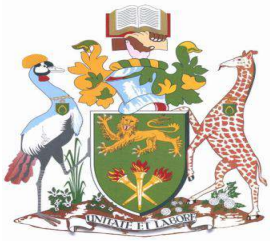

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School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

Volunteered Geographic Information: Application to Community Based Policing

BY

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A Project submitted in partial fulfillment of the requirements for the Degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi

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Declaration

I, Ibrahim Abdi Itambo, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

…… ……

Name of student Date

This project has been submitted for review with my approval as university supervisor.

…… ……

Name of supervisor Date

Acknowledgments

Thanks to Allah, the Almighty, for giving me the opportunity, good health and presence of mind to pursue this project to completion, without whose gracious help it would have been impossible to accomplish this work.

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To my daughters Shamim, Sawdah and son Abdulswamad. You always give me strength and reason to work harder and smarter everyday.

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Abstract

The role of citizens as producers of geographic information has gained considerable focus within the research community in Geographic Information Science. A core outcome of this has been the well grounded concepts of Volunteered Geographic Information.

This study attempted to establish the benefits of employing Volunteered Geographic Information in Community Based Policing initiatives specifically in Nairobi, Kenya.

Available VGI techniques and tools were availed to the research participants. A non commercial and easily accessible mobile application, ODK Collect, was used for crime reporting while a central web platform www.datahub.co.ke, built specifically for this project, used for for data reception, storage and analysis.

The participants were required to report on crime incidents together with the respective geographic coordinates in addition to photographic evidence using especially designed data collection forms. Without any training or official invitation members of the public were able to collect and submit crime incidents.

All systems were fully functional enabling data reception and visualization to be done at near real-time from the server side. The data received was found to be useful, representative and actionable too.

The community was found to be capable and motivated to use VGI. A dataset of reasonable quality was collected from untrained volunteers who were enrolled through social media awareness. Community Based Policing using VGI has been found to be very affordable and practical too.

To get data of the highest quality for community policing, it is therefore recommended to use trained volunteers and take strict control of user input in terms of input data types, location accuracy and submission times. All this using a more simplified and user friendly mobile application than those currently being employed.

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NOMENCLATURE

GIS – Geographic Information System

VGI – Volunteered Geographic Information

f-VGI – facilitated Volunteered Geographic Information

IMEI – International Mobile Equipment Identifier

CBP – Community Based Policing

ODK – OpenDataKit

UGC – User Generated Content

GVA – GeoVisual Analytics

SDSS – Spatial Decision Support Systems

GUI – Graphical User Interface

QA – Quality Assurance

CHAPTER 1: INTRODUCTION

1.1 Background

GIS is always envisaged as contributing to organizational effectiveness through the provision of basic data as well as stimulating more complex analyses which would enhance decision-making capabilities at operational, managerial and strategic levels. Fundamental to such claims is the capacity of GIS to integrate data sets from a wide variety of sources. As a result, GIS is regarded as a facilitator of data sharing which in turn would lead to more informed decision-making and logically better decisions (Campbell and Maser, 1995).

In the past, the production of geographic information in developed countries was principally the responsibility of the national mapping agencies, which were variously under civilian or military control. However, the advent of services based on Web 2.0 concepts provides a new, exciting and at the same time problematic alternatives which includes citizens volunteering geographic information (Goodchild, 2007).

A set of developments within the field of geosensors is to engage citizens to act as sensors, thus providing the so-called Volunteered Geographic Information(VGI). This is a tradition of non specialists contributing to the production of geo-referenced information (Schade *et al*, 2010).

The Kenyan government recently stepped up plans to reintroduce an old strategy, community policing, to prevent crime, terrorism and inter-community violence. This strategy, is intended to be an early warning system and guide the intervention mechanism by law enforcers.

Community Based Policing has been identified as one of the best approaches to taming rising cases of insecurity and social injustices in many countries of the world with significant benefits in the areas where it has been implemented (Nyaura and Ngugi, 2014).

This study focused on how to use GIS and specifically VGI to improve the core function of Community Based Policing: “the creation of and reliance on effective partnerships with the community and other public/private-sector resources”

It should be noted that, VGI does not intend to replace the law enforcement agency’s process of collecting and storing information in a database. Rather, it enhances the agency’s ability to use the data in a way that is both effective and efficient.

1.2 Problem Statement

Much of the active focus on crime and crime prevention has been on the police force and law enforcers while the collaborative/voluntary aspect of the citizens given little priority. Current approaches to voluntary security information include suggestion boxes, whistle-blower sites, police hotlines and social media.

Most of the above approaches have proved ineffective due to a variety of reasons ranging from lack of timely notification, lack of anonymity, overload of analogue information, and most critically, arbitrary spatial information which is not actionable by law enforcers.

Use of GIS will enable real-time data exchange and processing of security data in addition to critical geospatial information that is actionable now and in the future.

1.3 Research Objectives

1.3.1 Overall

To demonstrate the applicability of Volunteered Geographic Information (VGI) to Community Policing.

1.3.2 Specific

1. To design an architecture for collection and aggregation of georeferenced data from the community on security related matters.
2. To demonstrate the various software tools for voluntary capturing, sharing and analysing geo-referenced data.
3. To measure the accuracy of the collected security related data and its fitness for use in community policing.
4. To assess the willingness of the members of the public to accept VGI technique and highlight their concerns on the same.
5. To identify the underlying challenges that community based policing is facing and how the some of them can be solved using GIS technology.

1.4 Justification for the Study

The study is supposed to showcase several available GIS tools and alternatives that can be used by members of the public to share crime related information with the law enforcing agencies while maintaining their privacy as needed.

Submitted security related information will not only contain just narratives of the situation but also multimedia and location information. Such information is believed to

be rich enough to assist law enforcement agencies in coming up with tactical response and prevention measures.

It is only after doing such a project which will act as a proof of concept on the benefits of VGI that will lay the foundation for actual implementation or future research on the topic.

1.5 Scope of work

- The study included respondents residing within Nairobi County. Sample data outside of Nairobi was received but had to be excluded in subsequent analysis and discussions.

- Crime incidents and other security related information was reported in addition to geographic coordinates provided, via GPS and location services provided by the mobile device.

- A freely available standard for online survey design was be used:- XForms. A data collection mobile app that allows coordinate capturing was the the primary VGI technique. The preference being on ODK Collect though data submitted using GeoODK Collect was admissible.

- Only general crime incident mapping and statistical analysis was undertaken in this study.

- The quality of the data was assessed based on a geospatial and statistical analysis while subjective opinion of the security experts omitted for maximum objectivity.

1.6 Organization of this report

This report is addressed largely to those who can effect future policy in light of the information gathered in this study.

The report begins with an introductory chapter “CHAPTER 1: INTRODUCTION”, which contains the background that discusses the contribution of GIS to decision making then describes VGI before introducing community based policing to the reader. The problem statement follows with an outline of the existing communication gap between the citizens and the law enforcers with regard to community policing initiatives. The overall and specific objectives of the study are afterwards listed in detail. This chapter discusses the justification for the study before concluding with a discussion on the scope of work.

The remainder of the text is divided into four more chapters.

CHAPTER 2: “Literature Review”, is divided into four sections:- “Volunteered Geographic Information”, which introduces the concept of VGI. The next section “Vagueness In VGI” discusses the fundamental challenges that VGI initiatives will have to contend with. In the section “Motivations for Contribution in VGI” the author discusses the different motivators for individuals and organizations to contribute geographic information. This chapter ends with a case study of success of VGI in the aftermath of the Haiti Earthquake of 2010.

CHAPTER 3: “Materials and Methods”. The bulk of the work of this study is contained in this chapter. It defines the study area and the motivation for choosing it. The overall methodology is outlined including the description of the mobile application and the data aggregation platform built for this project. Details of the data collection devices used, how the questionnaire is converted into a digital form and how these are shared between the device and the server are given. It is in this chapter that the full workflow from data collection, data submission, data reception, visualization and data analysis are discussed.

CHAPTER 4: “Results and Discussions” reports the research findings and also discusses the challenges to expect in future VGI undertakings on community policing.

CHAPTER 5: “Conclusions and Recommendations” gives the conclusions and the recommendations of this research.

CHAPTER 2: LITERATURE REVIEW

2.1 Volunteered Geographic Information (VGI)

Resch (2013) observed that a significant limiting factor of GIS and GIS-based Spatial Decision Support Systems (SDSS) is that they are often not – or only conditionally - suitable for the integration of measurement data in real time. Current Geographic Information Systems are primarily designed, either incidentally or coincidentally, for integrating quasi-static data without high spatio-temporal fluctuations (Resch *et al*. 2010a). Meaning that they are used to carry out processing and analysis that does not require or requires minimal consideration of the temporal differences. This is partly due to the fact that geo-data is per definition historic and so far, geospatial processing has focused on analysing static data, with low temporal fluctuations.

Some applications of GIS for decision making like security and disaster management require almost real-time access and analysis of geospatial data. That is the only way a timely response and efficient resource allocation can be mobilized to prevent damage or minimize the extent of the same. VGI allows a multitude of people to share geospatial information for access by even more people in a process that is near real time. This allows almost zero training, minimal onboarding and non-supervised recruitment process.

Volunteered geographic information (VGI) is the harnessing of technological tools to create, assemble, and disseminate geographic data provided voluntarily by individuals (Goodchild, 2007). This a special case of the larger web phenomenon known as user generated content (UGC).

Resch (2013) further observed that VGI is heavily reliant on the *People as Sensors* approach, which he defined as a measurement model, in which measurements are not only taken by calibrated hardware sensors, but in which also humans can contribute their individual 'measurements' such as their subjective sensations, current perceptions or personal observations.

VGI can be used to increase the societies' resilience to disasters, both natural and man-made (Horita *et al*, 2013). When correctly designed and implemented, VGI can be used to recover from natural disasters such as tsunamis, earthquakes, hurricanes, and to counter man-made equivalents like terrorism and nuclear-reactor breakdowns and to minimize the damage caused by the same. To achieve this Horita *et al* (2013) even proposed a generic model in which people can use cell phones to contribute data to a centralized system though which up-to-date maps can be generated and relayed to the necessary decision makers in near real-time.

VGI has been employed in crime analysis and investigation with remarkable success especially when incorporated with Geo-visual Analytics (GVA) as shown by Jeremy and Roth (2014). Voluntary geospatial information, generally microblogging websites and specifically Twitter has been successfully used for crime analysis.

Boba (2005) describes five forms of crime analysis: criminal investigative analysis, intelligence analysis, tactical analysis, strategic analysis and administrative analysis. A case in point is one desktop application proposed by Jeremy and Roth (2014) that leverages VGI and GVA to assist in all the types of crime analysis described by Boba (2005). This goes to show that VGI, accuracy concerns notwithstanding, and when applied correctly, is able to bridge the gap in our Community Based Policing initiatives.

It is generally agreed that there are three key components to the community policing philosophy Jose Docobo (Summer 2005). These include

1. The creation of and reliance on effective partnerships with the community and other public/private-sector resources,
2. The application of problem-solving strategies or tactics, and
3. The transformation of police organization and culture to support this philosophical shift.

Community policing is therefore a philosophical approach to how policing is conducted. At its core, community-oriented policing is based on law enforcement and the community joining together to identify and address issues of crime and social disorder.

VGI has its fare of challenges and criticisms, the most notable of all is the accuracy, repudiation and correctness of the data. Traditional mapping agencies operate under strict guidelines and standards. VGI on the other hand relies on the voluntary part and the main motivator for contributors is self promotion, Goodchild (2007a).

Currently VGI is commonly implemented as online surveys where forms are predesigned and volunteers are allowed to download, fill and submit back to the servers. ONA, hosted at www.ona.io and KoboToolbox hosted at http://www.kobotoolbox.org/ are the leading open source tools being currently used. Both of these were derived from the defunct formhub hosted at www.formhub.org.

2.2 Vagueness In VGI

A concept is considered as vague if at least one of its characteristics does not obey boolean logic. For instance, we cannot identify a fixed value N, the number of meters between the point A and the point B such that if distance between A and B is less than N then A is **close** to B, else A is **far** from B. The fundamental argument is that it would have no sense if a single meter drastically changes the spatial relation between A and B.

People's and volunteers' perceptions of spatial and environmental phenomena is mostly an approximation even though many end users of spatial VGI products assume or expect high precision output. People will generally have no problem sharing a coordinate pair (point) to describe an entire region (polygon) where a phoenomenon was experienced. This may be due to inherent vagueness of the phenomenon or practical difficulties of achieving the desired accuracy. Similarity can be drawn to the practise of measuring rainfall using a rain gauge then using the recordings to represent a whole region.

Volunteers of geographic information (Longueville *et al*, 2009) might themselves be unsure about the spatial extent of the phenomenon they witnessed, as their perception is recovered from memory, or they perceived only part of the entire phenomenon. This is well described by the statement:- 'from here I can see the forest fires'. In other words, the reporter's physical location, their perceptions and the geographical extent of the phenomenon are geographically vague.

Longueville *et al* (2009), continue to argue that when it comes to existing VGI systems there turns out to be a lack of how to express such spatial vagueness, both when the information is entered by one stakeholder, and when it is browsed and displayed by others.

This implies that whenever we collect geographic data using voluntary participants we should be aware of the inherent vagueness and inexactness either by intention or due to prevailing circumstances.

This vagueness covers not only the spatial component but typically includes the temporal and thematic component. This has led many researchers and authors to suggest the concept of degree of truth (Fisher, 2000) whenever working with VGI.

VGI participants are not calibrated digital probes that are sending precise numeric values through a network of sensors. They are human beings interacting with ICT devices to share their perceptions (Goodchild, 2007).

2.3 Motivations for Contribution in VGI

Not long ago, map making was the business of government agencies and private companies. But with increase in internet penetration, the proliferation of mobile technologies, improvement of portable GPS technology and web 2.0 technologies, end users are now able to produce and share their own information and most importantly geographical information. For all intents and purposes these end users are not necessarily subject matter experts neither are they geographic experts.

In VGI indeed, geographic information is the main information, but technically, the contributor may not or does not have to realize that they are sending geographic information, because the system can convert the textual or visual information that they send into geographic information (Yusra, 2011).

Seeger (2008) coined the terminology facilitated-VGI (f-VGI) to refer to the VGI which has already been built to send information based on pre-defined criteria and VGI to be the one developed based on his/her own information.

Other authors also try to distinguish VGI in many ways. Goodchild (2008) differentiates VGI into simple VGI where the information which is gathered not so much needs an expertise behind it and complex VGI where if individual wants to contribute, s/he needs special knowledge about the subject.

Furthermore Grira *et al* (2010) distinguish VGI into two dimensions which are power and capability, where power represent authoritarian or volunteer type of social relationship and capability represent the nature of the action about how to collect spatial data. As a result of these dimensions, they differentiate VGI into four components:-

- volunteered with full capability,
- authoritarian with full capability,
- volunteered with limited capability and
- authoritarian with limited capability.

To see so many contributors and reporters producing spatial information at OpenStreetmaps, Flickr, Four Square, among others it is important to know why people want to contribute and their motivations behind it.

Goodchild (2007a), from his point of view identified self promotion as the main reason why people participate in VGI. As for participation in f-VGI such as Openstreetmap, the motivation would be personal satisfaction that people can see their work directly after contributing. For a web 2.0 user, the motivation is as a convenient way of making it available to friends and relations.

