPS application which is managed by the Calgary Police Service 0.

Analysing the relationship between crime and place is not a new phenomenon. In the 19th century, scholars focussed on the variation of crime in large administrative districts like provinces and countries. At the turn of the 20th century, a group of sociologists took the initiative to undertake new research on urban problems which centred in part on crime. Thus crime and place research was now focussing on comparisons within cities 0. Techniques that can be used include identifying patterns and concentrations of crime, exploring the relationship between crime and the environment including the compelling socio-economic aspects. Analysis of individual criminal events and of individual persons, building or street victimization studies provides a starting point for fighting crime but for practical purposes individual criminal events must be aggregated in order to assess patterns and devise methods for addressing them

Law enforcement is a relative latecomer to the use of GIS 0. Typical use entails using base map components such as streets, land parcels, and aerial photography. The addition of dispatch records, incident records, citations and intelligence reports would then follow. This will not only uncover the patterns in collected crime data and drive new ways to view the criminal justice system, it will also change the way many in criminal justice are doing business. Crime analysis is greatly advanced by having automated crime maps that are easily updated and mapped using customisable search algorithms which are tailored to the specific needs of a user 0. The United States' National Institute of Justice championed the use of crime mapping in other countries like the United Kingdom, Australia, South Africa and across South America 0. Applications of crime mapping include recording and mapping of police activities, information dissemination in the police force, identifying hotspots, monitoring the impact of crime reduction initiatives and aiding decision making in resource allocation.

Other developed countries have also adopted Crime mapping as part of their overall set of crime fighting tools. The New South Wales Police Service in Sydney, Australia, projects maps of crime distribution onto a large screen for management and senior police executives to determine policing strategy 0. In the UK, the Crime and Disorder Act (Home Office 1998) makes it mandatory for every police service and local authority to produce a crime and disorder audit 00. This has had a significant role in bringing crime mapping to the forefront in the crime and disorder arena.

From this it follows that the active use of crime mapping even in modern countries have only relatively recently taken off. Developing countries such as many African countries that would implement crime mapping systems based on these experiences would essentially have the cutting-edge tools for crime solving, decision and policy making. While the emphasis here is on crime, the mapping of e.g. road accidents with other GIS data pointers would also be a powerful tool for decisions makers, e.g. changing of speed limits, redesign of road grid or pre-emptive actions before flooding of roads.

TOWARD A MOBILE POLICING SOLUTION

We are exploring mobile solutions for many reasons, but mainly it is due to the ubiquity and mobility of these computing platforms. A mobile solution enable law enforcement officers to report crime on location and incident details in real-time using GPS and wireless data networks to potentially enable quick and accurate response to crime scenes and accidents. The GPS allow the officers to capture accurate co-ordinates for the incidents and the networks allow the information to be uploaded back to the central database in near-real time. Of course, the uploading of information can also be done at the office when the officer returns. The use of mobile devices thus can lead to benefits such as improving the end-to-end cycle of reporting an incident to taking action. Capturing and storing data with geographical metadata would enable the data to be analysed to identify trends within and across districts boundaries 0.

- Modern mobile devices also have many functions that can aid in the data collection process. Some of these functions are:
- Camera for taking pictures and video for later evidence, e.g. of cars involved in a car accident.
- Microphone and voice recorder for taking statements from witnesses at the scene of a crime
- GPS for exact location of the crime, but also for geo-referencing the collected digital evidence.
- Wireless networks for uploading and downloading data from the central servers
- Relatively long battery time life possibility for recharging though a car charger

These functions will be used to ensure that all the necessary data pertaining to the crime and crime scene is collected.

Feasibility through Available and Affordable Mobile Technology

For the sustainability and scalability of the solution it is imperative to consider the cost-effectiveness. While the added gain and effectiveness has been argued above the cost perspective must also be considered. The solution calls for a certain sophistication of mobile devices and more than a few devices to be aquired. However, all trends point towards more powerful devices and lower costs; a development that has already spawned a new wave of low-cost high-capability devices 0 that are now finding wheir way into emerging markets. Thus we have reasons to believe that the near-future will bring a plethora of affordable and useful mobile devices to the Southern African markets.

