UNIVERSITY OF NAIROBI

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

Web GIS Application for Real-time Highway Incident Reporting in KeNHA – Nairobi Region Leveraging on Social Media.

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Research Project submitted 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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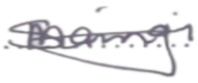
Signature: 

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Abstract

The road incidences occur everywhere on the roads. However, road users and witnesses of road incidences lack a medium of reporting the information for timely response. The authorities lack concrete evidence to solve road incidents since there is no proper road incident reporting system. With the increase of use of smart phones in Kenya, an opportunity exists because of the untapped gap of incident reporting. The objective of the research was to develop a web GIS road incident reporting system that will contribute to road safety by improving reporting and response as well as improving the dissemination and analysis of information arising from the incidents.

In this project a web application that can be used to report road incidents was developed by coding and harnessing the ArcGIS Enterprise platform. The system has a real time data collection and reporting of the incidences as reported and response. The application developed was able to scrape the social media data from Twitter, Flicker, and Webcams among others and the interface for reporting was successfully used by citizens to report road incidents. The dashboard created for visualization of the incidences was also successful. The benefits of the system will be location based and real-time data collection which will enable prompt management of the incidences to avoid inconvenience to road users, quick resolution and easier decision making, hence improving the effectiveness and efficiency in service delivery. The big data from social media posed challenges in filtering the information into useful data for the system. However this was overcome by assigning incident category and filtering using a dictionary of key words. There was also the challenge to verify the incidences reported whether they actually occurred. In conclusion, the project achieved the aim to develop a web based application for incident reporting and highly recommend the road Authorities such as KeNHA among others to adopt and implement it.

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CHAPTER 1: INTRODUCTION

1.0 Background

Road incidents are referred to as occurrences which happen on the roads and may be fatal or non-fatal. These occurrences may lead to damage and loss of property and infrastructure. The incidences are usually classified as accidents, damaged road signage and furniture, hazards like fallen trees on the roads, flooding, and damaged bridges. Road incidences include: road accidents, road hazards, road condition e.g., potholes, obstructions like fallen trees, flooded rivers, vandalized or missing road signage, damage to road assets,

Road accidents are the major and most commonly reported incidences. Every year, the number of people that die on the world's road is over 1.2 million and it is estimated that another 20 and 50 million people suffer from injuries which do not lead to death (WHO, 2019). Whereas the epidemic of road traffic injuries has been declining in high income economies, it is still increasing in middle and low income countries (i.e., 21.5 and 19.5 per 100 000 population respectively). In fact, 93% of the world's loss of life at the highways occur in low and middle-earning states, despite the fact that those countries have approximately 60% of the world's vehicles. Road incidences injuries remain a global public health concern and it is predicted that by 2030 road traffic incidences will become the most lethal causes of death (WHO, 2019).

While motorists, cyclists and pedestrians account for over half of the road incidents that result in death, they are also the most vulnerable users of the roads. (WHO, 2019). Besides the deaths, road incidence injuries cause considerable socio- economic losses to people, their relatives, and nations. These losses are as a result of the debts incurred seeking treatment as well as lost productivity for those who die or are rendered disabled by their injuries. The family members who take out time from working hours to care for those nursing injuries from road accidents. According to the WHO (2019) report, road traffic injuries cause the most deaths among children and young adults aged 5-29 years.

There are diverse causes of road incidences. They range from driving while drunk, to over speeding, as well as distractions that impact the driver concentration. Some other avoidable causes include not stopping or slowing at appropriate road signage posts and not using road safety gear such as car seat belt. Others are non-adherence to lane driving and overtaking in a wrong manner,

faulty road infrastructure, driving road-unworthy vehicles and not enforcing the traffic laws effectively (WHO, 2019).