McDougall (2009) investigated the motivations for organizations to share information and found that their main aim is to increase the benefits to society that comes from the availability of spatial data and to create connection in dispersed databases.

Coleman, *et al*, (2010) mentioned about altruism, professional or personal interest, intellectual stimulation, protection or enhancement of a personal investment, social reward, enhanced personal reputation, outlet for creative and independent self expression and pride of place to categorize motivation in contributing VGI.

Motivations behind participation of users can be many (Gouveia and Fonseca, 2008). The purpose of the f-VGI and motivations from participant point of view is not always in line. Hence, it is prudent to note that motivation of the volunteers may not always be the same as the objectives of the f-VGI project.

2.4 Case Study: The Haiti Earthquake, 2010

The author made considerable effort to locate a case study of VGI in the area of community policing. This would have been an enriching undertaking that would have added immense value to this project. Only informal and non academic literature is available which proved to be very unfit for a scholarly discourse. In its place the author wishes to discuss a VGI intervention in disaster management in the aftermath of the 2010 earthquake in Haiti.

On January 12, 2010, a magnitude 7.0 earthquake struck Haiti and immediately there was need for maps. Emergency responders had to know where the people who were most in need were located and how to get assistance and relief to them. Part-au-Prince, the

capital, and many other parts of Haiti, had minimal coverage in the standard web mapping services (eg Google Maps) that many in the developed and developing world take for granted.

States and other quasi-governmental agencies have for the most part been assumed by researchers to be the primary actors in disaster relief. NGOs have been assumed to be playing a secondary role. Therefore it comes as no surprise that the role of IT was primarily viewed as a means to enhance the command, control, and dissemination of information for the regular actors in disaster management (Comfort 1993; Gruntfest and Weber 1998; Quarantelli 1997).

Concurrent with this shift of emphasis from the role of IT in state-led disaster response is the growing significance of what is often referred to as Web 2.0. Also referred to as peer production, crowd collaboration, or crowd sourcing, the phenomenon refers to the ability of people from around the world to collaborate on projects that are often highly ambitious in both their scale and scope (Graham 2010a). It also marks the "...increased ability for individual users and loosely affiliated networks to construct and shape cyberspace and their daily lives" (Crutcher and Zook 2009: 524).

The peer production of information has reshaped a variety of otherwise standard practices, but arguably none as profoundly as the production of geographic information where many users have moved from being passive recipients of geographic information to being producers themselves (Budhathoki et al, 2008).

Two crucial questions that needed to be answered immediately after the earthquake hit on January 12 were: Who needs help? And where? Relief efforts had to get food and medical supplies and resources to the parts of the country most desperately in need, but it was very difficult to know where to deploy resources because due to lack of a systematic plan or data in place to help make such decisions.

The lack of up-to-date information complicated rescue and recovery efforts in the first days after the quake. Typical informational databases are built up over many years through GISs requiring a cadre of trained professionals to operate and maintain. However, in the Haitian crisis, much of this critical geographic information needed to be built up from scratch and much of the data that was available needed to be updated based on landscape change resulting from the disaster. The databases that typically required years to create now had to be accomplished in a matter of days. Even further complicating the situation was the need to identify those in need, in a country with already poor information infrastructure that had been severely damaged in the quake.

In response to this need, a rather unexpected solution appeared: volunteer community efforts matching simple web-based tools with non-professional data contributors. People and organizations around the world realized that they didn't have to be physically present in Haiti to provide meaningful assistance to those who were. Information about opportunities to contribute spread quickly through a variety of online outlets, including blogs, emails, tweets, and status updates on social websites.

Ushahidi

A very different model of crowdsourcing was employed by the *Ushahidi* project. With its roots in the Kenyan post-election crisis of 2008, the *Ushahidi* platform enabled users to submit reports through SMS, MMS, or an online interface. Text-based reports were then manually geo-tagged to a particular location within an interactive map.

The Ushahidi project was reportedly able to make a significant impact on the relief efforts. By geo-locating urgent messages like "I'm buried under the rubble, but I'm still alive," in addition to simply publishing relatively less immediately actionable messages such as "our community has run out of water," the project could direct vounteers and relief workers to locations in which relief actions were needed. Key to the usefulness of

Ushahidi was the ability to connect short statements about problems and needs with geographic coordinates.

These coordinates were then used by relief workers to find individuals and communities in need.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

This research was conducted in Nairobi County, the capital city of the Republic of Kenya.

Nairobi was chosen due to a variety of factors, mainly the following:

- It is a cosmopolitan city thus providing a potential of reaching volunteers from different social, economic, educational and religious backgrounds.
- Being the capital city, it was found to be populous enough for testing volunteer initiatives.
- Nairobi has good internet connectivity with a good number of people with internet enabled smartphones.

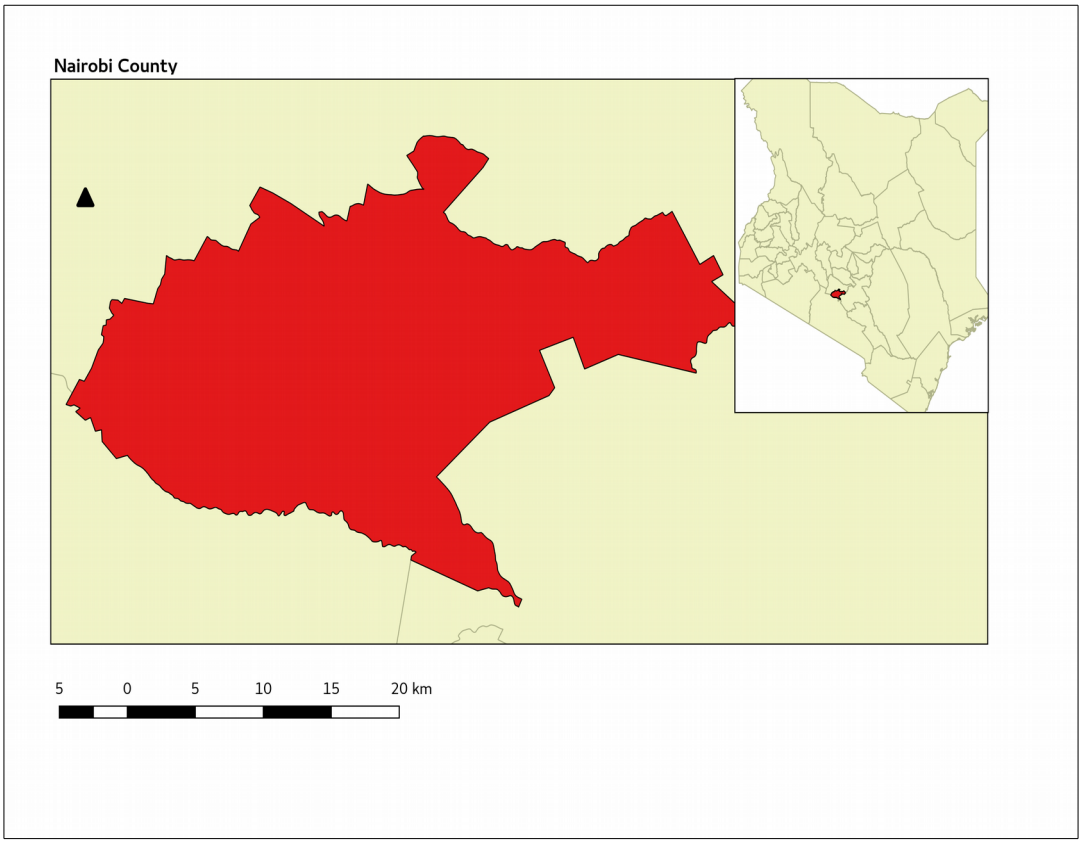

Fig 3.1 The study area

3.2 Methodology

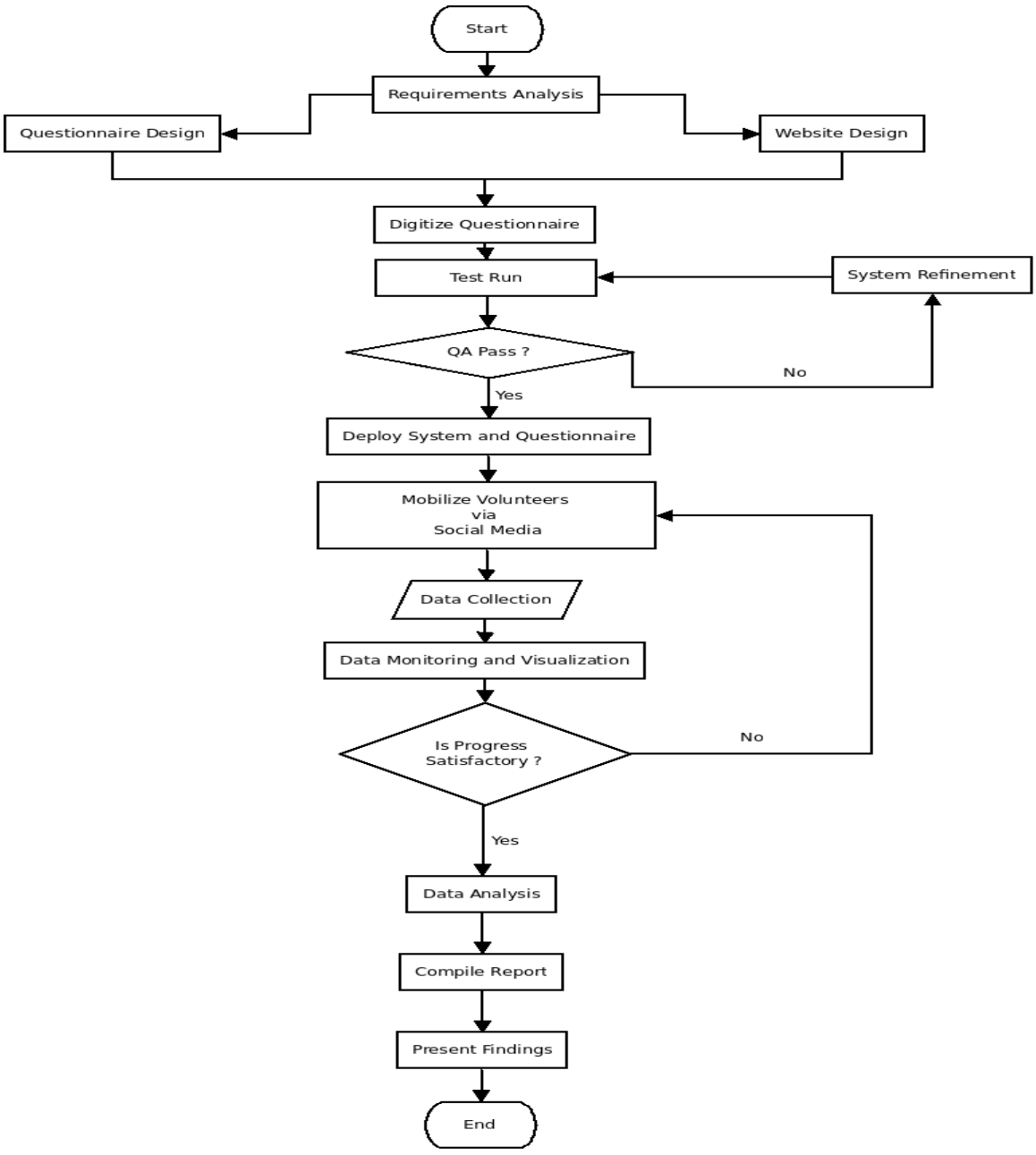

Fig 3.2 Project workflow

3.3 Materials

3.3.1 Mobile App

The initial idea was to build a mobile application specifically for collecting data for this project. After background research and review of case studies this became a very bad idea because:

1. The application built this way would be specific to this project and would have to be discarded afterwards.

2. The design of the questionnaire was likely to change between design, user feedback and eventual data collection.

3. There are existing open source solutions for doing the same. There are free android applications for data collection and subscription-based servers to receive the data.

The above made the justification for using ODK Collect as the primary mobile application for data collection.

ODK Collect is a free and open-source Android application for data collection. It is used to load, view and respond to survey questionnaires designed using xForms standard and hosted online. Its ability to capture coordinates in addition to multimedia as part of its data collection functionality has endeared it for many data collection projects that require geo-tagging. From forest-fire reporting to bird-watching to hobbyist georeferenced data collection, it has truly stood out, together with GeoODK, which is a derivative of ODK Collect but with superior geospatial features.

This app is able to automaticaly capture the IMEI of the device, start and completion time of filling the questionnaire. It also allows sending of multimedia data (photos, audio, video) though for this project only photos were expected from participants.

3.3.2 Data Aggregation Platform

The current practice in the smartphone-based data collection is such that the mobile apps are readily available but to receive the data one needs a paid subscription to a commercial website. For this reason there was need to build an online system to interract with the data collection app chosen, ODK Collect or GeoODK Collect. The good thing is that within both the apps there is a setting to define which server you want to link with.

Based on best practises learnt from www.ona.io , http://www.kobotoolbox.org/ and the defunct www.formhub.org the server was designed. The primary interest was the ability to serve questionnaires and to be able to receive submitted data and provide a visualization for the same.

The end product, hosted at www.datahub.co.ke, was used to receive the data transmitted by the data collection mobile applications. This site was specifically built for this project and through it volunteers were able to download the questionnaires, fill questionnaires with security incidents and submit them for aggregation and further analysis.

Features available in these web applications include download of submitted data, geo visualization and frequency distribution analysis.

http://datahub.co.ke is the main website while the sub-domain http://live.datahub.co.ke is the actual endpoint where data is received from mobile devices. This is a deliberate design choice so that the main website can contain other information including user guides, status updates while the actual work redirected to the sub-domain. This makes for easy technical support in case of issues with the backend data collection engine.

Overall System Design

a. Database Management Systems

PostgreSQL

This advanced SQL database is used in the system to manage the fundamental system components like the users, roles, permissions with the exclusion of questionnaire design.

Mongodb

This is a NoSQL database. MongoDB is a document database in which one collection (similar to a table in SQL databases) holds different documents (analogous to rows in a table). The number and structure of fields, content and size of the document can differ from one document to another within the same collection.

This database was chosen in-order to be able to host multiple questionnaires with varying fields and at the same time it allows modifying the form design without the need to change the database design.

b. Main Programming Language

This application was designed using python 2.7. Python has a lot of utilities for GIS manipulation and shapefile support with a relatively simpler and cleaner syntax. Furthermore many GIS desktop applications provide python plugins and support.

c. Web Framework

Django Web Framework version 10 was chosen in place of other python web frameworks mainly due to the authors familiarity with the framework as opposed to the others like flask among others.

Fig 3.3 The data reception and visualization website

3.3.3 Data Collection Devices

An Android mobile phone or tablet is enough to install ODK Collect which is available in Android and Apple platforms. Location services must be installed and enabled but GPS capability is preferred for higher accuracy and precision in picking coordinates.

A data network is only necessary during submission of the forms after successful collection and confirmation of the data.

3.3.4 Form / Questionnaire Design

The project was administered through a questionnaire which had to be converted from the paper oriented form into a format usable in a mobile and web platforms (Appendix A1).