In countries like Namibia, the mobile networking infrastructure is there but data connectivity is still prohibitively expensive. Again there is reason to be hopeful for a near-future with data plans and air time that are more affordable. However, the situation forces us to design the system to be able to operate in an environment of slow, costly and sporadic network connections.

Related Work

Smaller mobile devices like tablets and smartphones are highly suitable for field work where the officers need to move around and interact with people and objects. Mobile data capture has been used in African countries in many other application domains such as healthcare, education, business, rural innovation and governance.

ODK (Open Data Kit) 0 is a prominent example of an open source solution that have been applied in such domains with success. It is designed to be generally applicable, easily configurable and deployable way to collect field data, but for our purpose the problem with ODK is that data handling is a one way process, i.e. field data is collected through forms and uploaded to central repositories. It is not possible to interact directly with this data again or share it between multiple mobile clients. This seems to be a general tendency among tools and platforms developed for mobile data capture, including more sophisticated tools with automated capture of contextual data through the built in sensors, such as MyExperience 0 and RECON 0.

While we can learn much from the experiences of these projects in terms of the actual field data capture process, we will need rethink how such data can be shared and continuously updated with multiple stakeholders involved. We also need a specific and integrated solution that supports the workflow of the police officers.

Figure 3: Affordable (US$50-100) "low-end high capability devices" with GPS, camera, microphone and other sensors.

Methodology

We are applying an iterative user-centered design methodology in which we strive to involve the intended end-users as early and often as possible to ensure that the eventual system will be acceptable and suitable. For each iteration we develop prototypes with increasing fidelity and functionality and in this paper we report only up until the first design of the mobile user interfaces as a mock-up to communicate the design and intended functionality.

We have done requirements gathering and analysis of the current work flow with regards to crime and accident reporting. For this we have used semi-structured interviews in formal settings and informal open interviews. Police officers have been interviewed face to face to help the research team understand the current processes in order to come up with a better way of collecting data with the use of mobile devices without hindering the police mandate. The formal interviews were scheduled with the interviewee and after an interview is conducted, the data collected is then documented and forwarded to the interviewee to verify.

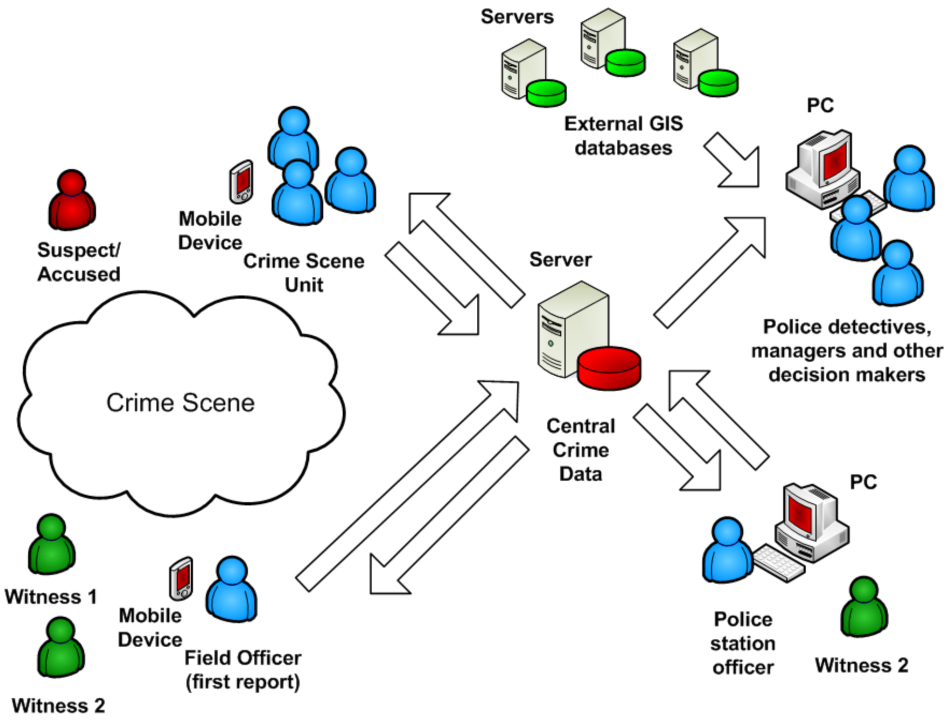

Figure 4: Conceptual System Architecture

SYSTEM DESIGN AND ARCHITECTURE

The main objective in this project is to gradually migrate from the current paper-based solution to an electronic solution and to introduce mobile interfaces for field officers to improve the effectiveness and efficiency of their work. For this purpose we are developing an electronic mobile system, CARAT (Crime/Accident Reporting And Tracking). It is designed to collect crime and accident data at any scene of incident. by used by both regular and specialized field police officers who collect data from the crime scene and file the initial report (docket).