Some of the recommendation to foster road safety include: taking into account all the road users' needs when making road policies and road design decisions that determine the road safety; public awareness campaigns and strict enforcement of road safety laws; fostering a multi-sectoral collaboration among institutions charged with enforcing road safety actions. They also encourage partnership among the varied sectors that have a stake in collection and reporting of the data on road traffic incidents. This will involve improving close linkage between relevant agencies whose policies impact road safety (NTSA, 2020).

According to the UN Sustainable Development Goals Goal 3- target point 3.6 is that by the year 2030, the volume of fatalities and injuries resulting from road incidents should have reduced by half (UNECE, 2016). In this same breadth, target point 11.2 aims to ensure there is access to sustainable systems of transport, which are safe, affordable and accessible to all. The purpose is to improve road safety while also expanding the capacity of public transport and ensure special facilitation for the vulnerable population such as children, people with disabilities and women come the year 2030. (UNECE, 2016).

Although the agencies, particularly the police and the National Transport and Safety Authority collect data on road incidents, there is still an identifiable gap in the quantity and quality of the data on road incidents that is collected and reported (Hutchinson et al, 2017). To effectively profile the causes of road accidents and probe the scope of the resulting injuries and fatalities, as well as, respond and intervene accordingly, it is crucial to have reliable data on road traffic incidents (WHO, 2018).

Crowdsourcing, in particular Volunteered Geographic Information (VGI) is established as a means of collecting data from the crowd. This approach can be utilized in collecting road incident data and information from the citizens instead of government agencies and the for-profit entities (Sui et al, 2013).

Crowdsourcing through social media has successfully recorded and facilitated traffic and navigation applications. These systems operate on VGI to provide services to travellers on the roads. Such applications include Apple Maps, Google Maps, Waze, and MapQuest, which to optimize crowd-sourced data use OpenStreetMap data (Attard, et al., 2016). Waze in the Kenyan

market competes with Kenyan service called *Ma3route* that provides updates and information regarding status of route traffic via Twitter, SMS and web (ma3route.com, n.d).

The main objective of Ma3Route is to ease travelling by democratizing timely transport information in developing countries through crowdsourcing. This can inform decisions related to city planning and transport by providing analysis of data and trends on roads, (ma3route.com, 2016).While users of this application can report road incidents, the data is largely amorphous and every so often lacks the required accuracy. Users also do not have a comprehensive channel for getting feedback about the resolution of the reported incident. An example of an incident that occurred along Wangari Maathai road where a lady was stripped by *boda boda* riders which caused a public uproar on 7th march 2022.

The aim of the research was to explore the potential of social media in road incidence reporting.

1.1 Problem Statement

Kenya National Highways Authority (KeNHA) is responsible for the development, rehabilitation, management and maintenance of all National Trunk Roads comprising Classes S, A, and B roads, totalling to approximately 18,101 Km (Gatitu, Kabubo, & Ajwang, 2020). Other players involved in roads subsector include: Nairobi Metropolitan Area Transport Authority (NaMATA), Kenya Rural Roads Authority (KeRRA), Kenya Urban Roads Authority (KURA), Kenya Roads Board (KRB), County Governments and Kenya Wildlife Services (KWS)

Among their core functions, the authorities collect and collate, monitor and evaluate data related to how roads are used. Although these authorities collect data on road incidents, there is still an identifiable gap in the quantity and quality of the data on road incidents that is collected and reported (Hutchinson et al, 2017). Since it's not possible for the authorities to collect this data, crowd sourcing becomes a feasible option for data collection. To make this possible, road users need a platform where they can file reports about road incidents and complaints to the authorities concerned directly. The authorities however lack tangible evidence to unravel road incidents since there is no suitable road incident reporting and management structure. Road incidents happen ubiquitously but the onlookers lack an expedient and well-organized method to report them. The frequency of road incidents that are ignored in Kenya is rising conspicuously, especially the hit and run incidents (Ngicabe, 2016).