Digitizing the Quetionnaire

Survey forms were designed using an open standard:- xforms (http://www.xforms.org). This is an XML standard that allows data representation across different platforms. XLSForms (http://www.xlsforms.org) is an intermediary specification that uses Microsoft Excel for design before actual conversion to xform via a python tool xls2xforms.py available at (http://www.xls2xforms.org). Simpler GUI based tools for designing the same are also available but they provide very basic form logic. Examples include KoboToolbox(http://kc.kobotoolbox.org) and http://build.opendatakit.org/**.**

The forms are available in English and Swahili, thanks to the multi-language support in both the xForms standard and the data collection applications.

GUI based digitization

The http://kc.kobotoolbox.org website offers an alternative mechanism for designing xforms. It provides a graphical interface which supports drag and drop. It is very simple to use but the downside is that it does not support the slightly advanced form logic that is necessary in this study.

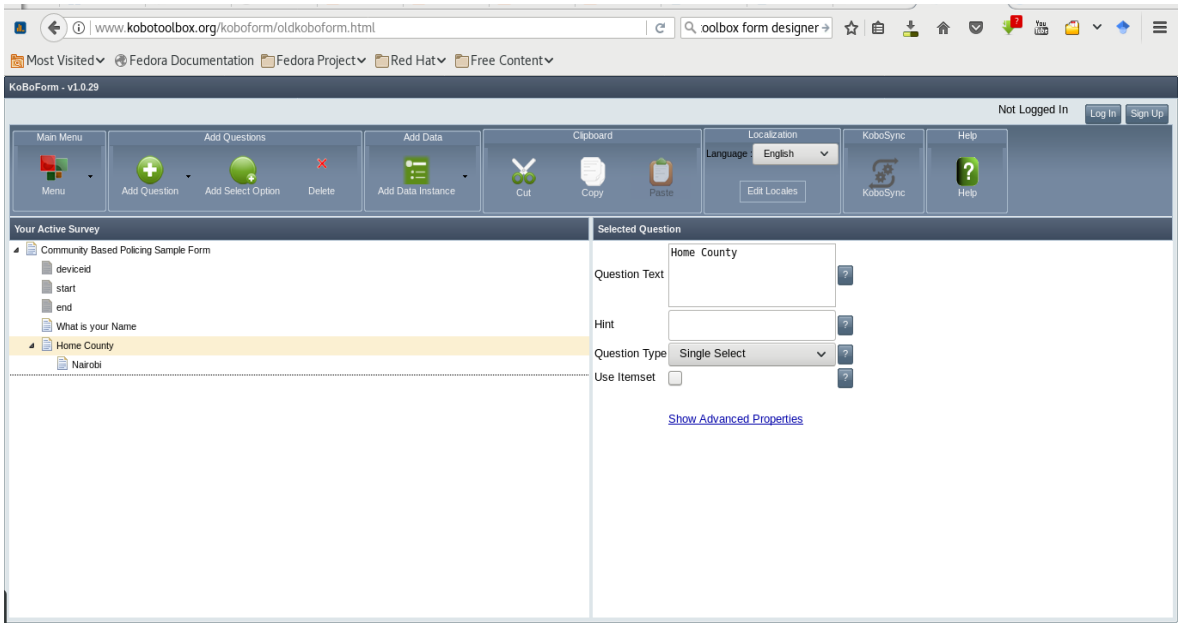

Fig 3.4 Form design using a graphical interface

3.4 Data Collection Workflow

The digitised questionnaire was uploaded to http://www.datahub.co.ke (an account is required to do this). Volunteers were invited to install ODK Collect and link it to the project website. They then download the questionnaire(s) and started collecting data. They were able to submit their data any time and this was received by the data reception and visualization website.

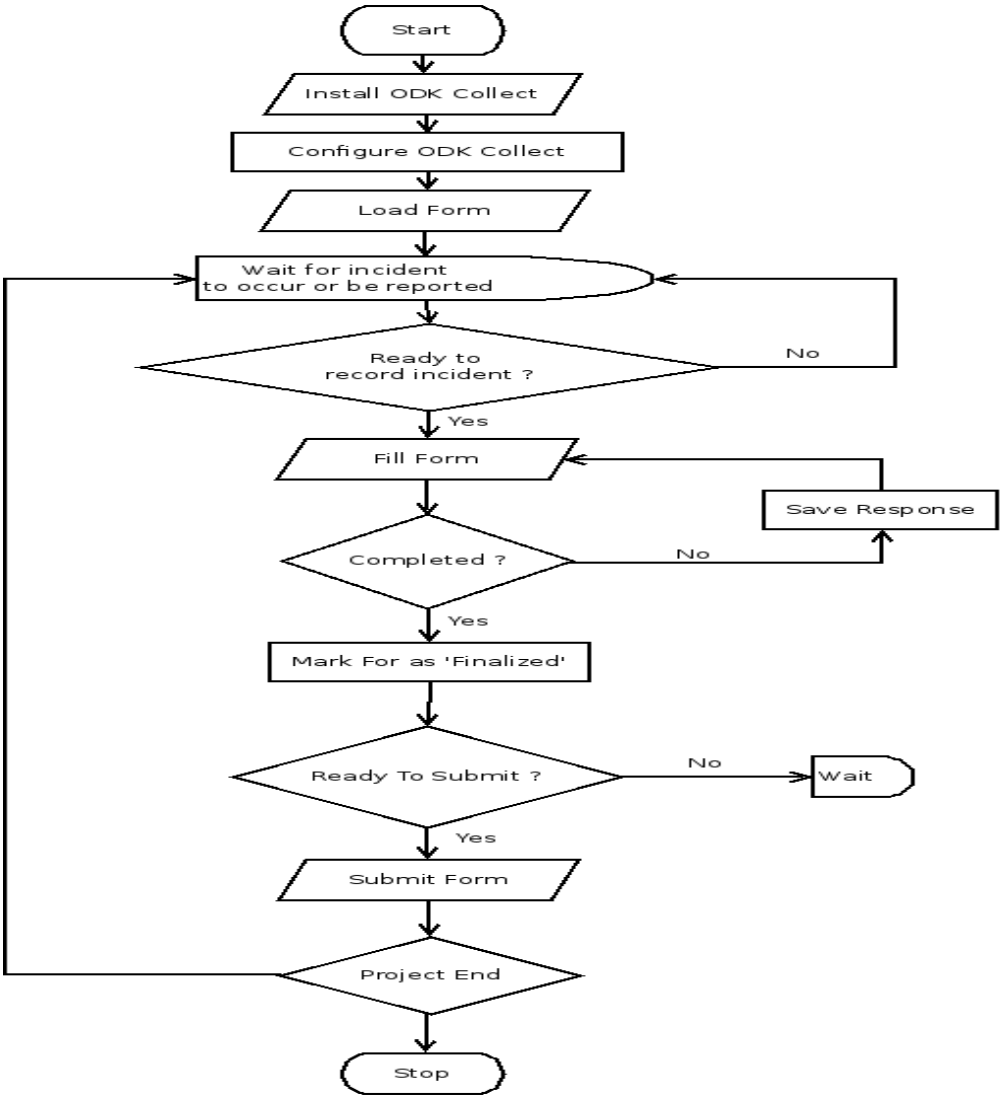

Fig 3.5 The data collection workflow

3.4.1 Data Collection and Submission

ODK Collect was used for the data collection, that is, incident reporting. While GeoODK Collect was admissible, only instructions on working with ODK Collect were provided.

To enrol participants an informal invitation was sent out to friends and colleagues using twitter and allowed them to share it further with their friends using any social website connections they might have.

This information eventually spread out within twitter, facebook and instagram in the form of a arbitrary invitation text accompanied by the following image as the guide. The rest of the details was left for volunteers to discover by themselves.