Concept

The proposed solution incorporates the use of mobile devices into a holistic system for crime and accident reporting as shown in figure 4. As the paper based solution is implemented throughout the organization the procedures have been adapted and optimized for this. Thus, our solution for digitalizing crime and accident data has to be incorporated throughout as well. The emphasis in this paper is mainly on the mobile components and how crime mapping can be introduced with the use of geo-spatially tagged data.

With existing paper based procedures we have identified a number of inadequacies and threats:

Risk of losing dockets.

Lack of proper version control of docket information. Various officers are able to edit the document leading to potential errors.

Inability to quickly locate a desired docket due to the size of archives and physical distribution of the dockets.

Inability to search for dockets matching a specified criteria.

Time delay in transferring dockets from one station to another.

Dockets are exposed to various physical hazards such as fire and flooding.

Inability to capture and store statistical data for decision-makers. Information such as crime/accident patterns and trends within certain geographical areas are not captured by the paper-based system. Such information resides with the police officers who have been stationed to that area over a period of time. If the officers retire this information is lost and may affect the effectiveness of crime solving. Time delays in collecting data.

Furthermore, the latency in sharing information through physical documents imposes delays on the decisions making abilities of police hence affecting their response and preemptive abilities regarding crimes and accidents.

The above issues are some of the main reasons for making the records electronic and accessible to the right persons throughout the organization. It also underpins the utility of crime mapping as a tool for extracting patterns in the occurrence of crimes if a central electronic crime repository can be established (as discussed in section 1.3).

Furthermore, CARAT allows the collection of richer data sets than normal procedures through use of the phone sensors in addition to human text input fields of the dockets. This is essentially additional evidence and can be captured at the scene of the crime or accident by the first-responding unit. Such rich data includes:

Pictures: To show immovable evidence from the scene, e.g. a broken window, beaten victim, or dented car.

Videos: Recordings of the scene while the police officer explains or the victim explains what occurred. Videos can also be used for recording of statements from witnesses.

Audio recordings: Recordings of witnesses - with build in audio processing this could be used to allow anonymous statements.

Richer data can allow for better scene reconstruction, i.e. the crime scene can be reconstructed during trial or even for other stakeholders like the insurance companies for claims. The additional data collected with the mobile device (such as pictures, videos, statements and location information) should prove to be more descriptive than data collected only through paper forms.

Also, for the tracking of reports and procedures following the initial reporting of an incident, the proposed solution has a number of benefits throughout the organization:

Access: Easy access to the data for those authorized enabling better decision making.

Search: Complex queries and matching of records in the database.

Identification of crime patterns: due to all the information being electronic, it will be easier to identify the witnesses who keep appearing at the same scene, suspects leaving signatures and similar venues of crime.

Analysis: With backend logic it will be relatively easy to conduct real-time analysis of the data collected which will ensure fast availability of statistics and reports thus empowering detectives to make more informed decisions during their investigations.

Process stability: Control measures can be put in place to ensure that the actions to be taken are part of a process and that process has to be followed properly otherwise some actions will not be executed. For example the ability to track modification of electronic docket information.

Effective deployment of resources: With the available statistical information from CARAT , decision makers will be empowered to deploy police resources in a more efficient and effective manner. It could also aid road authorities in decisions concerning the establishment of traffic control measures in high accident areas.

From a data integrity and reliability point of view, the data will be stored in a very secure database system which will be backed up according to the policies implemented by the Namibian Police and will be validated accordingly. Also, all the officers who work with this data will have user accounts and an audit process will run in the background to keep record of all the actions taken towards the data as well as the user account of the officer who took the action and when.