The existing application for reporting incidents at KeNHA is a HTML form which contains the name, email, contact, incident type, without linkage to location details. This makes it impossible

to locate and map the location of incidents. The system also does not have a response mechanism for checking the status of the reported cases, location and the photograph of the incident. These are essential components of verifying that the reporter was at the scene of the incident.

It is against this backdrop that a GIS-based Highway Incident Reporting and Management System was proposed. The system will have a real time data collection and reporting of the incidences as reported and responded to. The benefits of the system will be accurate and real time data collection which will enable prompt management of the incidences to avoid inconvenience to road users, quick resolution and easier decision making, hence improving the effectiveness and efficiency in service delivery.

1.2 Objectives

The main objective of this research was to develop a Web GIS based Application for Real-time Highway Incident Reporting system for KeNHA Nairobi Region that contributes to road safety by improving reporting and response as well as improving the dissemination and analysis of information arising from the incidents. Specifically, this project aimed to:

1) Evaluate existing local web-based systems for road incidents reporting;
2) Develop a web GIS application system through which users can report road incidents within KeNHA road network in Nairobi Region leveraging on social media
3) Determine the integration of existing social media platforms for road incidents reporting and the existing system with GIS.

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The project was carried out to answer the following questions (in Table 1) towards achieving the above objectives.

Table 1: Research Matrix

Objective	Research Question	Methodology	Data Required	Expected Output
Evaluate existing local web-based incidents reporting systems	What are the existing local web based incidents reporting systems	Literature review of existing local web based incident reporting systems	Journals, conference proceedings, books, project reports	Show the potential and limitation of the roads incidents reporting
Develop a web GIS application system through which users can report road incidents within KeNHA road network in Nairobi Region leveraging on social media.	What features should a system for road incident reporting have; how can such a system scrap data from existing social media that related to road incidents; how can such a system be integrated with GIS	Build a web based application through which users can use to report road incidences in KeNHA road network in Nairobi Region.	KeNHA road network Nairobi Region KeNHA regional boundaries KeNHA road network in Nairobi Region Police Stations in Nairobi Region Health Facilities in Nairobi Region Road incidences data	An interactive web application for road incidents with integration of data extracted from social media.
Determine the potential of existing social media platforms for road incidents reporting and their integration with GIS.	What is the potential of existing social media platforms for road incident reporting and integration with GIS	Evaluation of existing social media platforms for road incident reporting/ how to determine if a social media contains a road incident data/ how to scrap/extract data from social media platforms	Identify social media platforms for evaluation; identify factors/elements for evaluation	Establish the extent to which social media contain road incident data; chose specific platforms for data scraping

1.3 Justification for the Study

Road incidents appear anywhere, however the eyewitnesses to those incidents do not have a handy and green technique to file them. On the other hand, the government authorities lack concrete proof to remedy the incidents when you consider that there's no proper incident reporting and control system. The proposed platform will offer real-time spatial information and evaluation thereby making a contribution to enhancing road asset protection and road safety when it is utilized by the

public. The platform provided location information of the incidences which enabled timely reporting and interventions in the highways and the information collected will be analysed to establish the cause of the incidences to improve road safety. Moreover, the platform enabled prompt management of the incidences to avoid inconvenience to road users, quick resolution and easier decision making, hence improving the effectiveness and efficiency in service delivery. This way the platform leads to improved data collection analysis and information management. The collection approach supplemented offline data collection currently in use like the road patrol along the highways.

The current Kenya National Highways Authority (KeNHA) strategic plan (2018/2019 – 2022/2023) provides a road map that among others prioritizes interventions aimed at improving the highway road condition and preserving the road investment, providing quality and safe roads, securing our road corridor and ensuring value for money in operations. The proposed platform therefore directly linked to objective 5 of strategic plan intended to strengthen the institutional capacity through enhancing ICT process automation by implementing a Highway Incident Management System.

1.4 Scope of work

The project targeted both internal and external users. The external users including pedestrians, motorists, other stakeholders and interested parties will be targeted, while the internal users include the different Directorates with the authority.