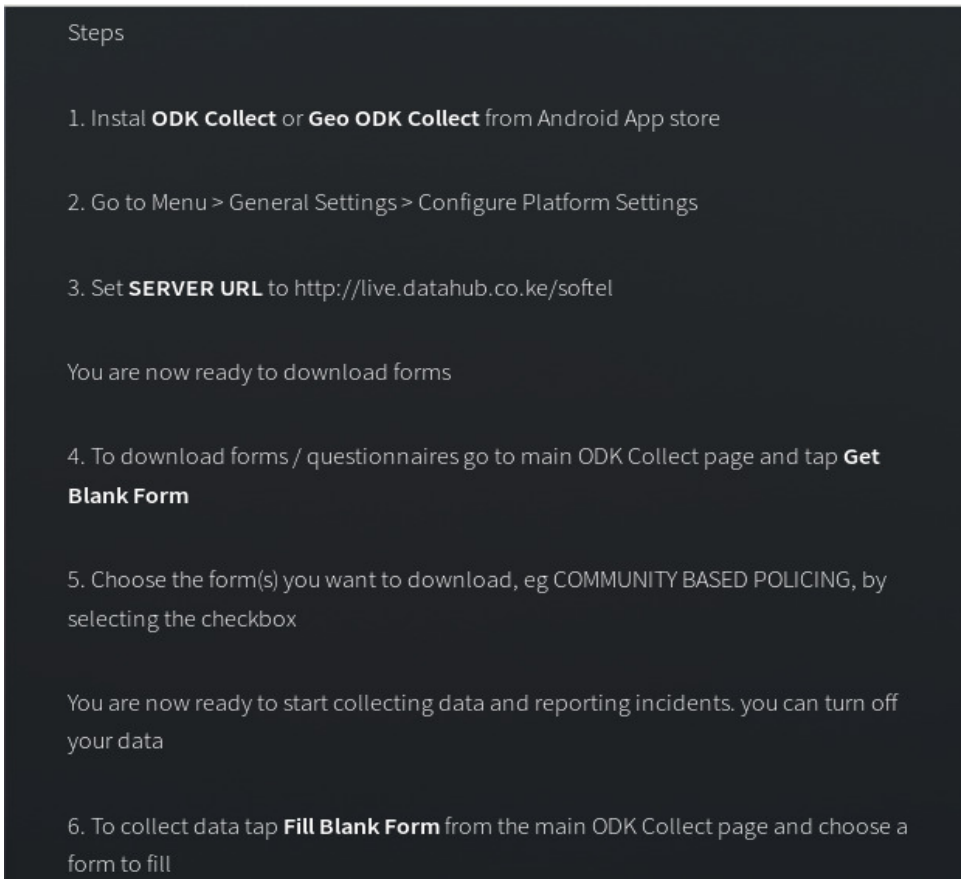

Fig 3.6 User guide for volunteers

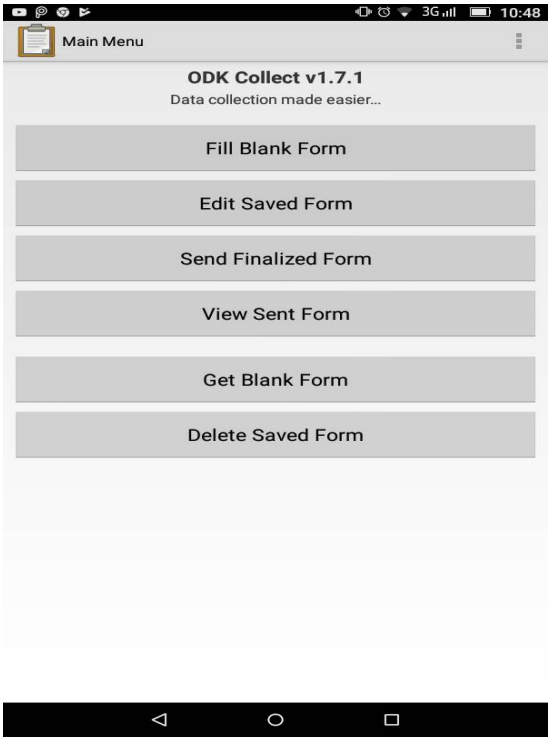

Fig 3.7 ODK Collect Main menu

Fig 3.9 Platform settings

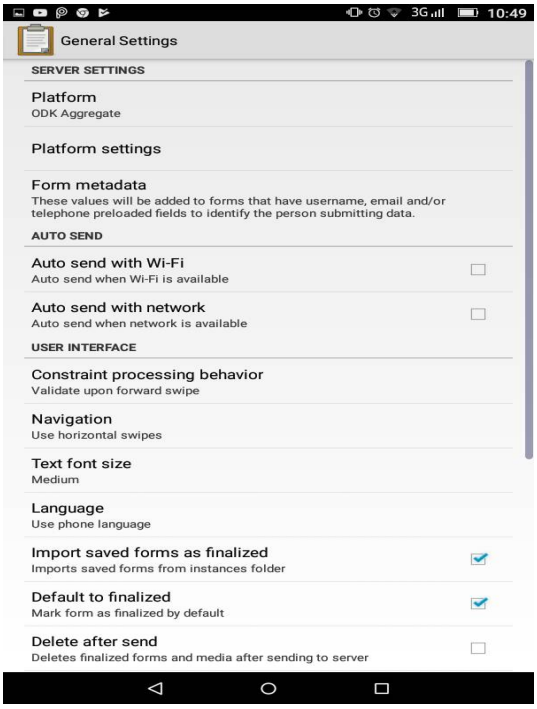

Fig 3.8 General Settings

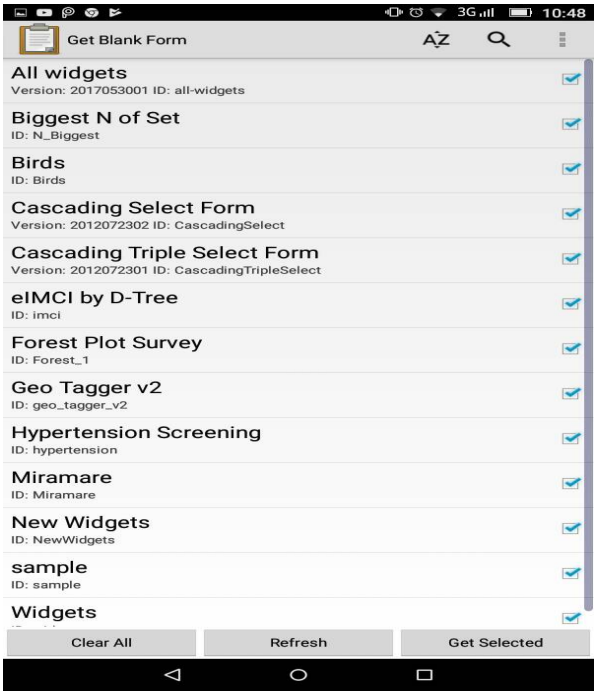

Fig 3.10 Choose blank forms to download

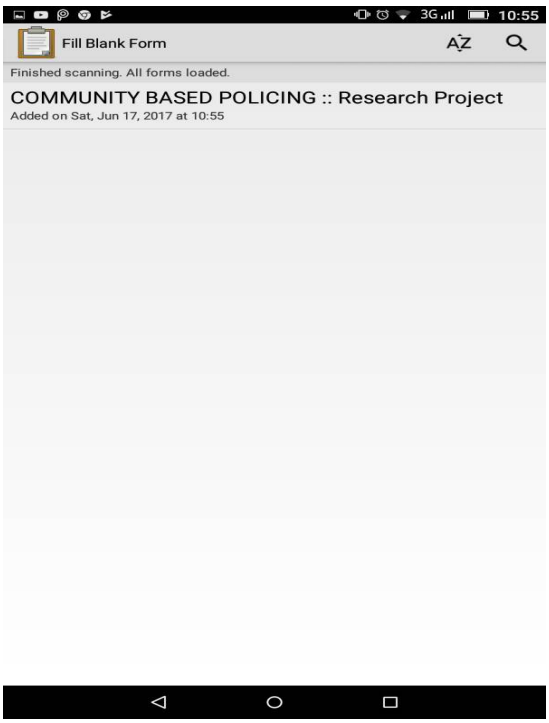

Fig 3.11 Choosing the form to fill

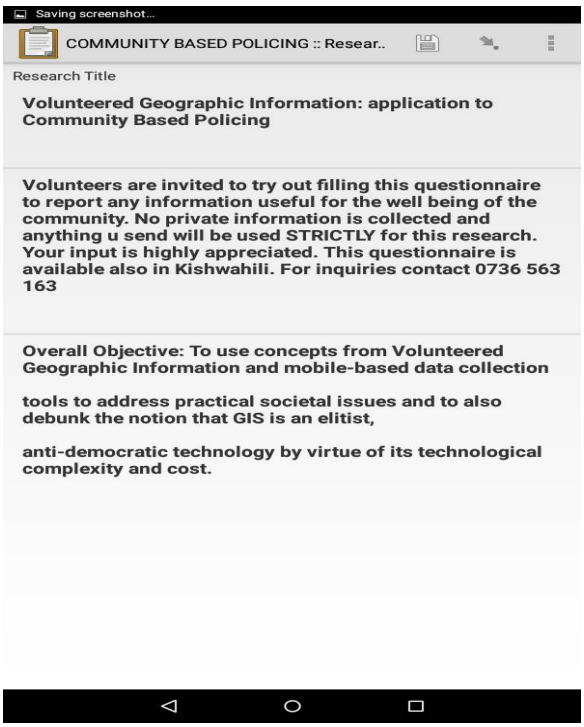

Fig 3.13 Research title page

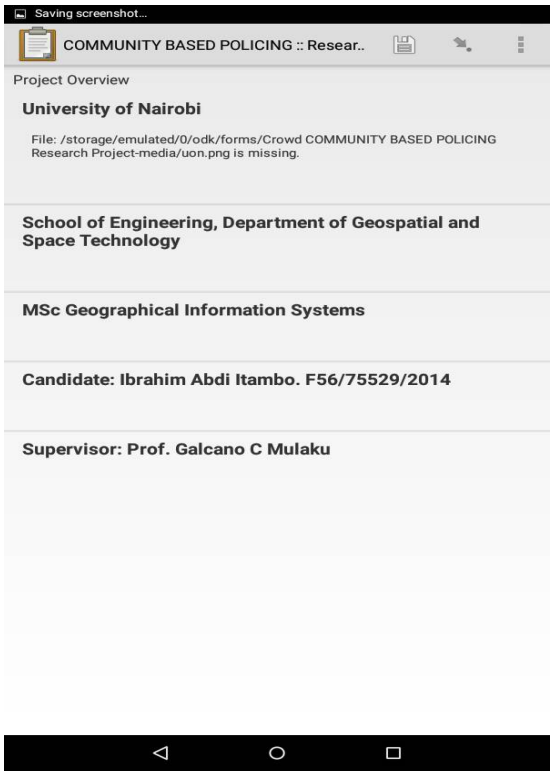

Fig 3.12 Project overview page

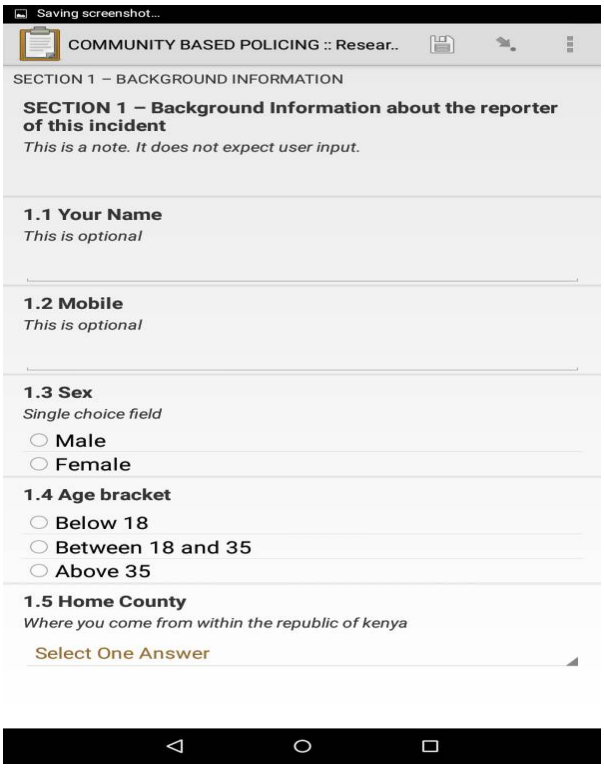

Fig 3.14 Section 1 of the form

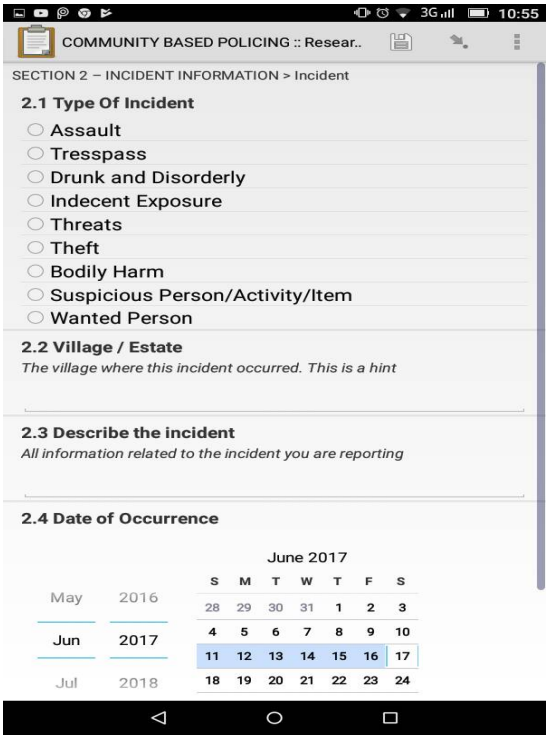

Fig 3.15 Section 2 of the form

Fig 3.17 Question 2.5.1

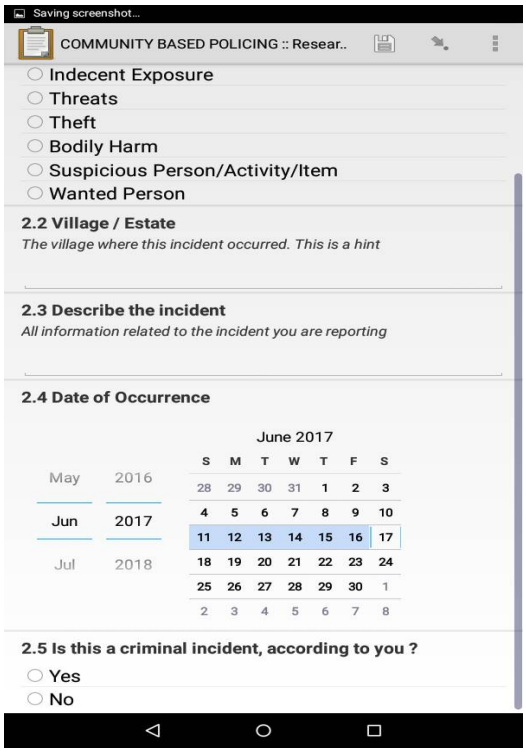

Fig 3.16 Section 2, continued

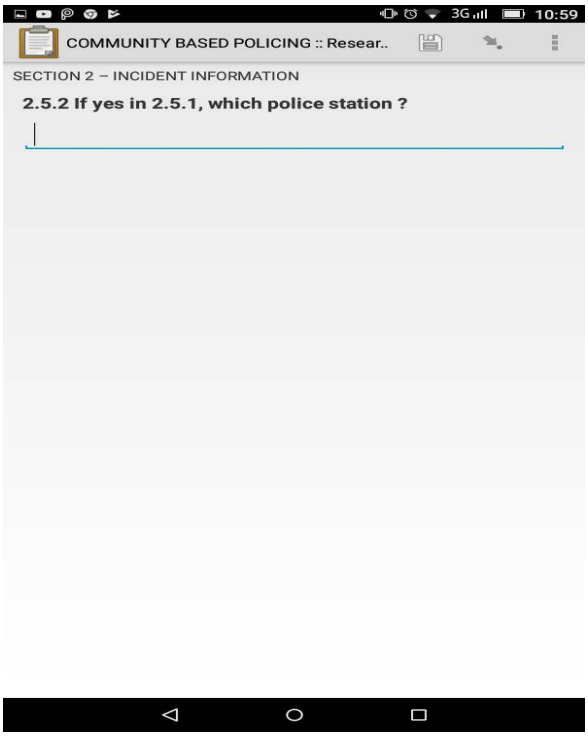

Fig 3.18 Question 2.5.2

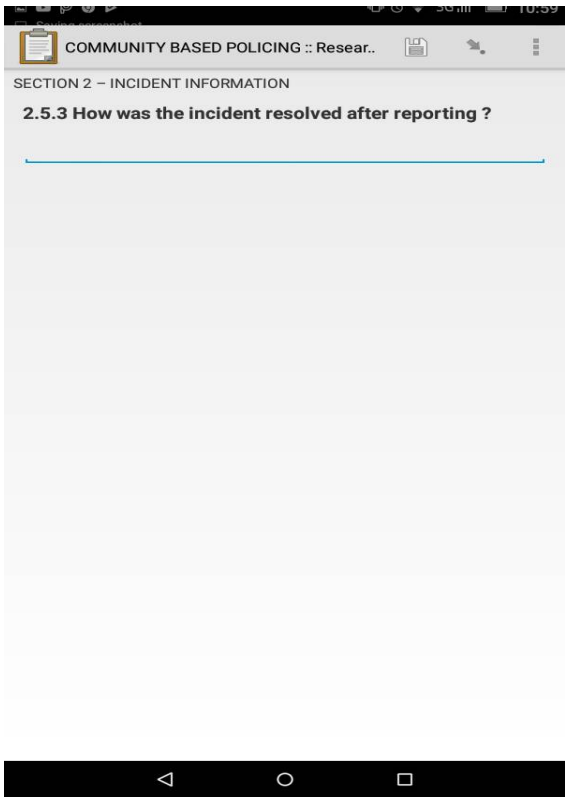

Fig 3.19 Question 2.5.3

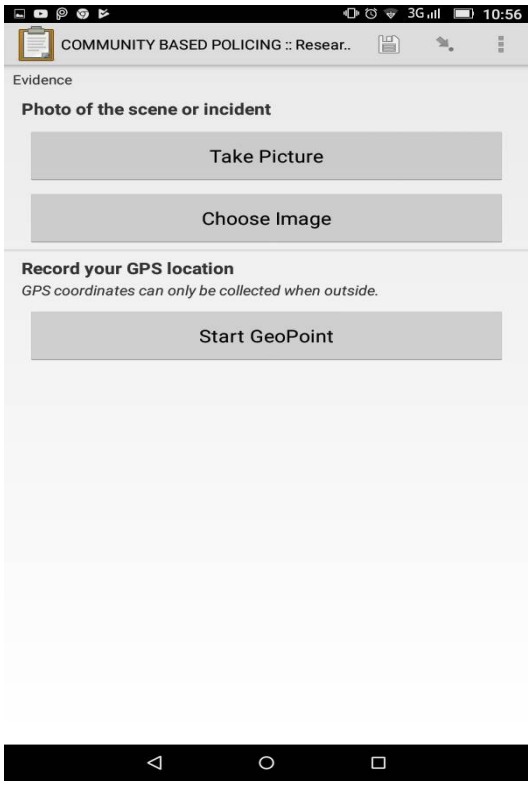

Fig 3.21 Collecting Evidence

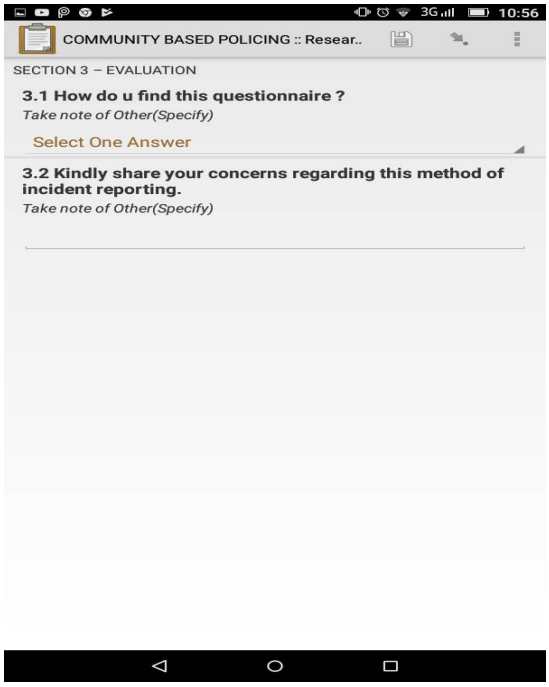

Fig 3.20 Section 3, User Feedback

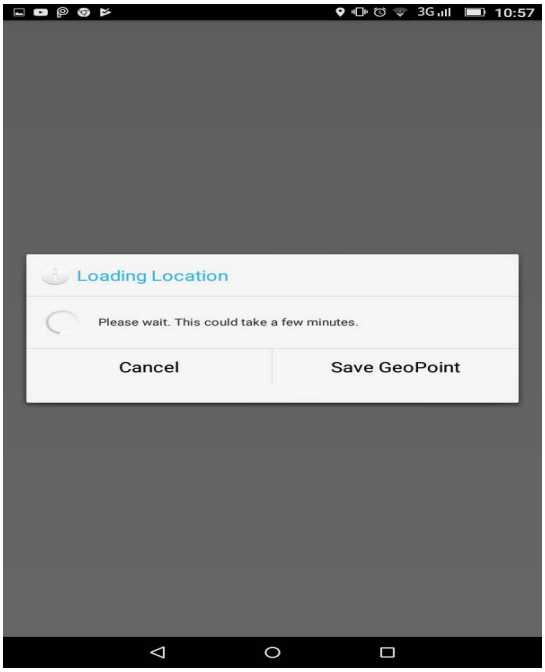

Fig 3.22 Picking GPS coordinates

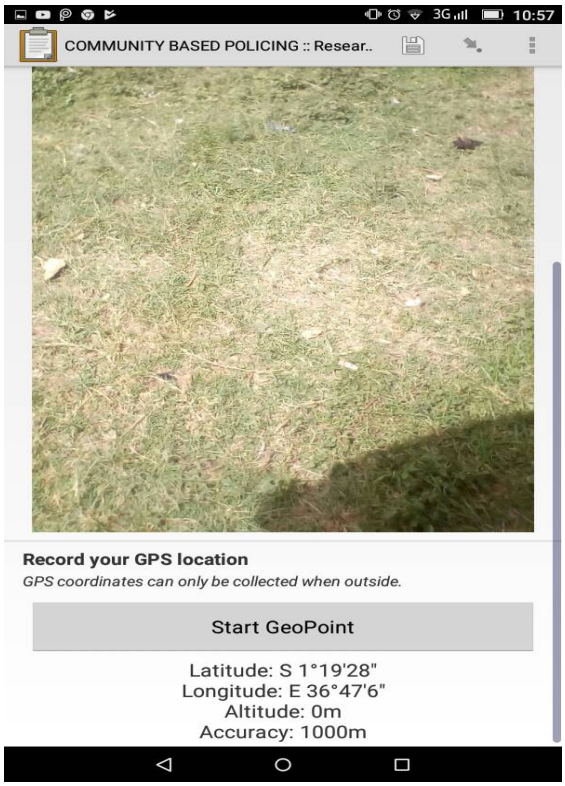

Fig 3.23 Photo evidence and coordinates

After filling the form with the incident details, the form is saved and submitted for visualization and analysis by the server;- http://live.datahub.co.ke.