System Architecture and Main Components

The system will be comprised of the following combination of mobile and computer technologies to facilitate more efficient crime and accident data capture as shown in figure 4:

Mobile Devices

Central Crime Database.

External GIS databases.

PC Terminals.

Data communication framework

The overall goal is to introduce these technologies at various points in the crime/accident reporting workflow in order to make it more efficient. Mobile devices will be used to capture rich data from crime/accident scenes by field officers. They will also serve as information portals for officers on the field to aid in their analysis of the situation. Once information has been captured it will be relayed back to the central crime database for purposes of record keeping and information sharing. Initially it will not replace paper-based systems but will work alongside them. Police officers at the station will have PC terminals allowing them to access and update captured crime/accident data throughout the course of the investigation. Once all this information is in place the crime/accident data will be combined with data from external GIS Databases thus allowing a visual overview of crime/accidents in a specific area. This visual overview will also be available as a networked application accessible via authorized pc terminals on the network. All of the communication will do done via the PolyMORF platform (section 3.6).

Mobile Devices

Mobile devices will be used to improve the field reporting aspect of this whole process. Situational information is usually gathered by field officers through the use of paper based methods (forms, etc.). As said, these are limited in that they cannot capture data such as images, audio and video.

Mobile devices on the other hand through various sensor technology (accelerometer, camera, GPS) are able to capture rich media and sensor data and are therefore appropriate for enhancing the task. For this project mobile devices using the android OS are the focus as they provide an extensive API for interacting with the devices various sensors and support a very large range of devices. These devices will contain applications that mimic and improve upon forms used to gather regular situational information and images, recordings and etc. Once captured, data is then transmitted via Wifi to the crime database server.

Furthermore, these mobile devices will serve as information portals for the crime scene unit as they further investigate the reported crime. This will allow them to have more contextual information regarding the crime, accident, victim and/or suspect being dealt with. Information such as victim or suspect's past incidents with the law and frequency of crime /accidents in that area will be available to field officers on scene.

PC Terminals

At least two PC terminals running custom developed applications will be present at the station. Applications running on these terminals will provide interfaces similar to paper-based forms allowing a verification and updating of mobile reports . Additionally, PC terminals will also serve as a information access point for officers and detectives to the case data within the server. Detectives will be able access all relevant case information (such as photo evidence, witness interviews and observation notes) during the investigation process. Using the main database, the detective can access victim's or suspects history or past cases related to the same crime etc.

Central Crime Database Server

As stated earlier this crime database will be used as a central repository for all crime/accident related data between all stations and units in the system. Information captured via mobile devices will be transferred to this crime database through secured networks. For our test system, the crime database server consists of a webserver hosting custom developed web services connected to a postgresql database. The web server hosts applications that will receive data captured from mobile devices, process them and store them in the database. The hosted web applications will also provide secure access to all crime/accident data for authorized police personnel. This will be done through special terminals made available at the various police stations as explained above. Furthermore, the crime database will also store and maintain GIS data related to each crime. This will make valuable information such as crime trends in certain geographical areas available to investigators and decision makers.

PolyMORF platform

The PolyMORF platform is designed for facilitating communication between web servers and Android devices. It is being developed for tackling a number of local aspects such as lacking stability of mobile data networks and data tariff challenges present in Namibia. The architecture also aims to provide libraries/components to support the rapid development of similar Android applications (figure 5) that consume data from web services. It is the enabler for the communication between the mobile data capture devices and the crime database server. This platform consists of a web server component designed to expose data contained within the web server where it is deployed and a network-sensitive Android component designed to intelligently communicate with the server component. Both component are provided to developers , who can use them to rapidly develop a variety of applications. Data exchange between the server and the android device is done via the use of JSON (JavaScript Object Notation) objects over https. JSON was chosen as a result of its small footprint, thus resulting in a cost-efficient communication.