The platform is web based. The system collects data on the road incidences including; road accidents, road condition e.g., potholes, hazards and obstructions like fallen trees, flooded rivers, vandalized or missing road signages within KeNHA road network. This data is useful for road asset management team to evaluate and take mitigation measures to improve road safety and timely interventions to avoid fatalities on the highways. The system is interactive; the reporter is be able to visualize the status of the reported incident, other users are able to like and comment on the incidences reported using social media platforms like twitter and Facebook. The reporter will also visualize once the incident is resolved. The reporter can track the stages of the resolution of the incident reported.

1.5 Report Organization

This report is structured into five chapters.

The first chapter is the introduction to why the study is important and it also outlines the objectives of the study and the scope of the project.

The second chapter reviews the literature on road transport in Kenya, road incidences and trends and application of GIS in road safety and reporting of road incidences. It also explores the importance of social media in reporting incidences. The third chapter explores the materials and methods used to carry out the study. The fourth chapter examines the analysis and the results of the study. The fifth chapter contains the conclusion and recommendations from the project and areas of auxiliary research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter evaluated the existing web based incidents reporting systems, the impact crowdsourcing and volunteer graphics information as an enabler. It also explores the extent to which the existing systems are integrated with social media platforms and GIS. Other systems for reporting are also discussed. The web applications used in the road industry sector have been discussed in this chapter.

2.1 Road transport in Kenya

Kenya road sub-sector accounts for over 80% of the country's total passenger traffic and 76%. The road network consists of paved, gravel and earth roads. Kenya's road network is 246,000kms. The road network is divided into classified roads and unclassified roads. Consequently, 161,821kms are classified roads while 34,000kms are uncategorized (new) roads with a reserve corridor greater than 9m and 50,000kms are narrow roads with road reserve below 9m. The data is in the custody of Kenya Roads Board (KRB) who manage and maintain the state of these roads in a geodatabase (KRB RICS, 2018).

Currently, the Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works is responsible for matters pertaining to roads on the provision (specifications, design standards and classification), maintenance of roads as well as the use of the roads. The Kenya Roads Board (KRB) has a mandate to oversee the road network and thereby co-ordinate its development, rehabilitation and maintenance. The Kenya Roads Act (2017) vests authority of undertaking the actual development, rehabilitation and maintenance of roads to Road Agencies. The establishment of the agencies include: the Kenya National Highways Authority (KeNHA), Kenya Rural Roads Authority (KeRRA), Kenya Urban Roads Authority (KURA), Kenya Wildlife Service (KWS) and the 47 County Governments.

The Kenya Roads Act (2017) sets out the classification and distribution of the responsibilities of the road network. KeNHA manages, develops, rehabilitates and maintains all the primary national trunk roads Classes S, A and B. Consequently, KURA is responsible for managing, developing, rehabilitating and maintaining al primary national trunk roads Classes H and J, while KeRRA manages, develops, rehabilitates and maintains the secondary National Trunk Roads classes C and

D. Kenya Wildlife Service (KWS) manages, develops, rehabilitates and maintains the roads traversing the National Parks and National Game Reserves. The 47 County Governments are charged with the mandate to manage, develop, rehabilitate and maintain the County Roads of rural classes D to G and urban classes L to P.

Despite the above arrangements, there are several challenges facing the road authorities. These range from inadequate funding to effectively completing all planned projects; inadequate operation management systems; escalating cost of road construction materials, land acquisition and availability for construction projects. The reclassification of road network which shifts some of the roads from one authority to another is also another challenge facing the authorities.