Keen observers noticed a setting ‘Autosend with WiFi’ and turned it on. This setting found in the General Settings page (Fig 3.7) allows the form to be submitted automaticaly whenever the mobile device detects a WiFi connection. The same can be done for Data Networks.

Alternatively the user will do the same by tapping on ‘Send Finalized Forms’ on the Main Menu (Fig 3.6).

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Results

The system was created and hosted online and volunteers were able to collect crime incidents and submit them using the ODK Collect android application.

Data reception and visualization was being done at near real-time from the server side.

4.1.1 Data Reception and Visualization

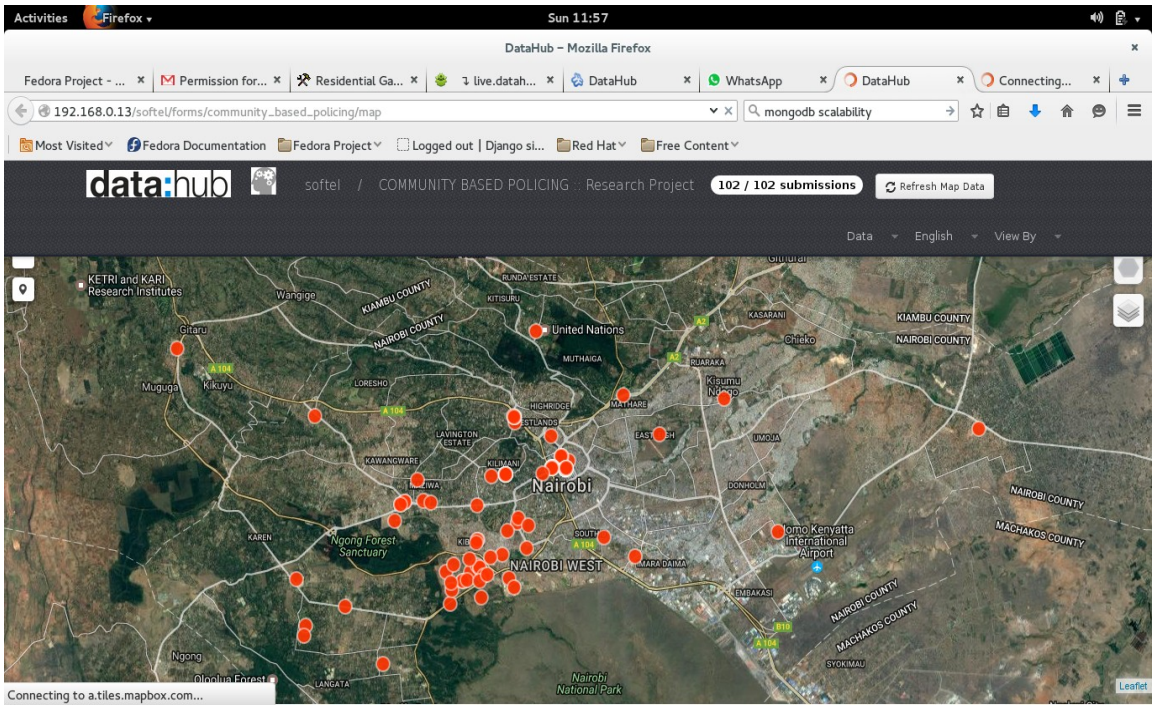

Fig 4.1 Submissions Overview

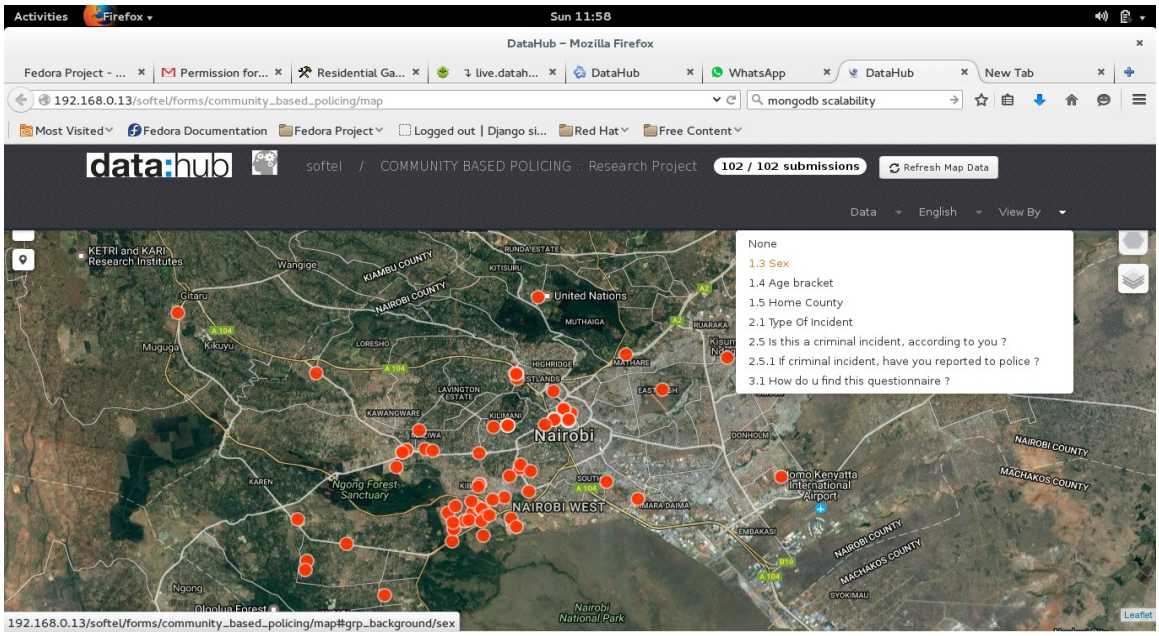

Fig 4.2 Functionality to allow preview of submissions based on specific questions