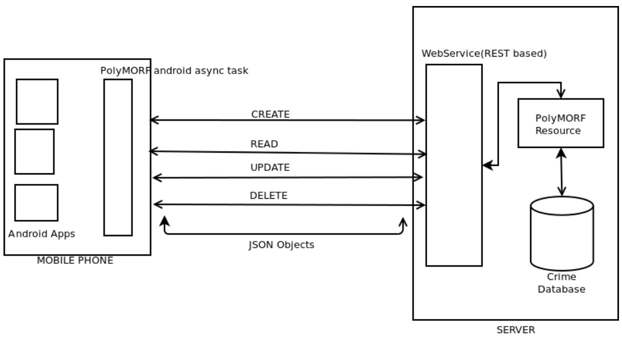

Figure 5: Communication over REST with PolyMORF Client and Server components

GIS Server

The GIS server is integrating the GIS data from external sources. Currently we are operating with a number of types of information that can be used to improve the crime mapping. Table 1 lists some key GIS data and the source where it can be obtained.

GIS Data	Source
Household Income	National Household Income Survey
Zoning	City Town Planning Maps
Population Demographics	National Population Census
Street Maps	City Street Maps

Schools	City Street Maps
Home Ownership	City Valuation Roll
Street Lighting	City Street Maps
Sheebens	City Town Planning Map
Boundaries of Police Districts	Police District Maps
Public Open Spaces	City Town Planning Maps
Location of ATM's	Banks
Digital Terrain Models	Available for download from the internet

Table 1: Useful types of GIS data and where they can be obtained

A GIS primarily handles spatial data. Geospatial data is positional data collected about geographical phenomena. Assigning a location component to crime data will enable the overlaying of this crime data with base maps and other geographic data of the area where the crime data is associated 0.

Chief amongst the geographical data would be the population demographics of the area. Demographics are the most recent statistical characteristics of a population. Commonly examined demographics include gender, race, age, disabilities, mobility, home ownership, employment status, etc. 0.

Using GIS, crime analysts can overlay other datasets such as census demographics, locations such as pawn shops, schools and industrial complexes to better understand the underlying causes of crime and help law enforcement administrators to devise strategies to deal with the problem. GIS is also useful for law enforcement operations, such as allocating police officers and dispatching to emergencies.

The Digital Terrain Models would be used in analysing the location of the crime in 3-D. Possible witness positions would be tested in order to be sure that the timing of events and lines of sight are consistent 0.

Geographic profiling is a criminal investigative methodology that relates the locations of a linked series of offenses to determine the most probable area an offender resides in. Coupled with both qualitative and quantitative methods, geographic profiling assists in understanding spatial behaviour of an offender and in focusing the investigation to a smaller area of the community. It also helps investigators to prioritize information in large-scale major crime investigations that often involve hundreds or thousands of suspects and tips 0.

Several fields of study focus on the relationship between crime and the location. Environmental criminology focuses on criminal patterns within particular built environments and analyses the impacts of these external variables on people's cognitive behaviour. Another application which looks at situational factors is the Crime prevention through environmental design (CPTED). This is based on the idea that situational factors such as poor lighting can make crime more likely to occur at a particular time and place (Birzer & Roberson, 2012).

PRELIMINAIRY RESULTS

In this section we report preliminary results from implementing and studying core components of the CARAT system: data capture through mobile devices, the communication framework and the crime mapping server and interface. We also discuss the first iteration of the mobile interface design through a mock-up prototype

Interface Design

From the information gained through interviews and analysis of official documents we have completed the first iteration of the mobile interface design. It is a hierarchical structure of input screens that allow the user to fill in all the segments of the existing forms, but also allows for extra data and use of sensors to create richer representations of the crimes and accidents.

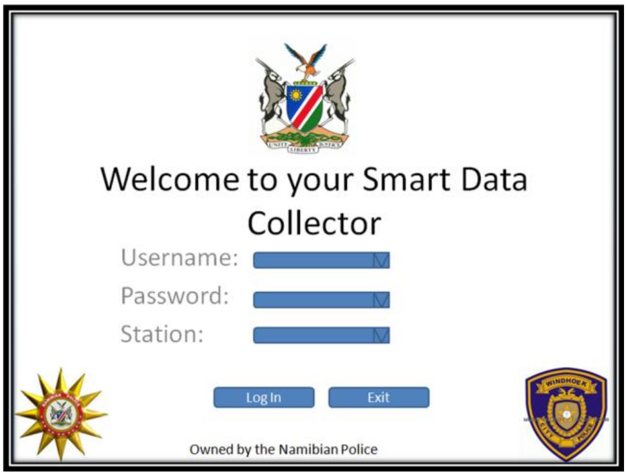

Figure 6: Login/authentication Screen.