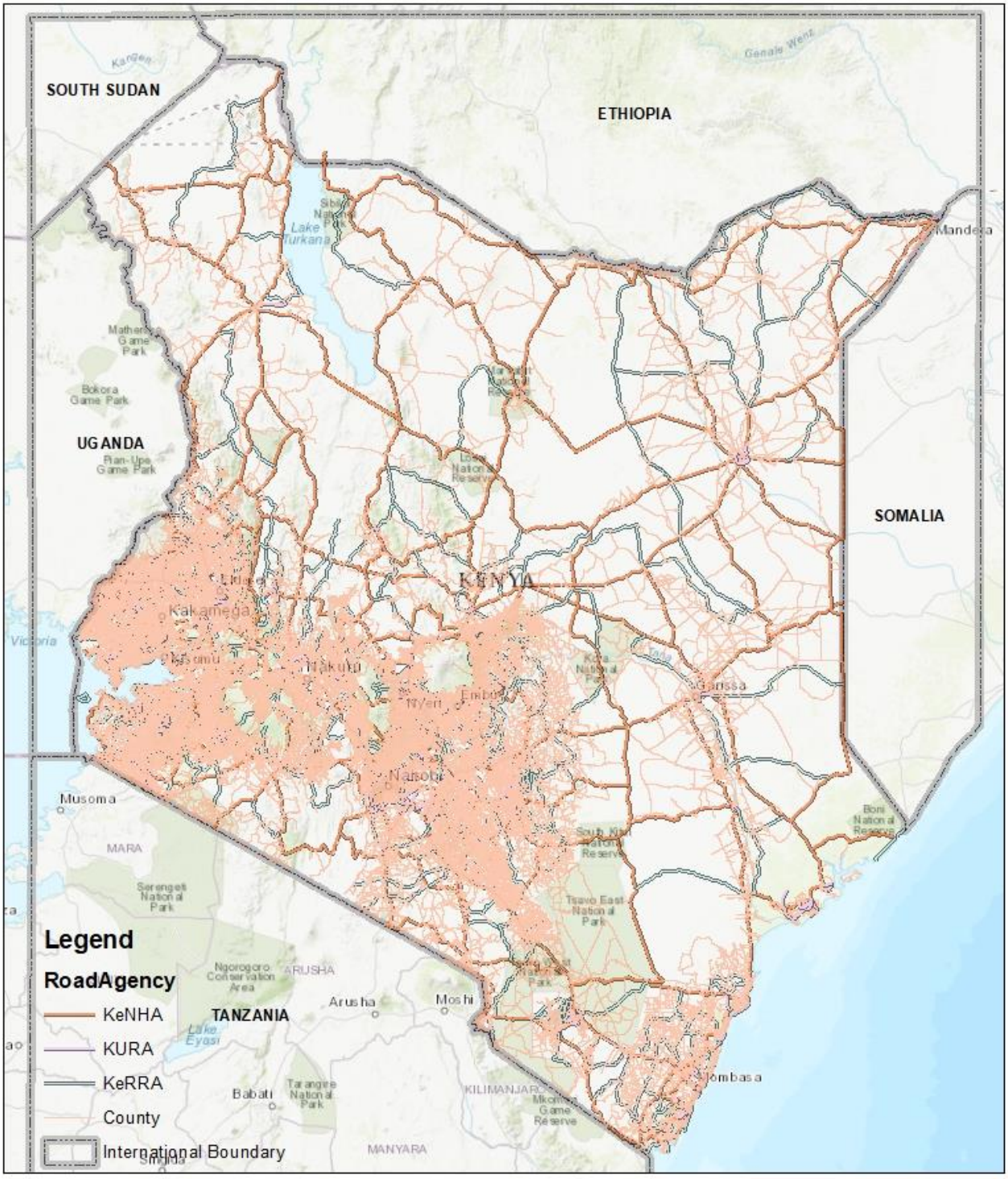

Figure 1:Kenya roads map. Source: KRB

2.2 Road Incidents

A road incident alludes to an accident, catastrophic event, work zone movement, extraordinary occasion or other emergency road user occurrence that antagonistically influences or obstructs the ordinary progression of traffic (Legal Dictionary, 2022). The occurrences incorporate hazards which is potential risk experienced while driving including yet not restricted to, potholes, rocks, wood flotsam and jetsam, metal parts, plastic, controls or scraps.