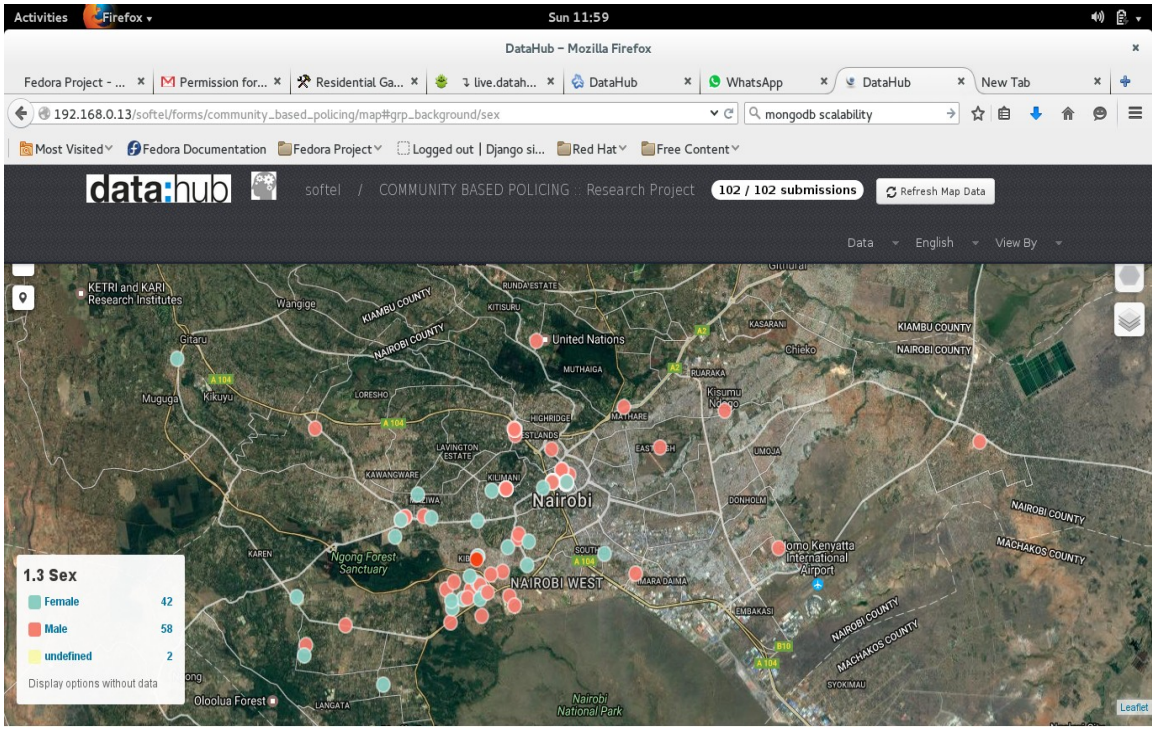

Fig 4.3 Preview of submitted data according to sex

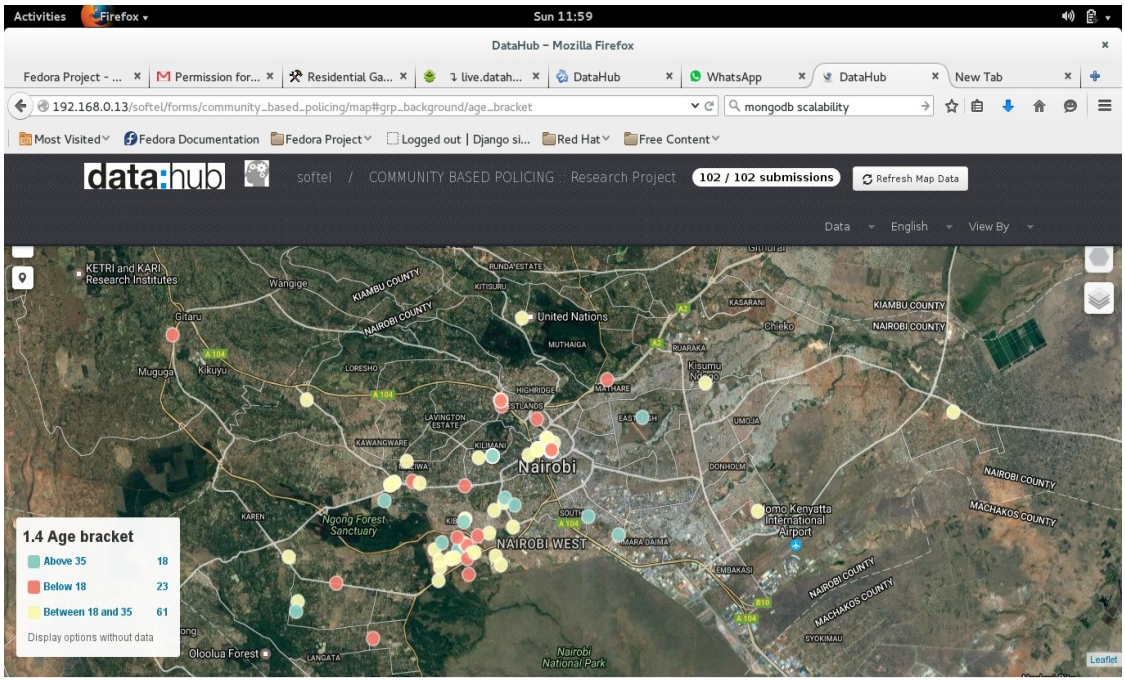

Fig 4.4 Previewing responses by age bracket

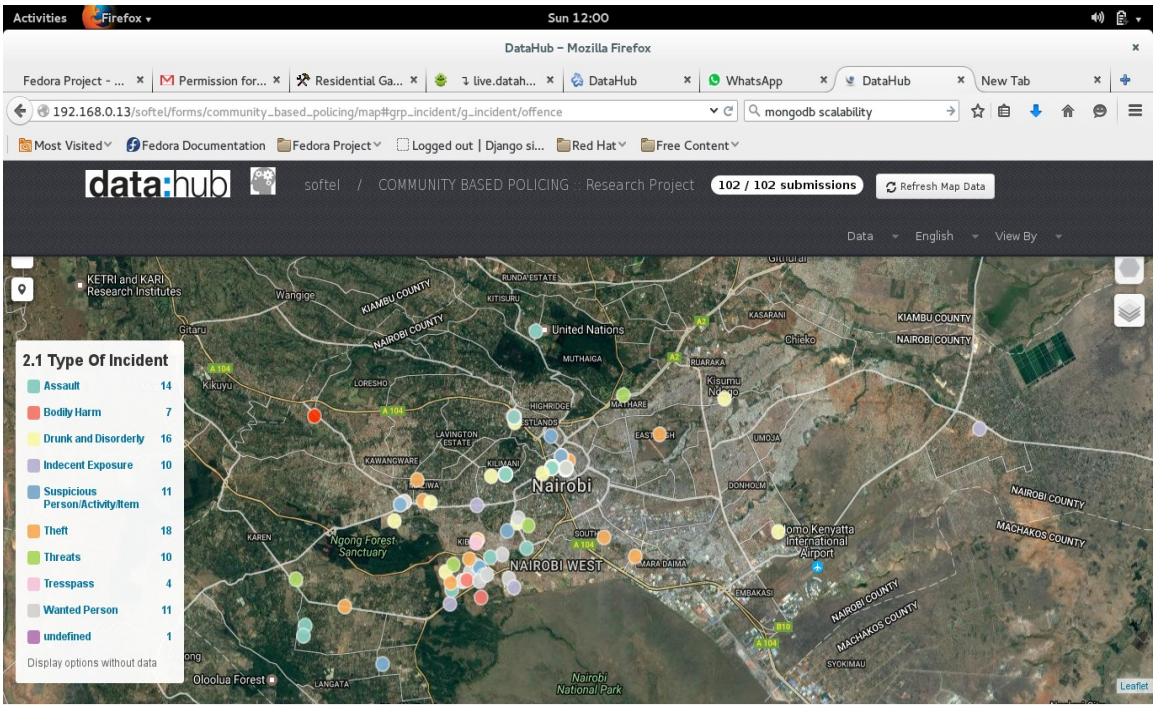

Fig 4.5 Preview by type of incident

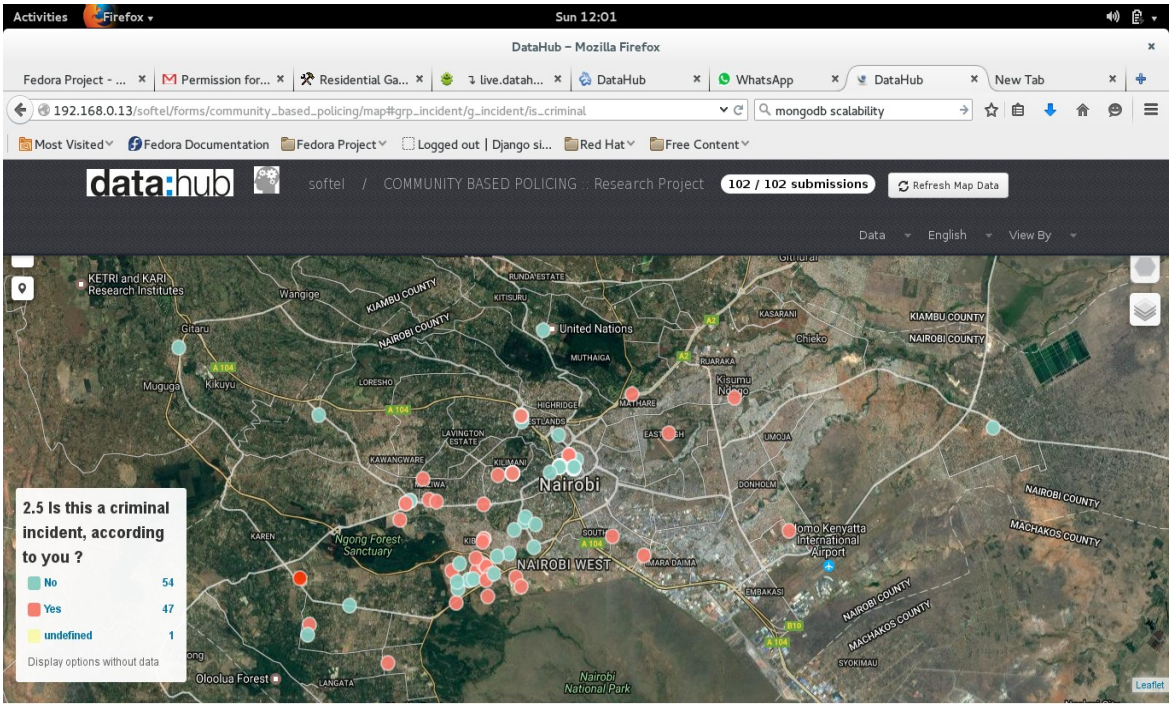

Fig 4.6 Preview respondents who think the incident is criminal or not

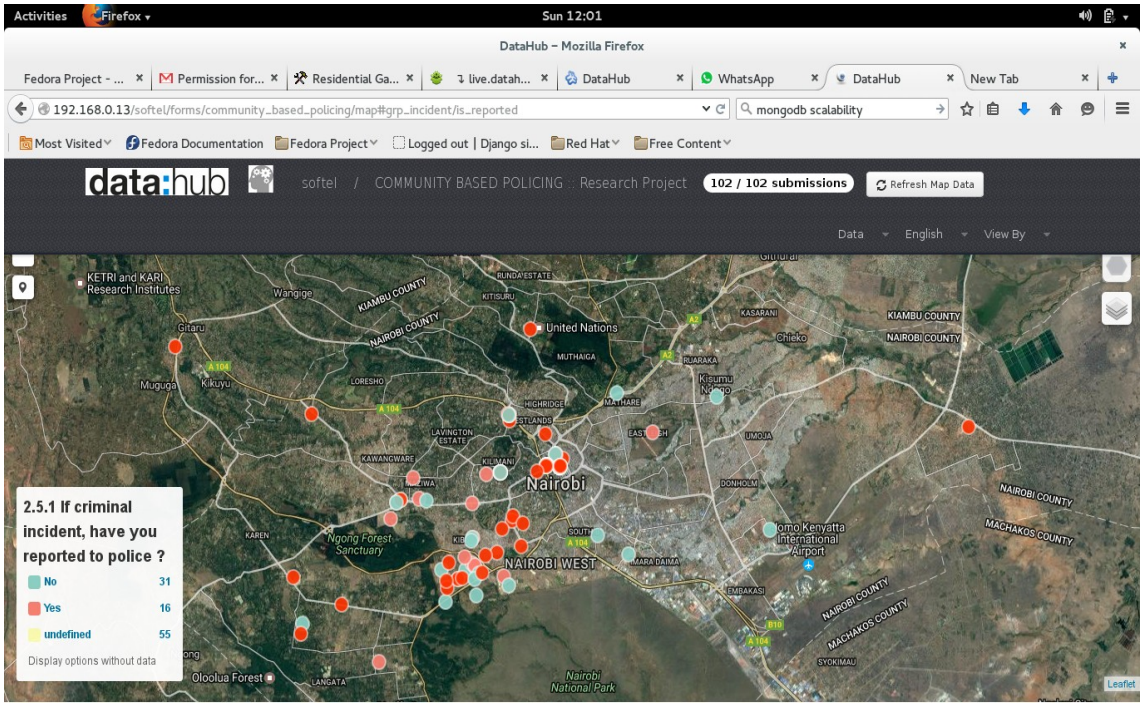

Fig 4.7 Preview cases reported to police

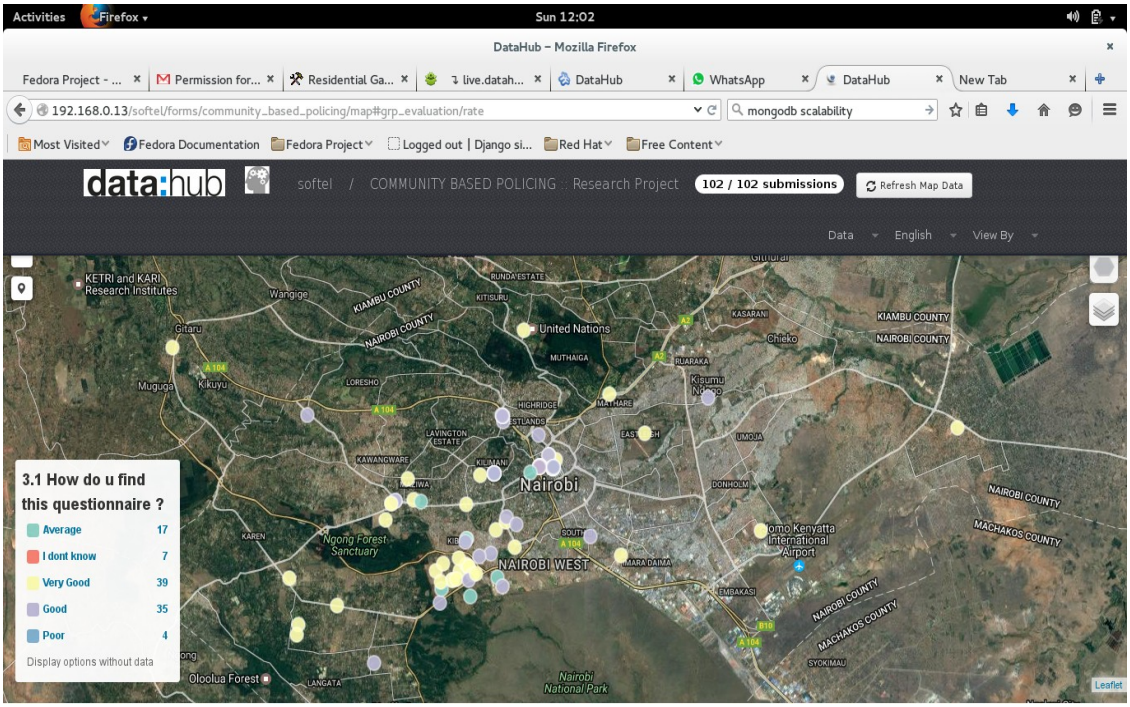

Fig 4.8 Preview by User Rating

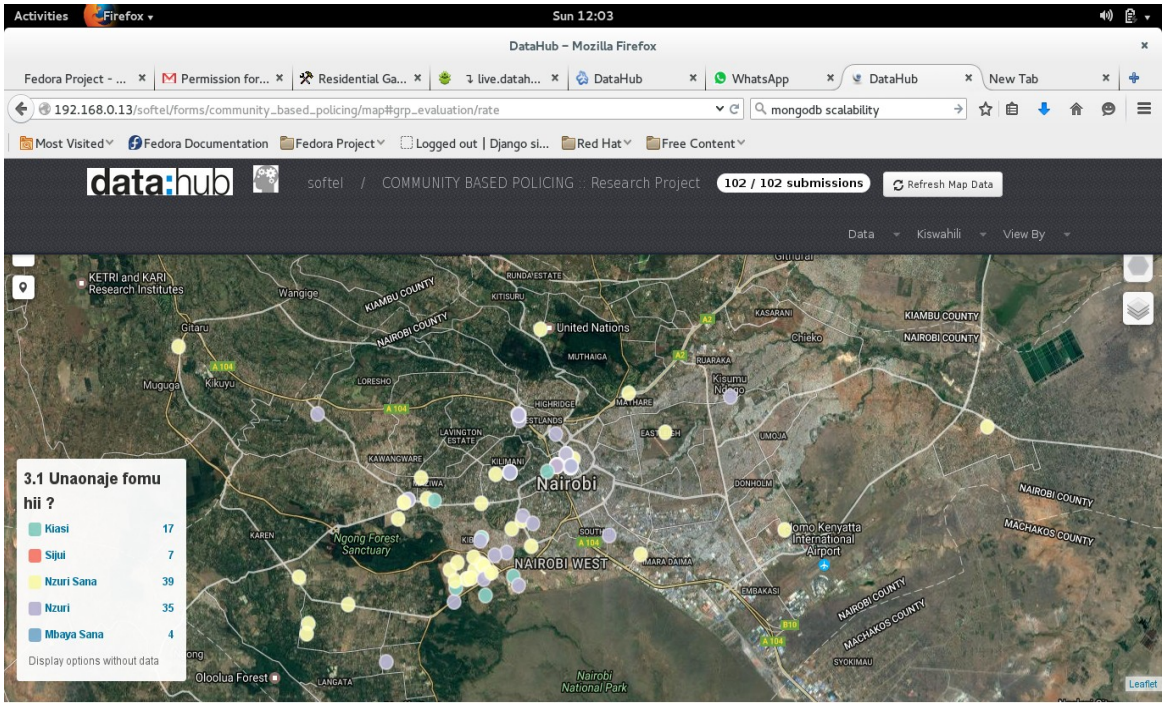

Fig 4.9 Demonstrating Multi-language support

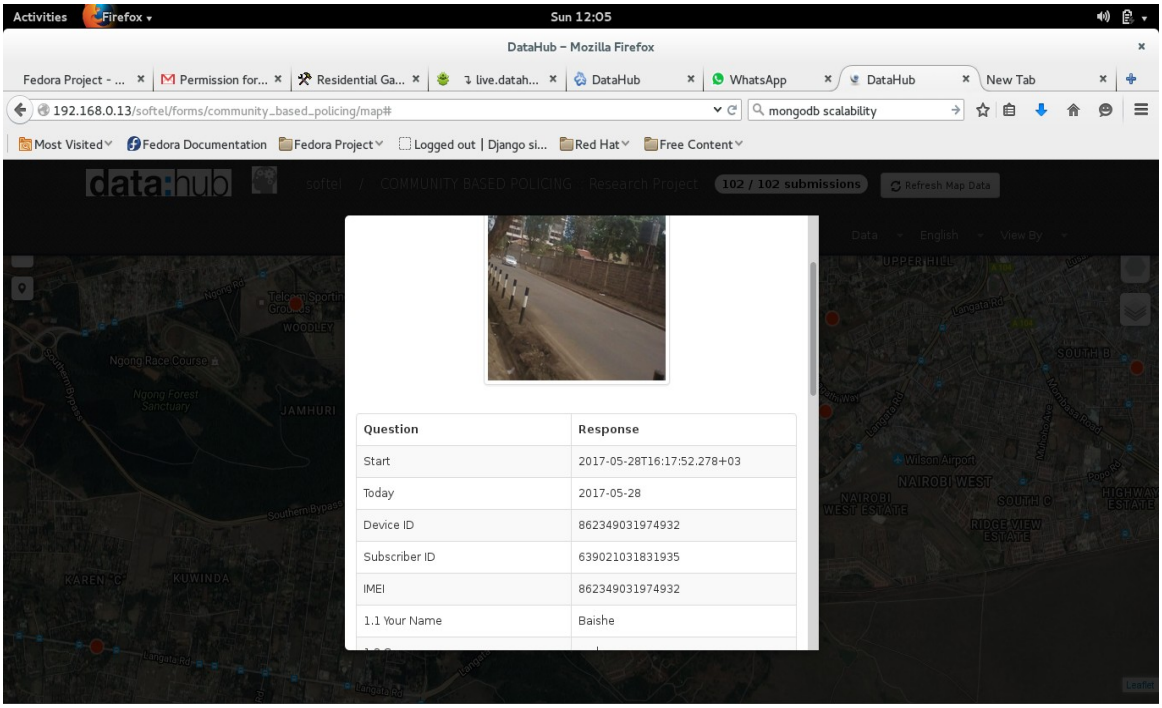

Fig 4.10 Preview submitted response via a popup after clicking a dot on the map

4.1.2 Data Analysis

The objective of demonstrating a GIS based solution for collection and reporting on security matters was successfully achieved and can be reproduced by following the processes highlighted in the methodology.

For further offline analysis though, data had to be downloaded in a spreadsheet format (Appendix A2). Other possible download formats include csv and kml.

The tools employed in investigating the dataset are as follows:

- QGIS for spatial visualization and analysis
- R for statistical analysis
- Ms Excel for statistical analysis

To guide data analysis, the process was designed to focus on the following three items:

1. Data Collection and Transmission
2. Data Accuracy
3. Fitness for use

A. Data Collection and Transmission

This is the analysis of the data submission by volunteer respondents. The daily submission trend, Fig 4.11, shows spikes in the number of submissions. This is a direct result of social media activity:- the more the invitation to participate is shared and re-shared the more number of submissions recorded.