Figure 6 shows the design of the first screen which authenticates the field officer so that he can access or enter data. A uniqe username and password should be provided to all field agents who need to collect the data. This will enable the system to keep record of all the field agents who are collecting data and also to keep record of all the changes they make to the data, and for tracking purposes it will serve to ensure that an agent can only access reports that he or she is authorized to see.

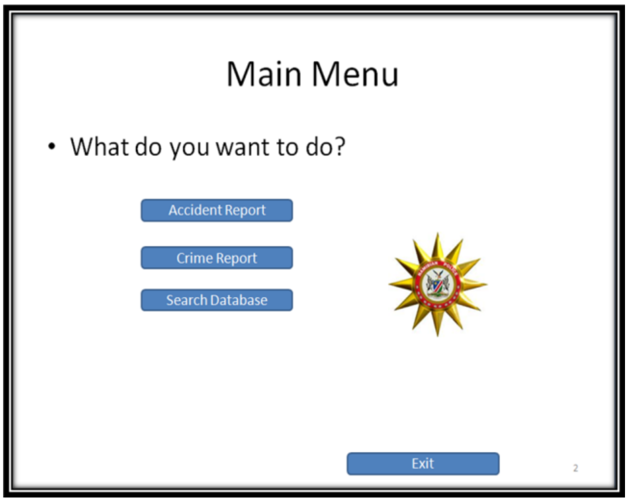

Figure 7: Main menu (simplified)

Once the field officers are authenticated they will be presented with the main menu screen (figure 7) which will then ask them or give them the choice of action next, for each choice a new screen will pop up with further details on how to continue or what fields they need to fill. If they do not wish to continue, they can exit the application.

Once the field officer chooses e.g. the crime report (CR), he or she proceeds to an overview of the components that make up the crime report as shown in figure 8. The officer then goes through these in sequnce as all these field need to be filled to make the crime report complete. If they wish to continue later, they can exit the application, but the status of that specific report will specify pending.

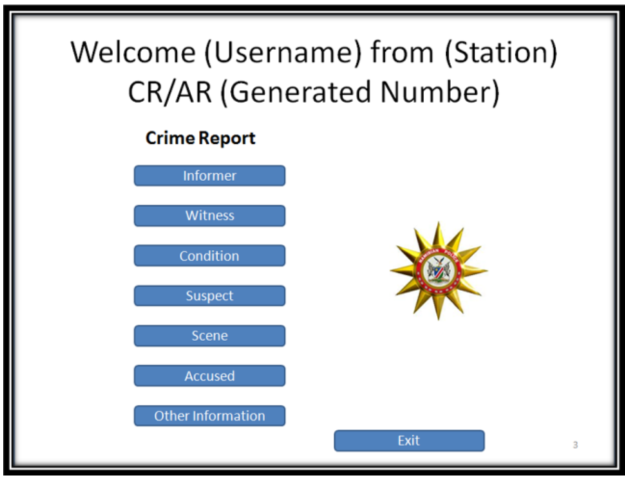

Figure 8: Screen for interacting with crime report data categories.

One of the components that need to be filled out as part of the crime report is witness details as shown in figure 9. As can be seen, this screen allows the field officer to not only record and write down the witness's statement but also to take a picture of the witness with the front camera of the mobile device. Also the application allows the field officer to check the witness's ID number against the central database, and if the witness already exists in the database, all the fields will be filled automatically and the field officer will only confirm if those details are still the correct. This empowers the field officer to do his work more efficiently. Once the field officers are done capturing the data, they save it and go back to the crime report list of components and choose one to continue capturing until the crime report is complete. For inputting other details such as place of a crime scene, the GPS of the device is used to automatically add the location and potentially street address to the form.