2.3 Trends in Road Traffic Incidents

Sustainable transport is essential to achieving most of the goals in the 2030 Agenda for Sustainable Development. The United Nations (UN) 2030 Agenda for Sustainable Development, target 3.6 aims for the reduction of global road traffic deaths and injuries by 50 per cent by 2020, and reduce to 5% fatalities and injuries. Target 11.2 aims to provide access to safe, affordable, accessible and sustainable transport systems for all by 2030. In addition, also target 9.1 aims to develop quality, reliable, sustainable and resilient infrastructure, including through investments in transport infrastructure (UNCTAD, 2018).

According to National Transport and Safety Authority (NTSA), the body in charge of transport safety in Kenya, the country recorded 3,572 fatalities, 6,938 serious injuries and 5,186 slight injuries as at December 2019 (NTSA, 2020). According to the trend analysis, fatalities and injuries have increased by 26% and 46.5%, respectively since January 2015 to January 2020 (Joseph Kamau et al., Cogent Engineering (2020). Injuries to pedestrians, motorcycle (boda-boda) commuters and riders augmented by more than 250% for this reporting window.

There is insufficient information of roads incidences due to improper reporting and documentation. Some incidents are never reported forming an information gap. The authority is does not get the reports on time and cause response delays. There is also lack of simple medium for reporting the incidents therefore there is no sufficient data to help policy and decision makers to solve the problem. The existing systems lack data sharing policies, procedures and workflows.

2.3 GIS in Road Safety and Incidents Reporting

GIS entails the framework for gathering, managing, and analysing spatial data and organize layers of information into visualization. The locations where road incidents happen have attributes/ descriptive information. Therefore this can be used to establish the connection of a GIS and the road incidents data.

The current application is a component of a Customer Relation Management System (CRM) which include; complaints management, visitor's management, and incidents reporting and management. The complaints and visitors management modules are actively being implemented though the incident management system has not been utilised. The figure below shows the status of the reported cases since the system has been operational.