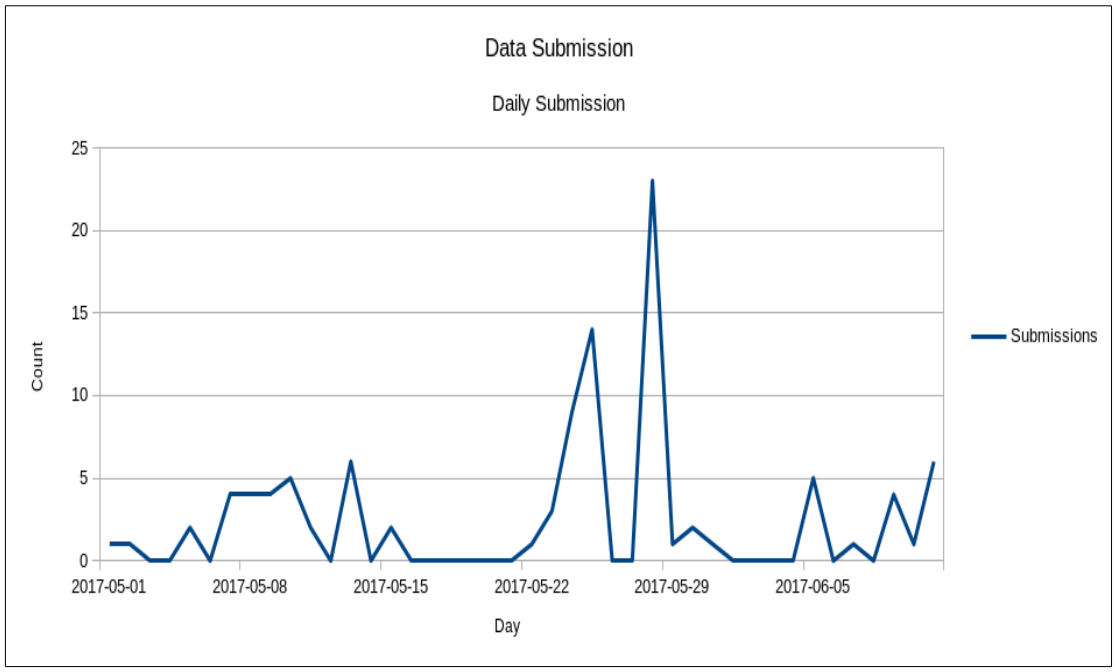

Fig 4.11 Daily data submission trend

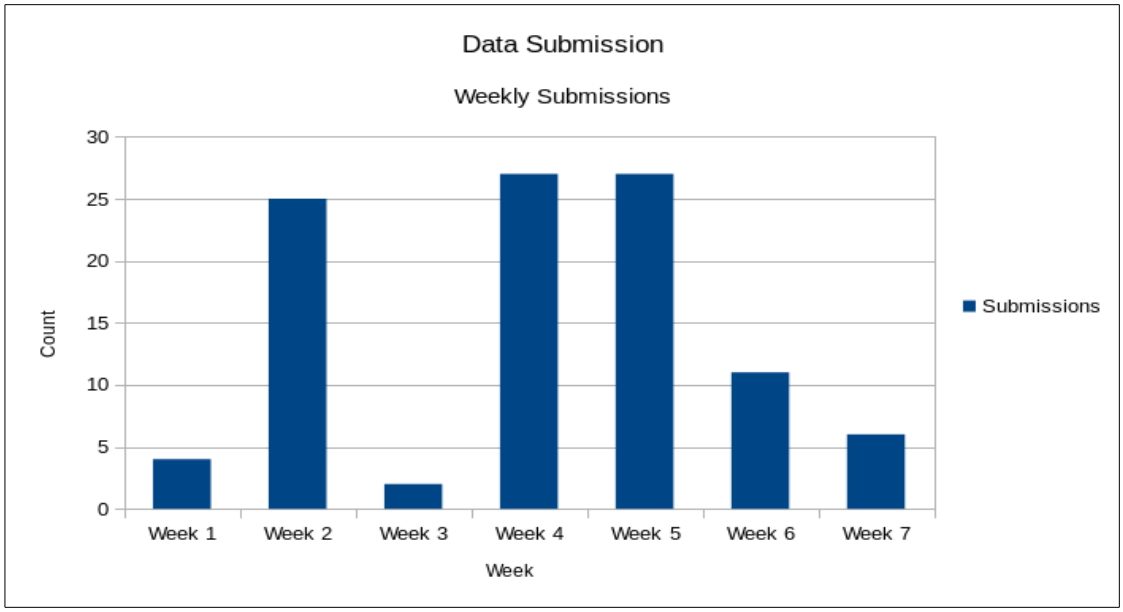

Fig 4.12 Weekly submission trend

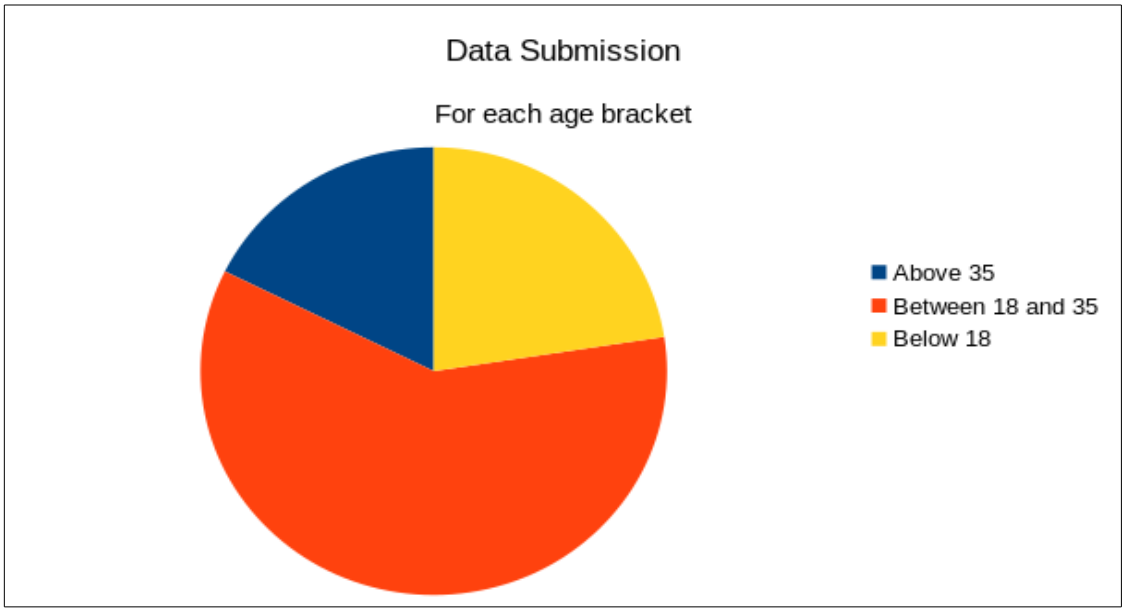

Fig 4.13 Data submission by age bracket

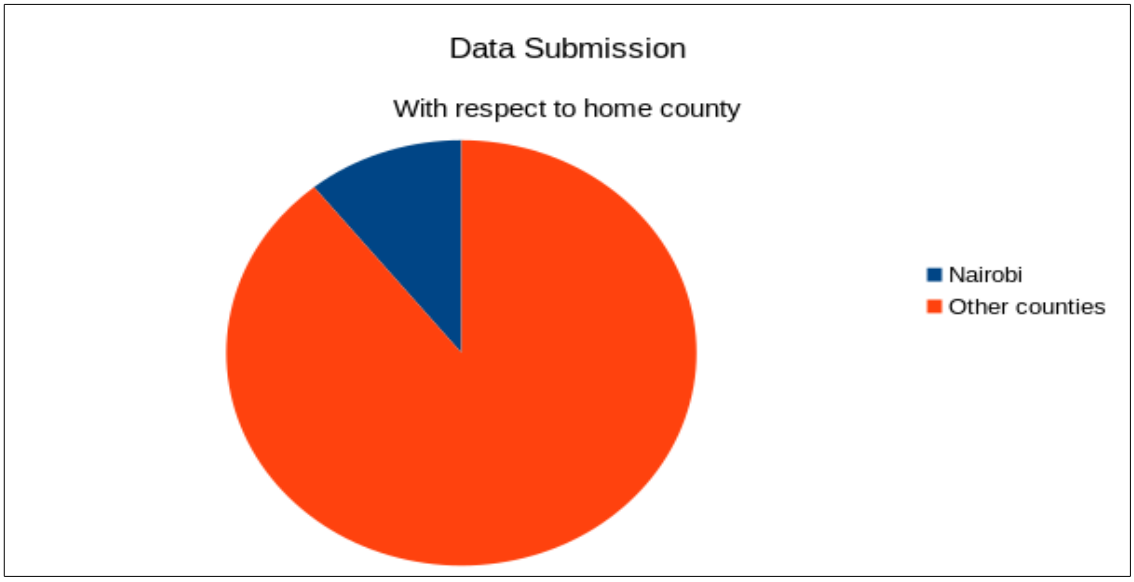

Fig 4.14 Data Submission by Residents vs Non Residents of Nairobi

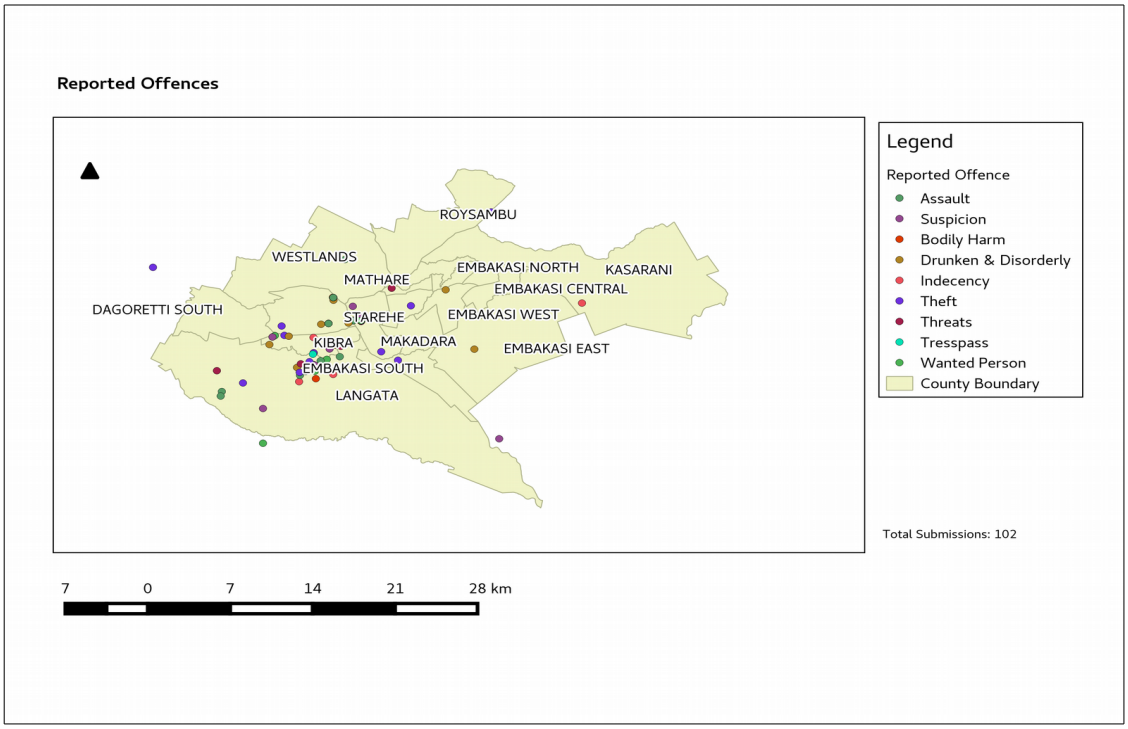

Fig 4.15 Spatial perspective of submissions

Table 4.1: Descriptive statistics of the dataset

Mean	2.4
Standard Error	.7
Mode	0
Median	1
First Quartile	0
Third Quartile	3.75
Variance	18.9
Standard Deviation	4.4
Kurtosis	12.5
Skewness	3.2
Range	23
Minimum	0
Maximum	23
Sum	102
Count	42

For the whole 42 days we were able to get at least 2 submissions per day on average. This translates to at least two cases of crime related incidents which need to be worked on by law enforcers.

B. Accuracy concerns

As a measure of accuracy, the following techniques are proposed for VGI as used in community based policing:-

i. *Number of submissions that fall within the research jurisdiction.*

We need to determine the number of data submissions that do not fall within the jurisdiction of the study. A value of 98 out of 102 indicates a very high general accuracy in terms of location information obtained.

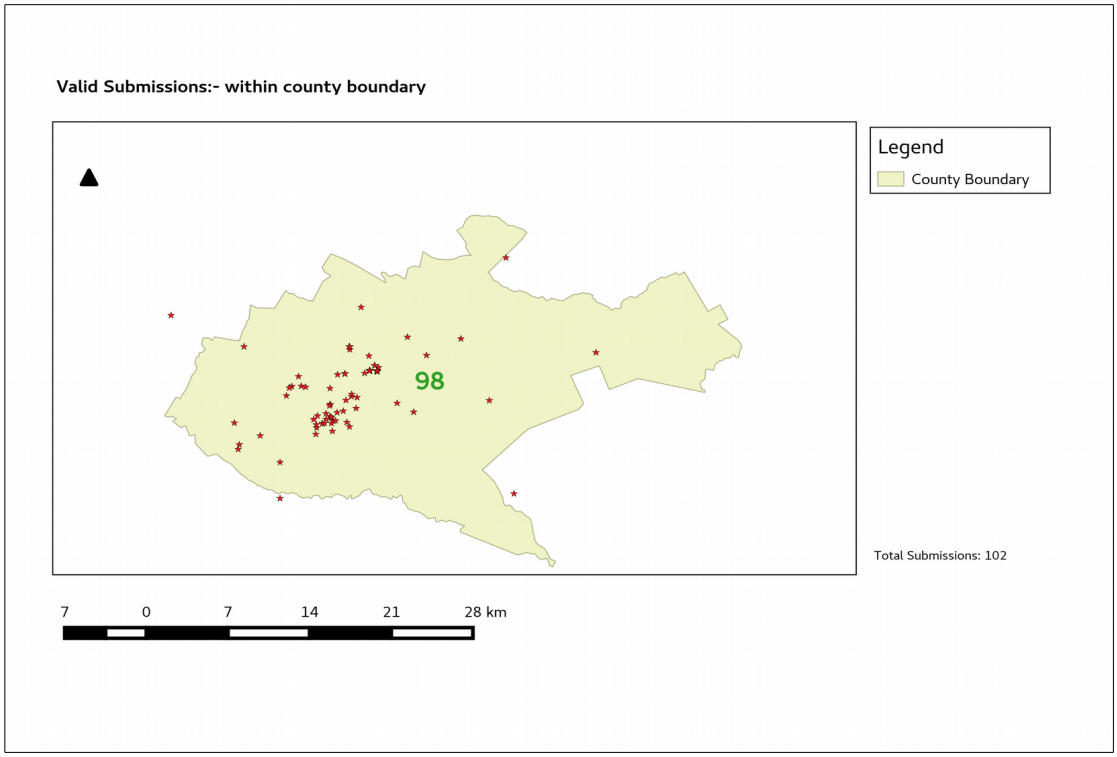

Fig 4.16 Data with valid vs invalid spatial information

ii. *Comparing system date and the reported incident date*

In the submitted data 14 cases had the incident date greater than the system date. This is equivalent to 13.7 % of cases reported *into the future*. This may be due to outright misreporting or wrong date configured on the mobile device which is very unlikely.

C. Fitness for Use

To investigate the fitness of the datasets for use the author decided to avoid subjective analysis as envisaged in the proposal. The approach looked for absolute uselessness in terms of unfilled and empty fields. This is a good measure of fitness for use since by leaving fields empty instead of using false values we can make arguments about the overall experience of users.

Missing / Empty fields

Empty fields are not useful. Here we intend to see how much of useful or useless data we were able to obtain in the field.

Table 4.2: Empty fields in the dataset

Empty Fields	Count	Total	Percentage
Telephone No	34	102	33.33
Offence	1	102	0.98
Incident Details	2	102	1.96
GPS Altitude (value=0)	87	102	85.29
GPS Precision (value=0)	42	102	41.18

As seen in table 4.2, 33 percent of respondents left the telephone number field completely empty. We can proceed to argue that in volunteer data collection anonymity is highly regarded by the participants. We might as well not bother asking for telephone contacts in future undertakings.