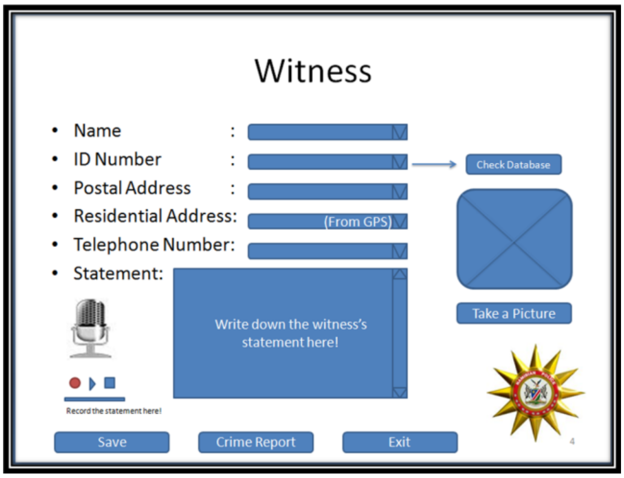

Figure 9: Witness data input with mix of user input, input through sensors (such as GPS) and input through media capture such as audio (microphoe) and picture (camera).

Mobile Data Capture Prototype

We rely on results from a parallel research project to test whether it is possible and feasible to gather larger amounts of geo-tagged data in the field through mobile devices. The context and media capture platform upon which we are building the CARAT mobile tool is the same as the CARACAL tool 0. CARACAL has been implemented and tested in field trials for capturing information through a number of sensors that we will need. Figure 10 shows and example of field data capture where the picture taken is augmented with contextual information from the sensors of the phone, e.g. the electronic compass in combination with the tilt sensors/accelerometers telling which angle the photo was taken from and the GPS giving the specific point. It also allows for user specific input before saving all the information together on the phone.

As mentioned, the CARACAL tool has been tested and evaluated in the field already for capturing and tagging various objects, places, points, paths and spaces of interest to rural indigenous communities. It builds on a generic context-capture architecture inspired by the RECON tool 0, and can be applied to both passively and actively capture information about a wide range of contextual information through the sensors of the mobile device. Figure 11 illustrates the resulting dataset from mapping out a small village. Each point represent some media captured and/or user notes about the content. With a working prototype of the platform, we believe the same approach can be applied for the CARAT tool.

Figure 10: CARACAL tool in use for tagging objects and places in rural areas of Namibia (from 0)

While the full details and analysis of this study is outside the scope of this paper, we deem that the Android operating system with CARACAL as middleware will be a viable platform for the mPolicing solution, as it is flexible, robust allow capturing all types of data with automated context-aware tagging of meta data in both urban and rural settings.

Figure 11: Results of a capture session in the rural village as visualized in Google Earth™. Each red arrow presents a data point with location and direction. (insert shows typical local building made from cow dung and metal) (from 0).

PolyMORF Prototype

The PolyMORF platform (Poly Mobile Online Resource Framework) as introduced earlier is the base platform for communication. It provides the mechanism for sending data collected by the mobile devices and “pushing” it to the database. Though still in the early stages of development it supports the pushing and retrieving data from the database through mobile devices on a local server hosted at the Polytechnic of namibia. The platform consists of a mobile library called the PolyMORF client (for android devices), a web service and a library for interacting with the database called the PolyMORF Resource.

PolyMORF Resource

The platform was developed with re-use as one of its primary goals, in order to achieve that communication between the mobile client, web service and database needed to be achieved. The PolyMORF Resource provides uniform access to data stored in any table within the database through its simple accessor methods, such as inserting and deleting data.

WebService

The web service is designed according to the principles of REST as it advocated the use of Http request methods for predictable and uniform access to a web services data making it extensible for future components, such as interfaces for the general public to report crimes and accidents.

PolyMORF Client

Applications running on the mobile device act as both data providers and consumers for the web service. All this is done through the PolyMORF Client. It encapsulates all the details involved in communicating with the service by providing a simple set of methods. Through these the client applications are decoupled from the web service. Details such as establishing the connection , and interacting with the web is encapsulated so that developer do not need to worry about this.

GIS Server and Interface Prototype

Figure 12 shows our current prototype for the Crime Mapping. As a proof-of-concept we have integrated fictional crime data (containing coordinates of the crime location) and geographical data into a geo-database.