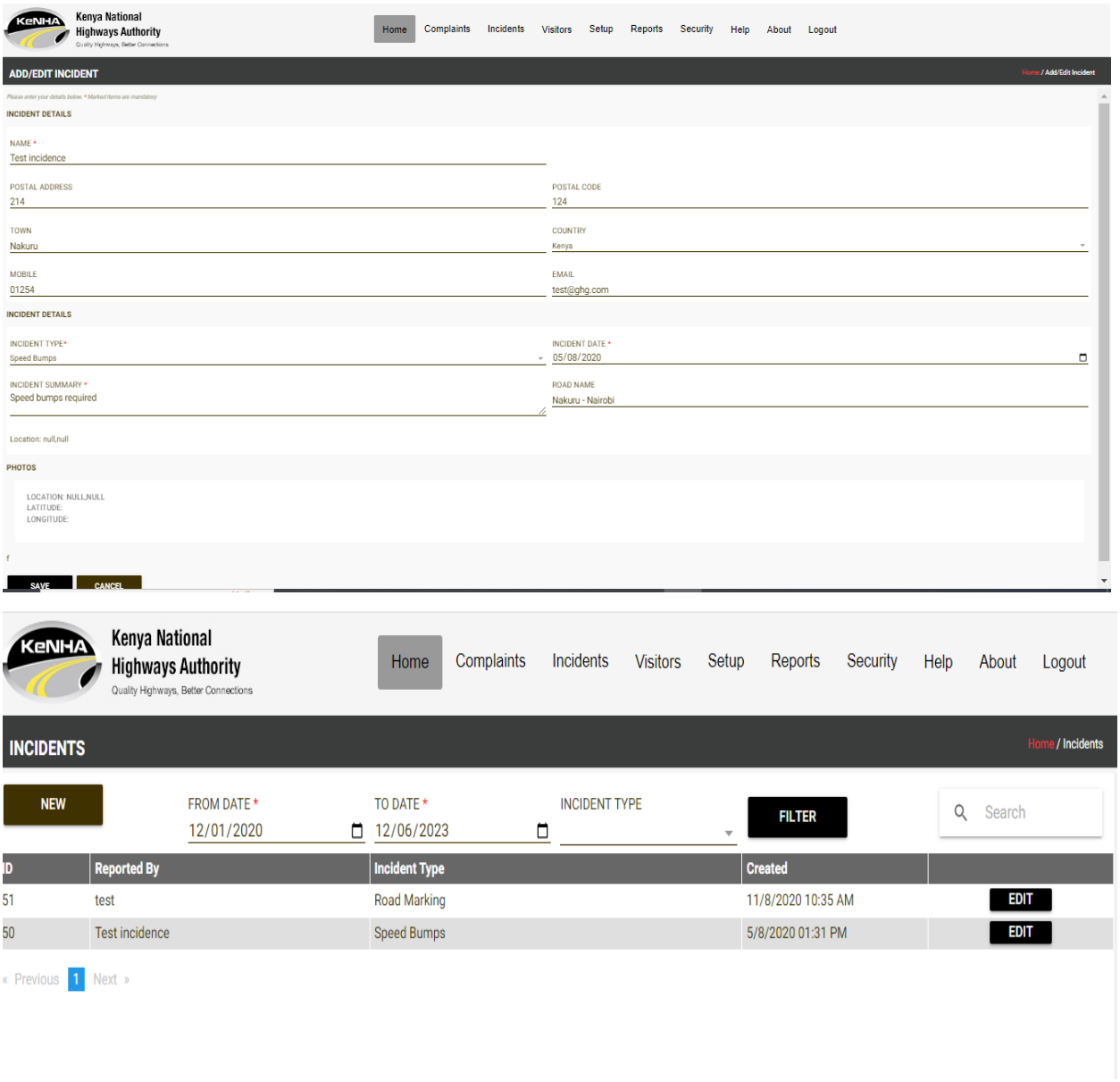

Figure 2: Existing incident reporting system

The shortfalls of the incident management include; lack follow-up, conversion, slow updates and data access, tracking resolution of reported incidents and positional accuracy. The solution of the problems above is to develop a real time responsive and interactive application which is able to report, track and accurately position the location of the incident and display the information through a web application.

The application is a PHP feedback form which is ambiguous in design, does not have database design flow, it also does not have the location visualization and is not geo-location enabled to pick location of the gadget used to report an incident. The omission of categories of incidences to guide a reporter and the constraints of location within which an incident can be reported makes it difficult to track and to classify the incidences reported.

2.4 VGI in Road Safety and Incidents Reporting

The advancement of volunteer geographic information (VGI) technologies enables participation by non-professional or volunteers in producing, sharing and consuming geographic data. VGI has the tools to collect, generate, and publicise geographic data and information availed voluntarily from the public. Some of the systems and capabilities include: OpenStreetMap, Ushahidi, Nduru, CrashData, Ma3Route, GIS-Alas and Esri Crowdsource Reporter.

2.4.1 OpenStreetMap

OpenStreetMap (OSM) is a cooperative undertaking to make a free editable geographic data set of the world. The geodata fundamental the guides is viewed as the essential result of the task. The creation and development of OSM has been spurred by limitations on use or accessibility of guide information across a significant part of the world, and the appearance of economical versatile satellite route devices. The OpenStreetMap Establishment was laid out to energize the development, advancement and dissemination of free geospatial information and give geospatial information to anyone to utilize and share. The cluttering of data makes it difficult to visualize specific data from the application.

2.4.2 Ushahidi

The Ushahidi application assists networks transform data right into it with an instinctive and available publicly supporting and planning instrument. By empowering the quick assortment, the executives and examination of crowdsourced supported data, Ushahidi engages everybody people, local gatherings, states, activists, associations to make significant change. The cluttering of data makes it hard to visualize the incidences.