One participant did not fill the offence and still managed to submit his/her data for analysis. This is also a useless piece of data for the task at hand. Two other participants did not bother to give details of the incident they are reporting. Again making it hard to believe this is a valid case. It should be noted that these two make a very insignificant percentage (less than 2 %).

Now as much as the devices will pick coordinates, we should be aware that these are mostly approximations. Normally we can use the precision value submitted by the device together with the coordinates but as it turns out not every device will share the precision values for use. 41 per cent is not a percentage that can be ignored.

Altitude is not necessary for this research but its good to know that some devices will report values for this field. It may be helpful in future investigations.

Prank comments and Photos

A quick glance at the photos revealed one thing:- chances of getting real photographic evidence of the incident being reported is low. This may be due to fear of victimization, false alarm, or false incidents altogether.

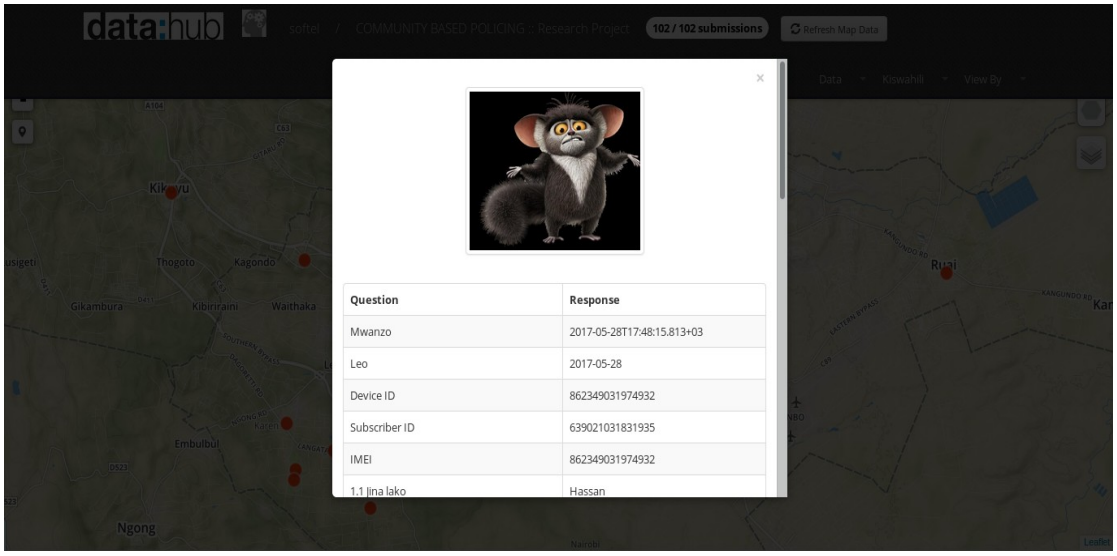

Fig 4.17 Useless photographic evidence

Ratings

Most respondents reported positive feedback about the potential of this mechanism for crime reporting. This is a good sign that the society is warming up to new modes of engagement with police.

Useful DataSets or Data types

One expected outcome is that, given an optional field, people will mostly not fill the field. It is therefore prudent to decide wether the field is really necessary to include in the questionnaire. If yes it may be more usefull to make it mandatory.

Choice fields will also be more usefull than free text fields for faster analysis. If choices are known prior and not so many it would be best to use them extensively.

System managed variables should be used extensively to improve quality of the submitted data. These include the data collection date, submission date, start and end time, IMEI, coordinates among others.

4.2 Discussions

Based on the response from Nairobi county for the 7 weeks of the study, it can be confidently concluded that our society is ready for VGI notably the 18 years to 35 years age group. Most respondents are in this group or identified themselves to be in this age bracket. Either way, this goes to show that we need to target the youth for future VGI efforts.

The technology, aptitude and capacity of the volunteers is obviously not a big challenge with respect to data collection, data transmission and analysis. For community policing the only concern might be the scale when this is done nationwide.

Without any training or official invitation members of the public were able to collect and submit crime incidents. Users were able to figure out and try many things. Accuracy is a concern but measures can be put in place to improve accuracy or minimize the effects of inacurate data. Collecting data and submitting are different things. Some may collect but may not submit in time for action by law enforcers.

Data Quality can be very poor to the level of being unusable. Care must be taken to choose the right participants and the best questionnaire design for the task at hand.

Privacy concerns abound to a level of mistrust and suspicion. This is a real threat to the use of VGI in sensitive disciplines such as community based policing.

The above became apparent as a result of the following:

1. People not willing to share their mobile phone numbers at all. Those who filled gave wrong or incomplete numbers.

2. Non residents not willing to participate. On the flipside residents reporting themselves as non-residents. All these point to fear of identification one way or the other.

3. Some photos were not descriptive of the incident being reported and sometimes outright misleading.

This study as expected was not without challenges. These include:-

- Motivations of the researcher and the volunteer are not always in sync. It is not surprising they might be very opposite. This must be taken into account throughout any VGI exercise.

- Proof of anonymity and non victimization of volunteers is paramount to maintain the goodwill for a community policing project using VGI.

- Remember we cannot control the volunteers. What they *input*, *where* they will collect the data and what time they will eventualy *submit*. These three variables need to be satified to a specific degree and will highly impact the quality of data. It can be seen by the careful observer that the same three variables will define the level of fVGI in terms of power and capability.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The objectives of this study were as follows:

Overall

To demonstrate the applicability of Volunteered Geographic Information (VGI) to Community Policing.

Specific

1. To design an architecture for collection and aggregation of georeferenced data from the community on security related matters.

2. To demonstrate the various software tools for voluntary capturing, sharing and analysing geo-referenced data.

3. To measure the accuracy of the collected security related data and its fitness for use in community policing.

4. To assess the willingness of the members of the public to accept VGI technique and highlight their concerns on the same.

These have been achieved and it is concluded that:

1. Members of the community in the study area are very much capable and highly motivated to use VGI for reporting crime incidents. This is evident from user rating as shown in Fig 4.8.

2. Data quality, as shown in Table 4.2, is still a major challenge that VGI initiatives must be able to overcome in order to be successful. The good news is that it is possible to monitor the accuracy of the data as it is being received making it possible to initiate corrective measures early on.

3. Reaching out to the members of the public using social media has been found to be a very effective and less costly means of generating awareness for VGI projects. This was proven during the research project as visible in Fig 4.11:- every time the numbers were too low, a notice or tweet was sent to popular social websites and almost immediately there was response.

4. Setting up a VGI platform for collecting and visualizing reported crime incidents in near real time is very practical and cost effective. The main cost drivers for such a setup is on the server side which the author believes is very well within the reach of state agencies dealing with law enforcement.

5. Data collected was very useful as it contained the type of crime, the description, location information and date information. Suggested improvements notwithstanding, the dataset is good enough for the purpose of crime reporting and action.

5.2 Recommendations

From the study it is recommended that:-

1. Any community policing project using VGI must take control of the user input options, location accuracy and the submission time.

2. To ensure data of highest quality possible it will require employing the services of trained volunteers, security guards or crime monitors to report crime incidents instead of having untrained volunteers.

3. It is the feeling of the author that, for a much greater impact, VGI should be employed to less sensitive projects like wildlife monitoring, environmental hazard monitoring, disaster management if untrained volunteers are the primary source of data.

4. A much simplified version of the popular data collection applications, ODK Collect, needs to be created. This is due to the usability challenges reported during the research. If possible, a single page mobile or web application that is accessible as a native smartphone app and also on the web.

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APPENDICES

A1. XLS Form, the digitized questionnaire

type	name	label::English	label::Kiswahili	hint	required
begin group	grp_project	Project Overview			
note	university	University of Nairobi	University of Nairobi		
note	school	School of Engineering, Department of Geospatial and Space Technology	Geospatial and Space Technology		
note	course	MSc Geographical Information Systems	MSc Geographical Information Systems		
note	candidate	Candidate: Ibrahim Abdi Itambo. F56/75529/2014	F56/75529/2014		
note	supervisor	Supervisor: Prof. Galcano C Mulaku	Mtahini: Prof. Galcano C Mulaku		
end group					
begin group	grp_research	Research Title			
note	note_title	Volunteered Geographic Information: application to Community Based Polici	Volunteered Geographic Information: application to Community Based Policing		
note	note_trial	Volunteers are invited to try out filling this questionnaire to report any information useful for the well being of the community. No private information is collected and anything u send will be used STRICTLY for this research. Your input is highly appreciated. This questionnaire is available also in Kishwahili. For inquiries contact 0736 563 163	Mnaombwa kujitolea kujaza hii fomu ili kusaidia utafiti kuhusu usalama vijijini. Habari zote unazotuma zitatumiwa kwa utafiti huu pekee. Tunakusihi uchangie kwa kujaza na kutuma. Unaweza kujaza kwa Kiingereza ukitaka. Kwa maswali piga 0736 563 163		
note	overall_objective	Overall Objective: To use concepts from Volunteered Geographic Information and mobile-based data collection tools to address practical societal issues and to also debunk the notion that GIS is an elitist, anti-democratic technology by virtue of its technological complexity and cost.	Overall Objective: To use concepts from Volunteered Geographic Information and mobile-based data collection tools to address practical societal issues and to also debunk the notion that GIS is an elitist, anti-democratic technology by virtue of its technological complexity and cost.		
end group					
start	start	Start	Mwanzo		
today	today	Today	Leo		
deviceid	deviceid	Device ID	Device ID		
subscriberid	subscriberid	Subscriber ID	Subscriber ID		
imei	imei	IMEI	IMEI		
phonenumber	phonenumber	Phone Number	Phone Number		
begin group	grp_background	SECTION 1 – BACKGROUND INFORMATION	SEHEMU 1 – UTANGULIZI		
note	note_section_1	SECTION 1 – Background Information about the reporter of this incident	tukio hili	user input.	
text	reporter_name	1.1 Your Name	1.1 Jina lako	This is optional	yes
text	tel	1.2 Mobile	1.2 Nambari ya simu	This is optional	
select_one m_f	sex	1.3 Sex	1.3 Jinsia	Single choice field	
select_one age_bracket	age_bracket	1.4 Age bracket	1.4 Umri		yes
select_one county	county	1.5 Home County	1.5 Kaunti unapotoka	Where you come	yes
end group					
begin group	grp_incident	SECTION 2 – INCIDENT INFORMATION	SEHEMU 2 – HABARI KUHUSU TUKIO		

A2 Sample of Downloaded DataSet

index	system_date	reporter_nam	tel	sex	age_bracket	home_county	offence	village	remark	incident_date	is_criminal	is_reported	police_station	police_respor	reason_for_n	rating	concerns	incident_image	latitude	longitude	altitude	precision
1	2017-05-01	Kaka	0734556789	male	Below_18	turkana	assault	N	N	2017-05-01	no					poor	Not comfy	1493634670366.jpg	-1.2879454	36.7988737	0	26.09
2	2017-05-05	Salma	No way	female	btwn_18_and	mombasa	suspicion	Cbd	Abandoned b	2017-05-05	no					dont_know	Not bad	1493965681822.jpg	-1.286322	36.8238503	0	57
3	2017-05-05	Lakan	0723456543	male	Below_18	turkana	suspicion	Nbi	Tout	2017-05-05	no					good	Good not safe	1493977327193.jpg	-1.2735866	36.8174677	0	1414
4	2017-05-07	Mustapha Mb	0799931934	male	btwn_18_and	nairobi	drunken_diso	Langata - Ngei	Making noise	2017-05-07	yes	yes	Langata police	The man was	charged	excellent	Easy and fast	1494136834652.jpg	-1.2993584	36.7561602	0	32.1
5	2017-05-02	Ahmed		male	btwn_18_and	taita_taveta	drunken_diso	Tanzania	There was a dr	2017-04-02	no					good	This is a very	1494138473965.jpg	-1.32805167	36.7815883	1747.2	5
6	2017-05-07	Jack	0724	male	btwn_18_and	nyandarua	theft	Adams	Market thief	2017-05-07	yes	no			Why	good	Good	1494149087305.jpg	-1.298212	36.7579428	0	1393
7	2017-05-07	Nzola Evans	0726084019	male	btwn_18_and	nairobi		Kabete		2017-05-03	no					good	Too much data	1494155913452.jpg	-1.2661336	36.7211627	0	100
8	2017-05-08	Mustapha	0799931934	male	btwn_18_and	nairobi	theft	Starehe	Stealing in sho	2017-05-08	no					excellent	Easy and fast	1494242161303.jpg	-1.2828974	36.8248171	0	22.563
9	2017-05-08	Biwott	0725	male	btwn_18_and	bomet	drunken_diso	Town	Walevi	2017-05-08	no					excellent	Not bad	1494220404827.jpg	-1.3063426	36.8039726	0	1750
10	2017-05-09	Jay	Mosaic	male	Below_18	wajir	drunken_diso	Westi	Mchele kwa ju	2017-05-09	no					good	Poa sana	1494331333837.jpg	-1.268478	36.8027085	0	1104
11	2017-05-09	Abdillahi	0721411400	male	Above 35	mandera	suspicion	Hurlinghum	Standing at on	2017-05-09	no					good	Easy	1494335999055.jpg	-1.2813096	36.8217891	0	19.207
12	2017-05-09	Grace	0721445	female	btwn_18_and	nairobi	bodily_harm	Ngara	Fighting ladies	2017-05-09	yes	no			No time	good	Good butneed	1494340244822.jpg	-1.2856793	36.8178204	0	1385
13	2017-05-10	Peter tosh	Jam	male	btwn_18_and	nairobi	theft	Civil servant	Lost my pho	2017-05-10	no					good	Ok	1494409376165.jpg	-1.2662935	36.802661	0	33
14	2017-05-10	Sally	@salybabe	female	Below_18	nairobi	indecency	West	Indecent wom	2017-05-10	yes	no			Time	average	Hard to use	1494415053782.jpg	-1.2662608	36.8025889	0	75.191
15	2017-05-10	Chilibasi	0725223789	male	btwn_18_and	taita_taveta	wanted_perso	Kinoo	Wanted by chi	2017-05-10	no					average	Beba	1494418624610.jpg	-1.2662488	36.8024941	0	67.091
16	2017-05-13	Khatwib	0728767972	male	Above 35	nairobi	wanted_perso	Mugumoini	Spotted in this	2017-05-13	yes	no			Needs more d	excellent	Very easy to u	1494659831170.jpg	-1.32468667	36.7844767	1761.6	4.4
17	2017-05-13	Margaret	0796798479	female	btwn_18_and	nakuru	assault	Park one estat	Talking rubbis	2017-05-13	yes	yes	Langata police	The person was	s jailed	excellent	Super	1494660163357.jpg	-1.32251667	36.7874667	1690.2	6.8
18	2017-05-13	Njeri	0725448559	female	btwn_18_and	muranga	suspicion	Southland	Stolen kinderg	2017-05-13	yes	yes	Kona mbaya	The chair was	returned to the	excellent	Easy	1494660746637.jpg	-1.32349167	36.788245	140.5	5.7
19	2017-05-13	Daniel		male	Below_18	muranga	suspicion	Sivo	Stolen cartoon	2017-05-13	yes	yes	Sivo police stat	The cartoon wa	s burn from t	excellent	Nirahisi	1494662002237.jpg	-1.32298	36.7882367	1679.2	5