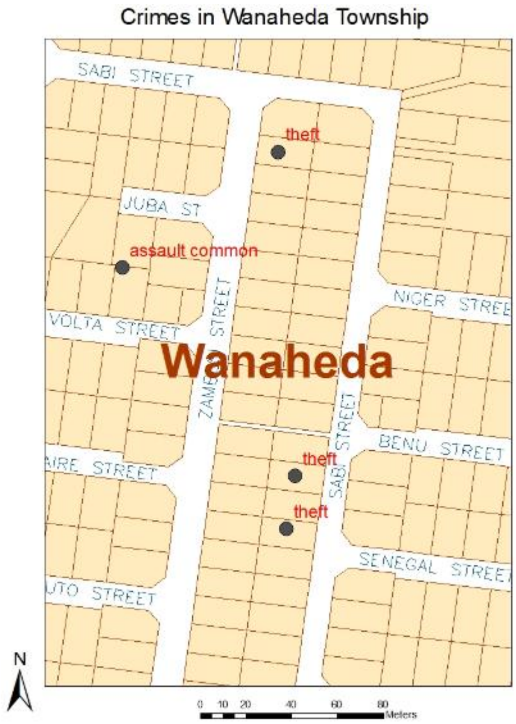

Figure 12 Sample Crime Map from the implemented prototype for part of the Wanaheda Township in Windhoek, Namibia (fictional crime data used for illustration).

The geographical data consists of the street maps of Windhoek as well as the township boundaries. Using ArcGIS 9.3, these three layers are then overlaid to produce the map shown in figure 12. From the map, the most common crime in the area is identified.

We have successfully been able to combine external GIS sources such as the ones listed in table 1 into one aggregate database which can then form the basis for the crime mapping interface. We are currently exploring the interactivity of the visualization interface, i.e. how users can search and browse data for police work such as crime solving or prevention.

DISCUSSION AND CONCLUSIONS

Through this paper we have looked at: crime and accident reporting using mobile devices; the digitalization of a paper based system toward a system with a centrally managed repository; and shown how this together with GIS data can be used to create interactive crime maps to aid decision makers in the police organization.

We argue that if a full scale system were to be implemented throughout a police organization it would have massive benefits over a paper based systems both with regards to effectiveness and efficiency. We also argue that the necessary technology is available and will only get better and cheaper.Thus we believe that moving towards an mPolicing solution is a scalable and sustainable approach - with huge potential in leapfrogging the "heavy" integrated ICT systems and infrastructures that are usually put in place to establish such functionality. But there are still many challenges to be addressed, not least those that arise at the human-computer interfaces.

Through isolated tests and evaluations of a range of prototypes representing the core components of the solution we have demonstrated that the functionality can be implemented, and from this we rationalize that it will be technically possible to implement the overall system. With the positive feedback we have had with various stakeholders in the police organizations, we will continue to work towards and end-to-end prototype that we can evaluate with Namibian Police to see if this can truly improve effectiveness and efficiency.

As stated this is still in a relatively early phase, and there are still many aspects to investigate before we can conclude that this solution would eventually work. We will have to look into usability, robustness, fault tolerance, safety and security of data within and around the system, and then there is organizational, legal, social, cultural, ethical and other aspects that must also be factored in.

The solution is highly modular, so more functionality can be added to support other processes such as dispatching units or coordinating actions. Also, while the CARAT system is now initially designed for the Namibian police, it is highly flexible and can be modified to fit other data collection and visualization settings.

Future Work

We will continue with the user-centered design process to investigate how appropriate user interfaces can be created at the various points of interaction with the system. A participatory approach will be taken as prototype will be iteratively designed and evaluated with relevant stakeholder and will eventually be implemented and evaluated with end-users. Eventually, to better understand how mPolicing can and should be used in countries like Namibia we will implement, test and evaluate functional mobile prototype applications through longitudinal field studies.

It is also planned to expand and elaborate on the interactive interface for the crime mapping prototype and evaluate this with higher level decision makers in the police organization and potentially government policy makers. We are interested in improvements on both the operational (e.g. improving responsiveness to incidents) and strategic (e.g. targeting specific crime types or accident areas) levels.

Furthermore, we will integrate and explore community based reporting with the system to include and empower Namibian citizens in both urban and rural areas. This will require new and different interfaces to be designed from those intended for the police organization. The goal is to open up for localized crowd-sourcing of crime and accident information to aid the law enforcement and other response units (such as ambulances) and investigate how to feed back relevant and timely information through e.g. mobile crime mapping services to improve public safety.

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