2.4.3 Nduru

Nduru is a mobile application for android devices which processes road incident data that relates to road safety and allows road users to air their views and distress regarding road safety. The application is helpful in flagging conditions that could result in an accident and reporting (Thomas, K, 2012). However, the application does not have mapping capacity to facilitate visualization of road incidents and no way to follow up resolution of an incident.

2.4.4 CrashData app.

This is application where data is sent to a centralized database for storing and retrieval. Recording of geolocation data recording is supported and entirely depends fully dependent on the smartphone's built-in GPS module and the Google Places API. The application provides a web interface for office managers who can use Google Maps to identify black spots by retrieving location information from the database. The accident data is used to assess the overall picture of accidents, identify road safety problem areas, measure trends, drive consumer information initiatives and form the basis for cost-benefit analyses of road safety initiatives and regulations.

2.4.5 GIS-Alas

This is a location-based highway accident database query system developed by the Iowa Department of Transportation (IDOT). It does not readily support spatial analysis of accident patterns or encourage integration of additional data.

2.4.6 Ma3Route

It is a mobile/web/SMS platform that collects transport data and provides users with traffic information, Matatu driving directions and trip reports. Ma3Route aims to facilitate travel in developing countries by democratizing timely transportation information. However, users do not have a defined way to track the outcome of reported incidents.

2.5 Social Media in Incidents Reporting.

Social media may be described as the on-line technology and practices that human beings use to proportion opinions, insights, studies and views with one another

According to Sicular S. Gartner’s definition of Big Data with four V’s characteristics—volume, variety, velocity and vague. Therefore social data as social media data is one kind of big data which can be harnessed for science data, event data, and transportation data to analyse both physical and real world.(Sicular, 2013).

A few outstanding examples of social media platforms are, YouTube (video sharing), Twitter (Info and hyperlink sharing), Facebook and MySpace (social networking), Digg (information sharing), Second Life (digital reality), Flickr (picturegraph sharing), Miniclip (sport sharing)). These web sites commonly use technology which includes blogs, message boards, podcasts, wikis and vlogs to permit customers to interact. On-line social media systems facilitate clean and speedy communique of real-time records with the aid of using generating a big quantity of virtual content (Gu, Qian, & Chen, 2016). Social networking and micro-running blog offerings which include Twitter have grown to be a treasured supply of records on cutting-edge occasions (Mitchell & Page, 2013). Widespread use of Twitter on cellular gadgets and private computer systems allows customers to proportion quick messages on any difficulty in real-time, for that reason making it appropriate for early detection of surprising occasions in which speedy reaction is critical. The proliferation of social networking software program blended with the growing pervasiveness of smartphones has mounted new reasserts of very well-timed and cutting-edge records. However, crowdsourced social media go through a few principal drawbacks, hindering its use (Chen, 2017). Aid corporations and corporations want as a way to rely upon a legitimate and applicable set of records, which they could include systematically of their reaction actions. The challenge is probably how to combine this new technology into present media and communication strategies.

The existing platforms integrates social media platforms like Ma3route reported an incident on Mombasa road on 1st march 2022 on a lorry spilling concrete on the road , Usafiri app, bolt app use social media data for traffic updates and navigation.

According to statistics there were 23.35 million people registering as internet users in Kenya by January 2022. The rate of internet penetration was 42.0% percent of the total population of Kenya at the start of 2022. There were 11.75 million social media users in Kenya in January 2022. The number of social media users in Kenya at the start of 2022 was equivalent to 21.1 percent of the total population. (DataReportal, 2022). According to social media statistics in Kenya,December 2022, Facebook had 41.67%, Twitter: 25.25%, Pinterest: 8.27%, YouTube: 12.96%, Instagram: 9.23%, Tumblr: 1.1% (Social Media Stats Kenya, 2022).

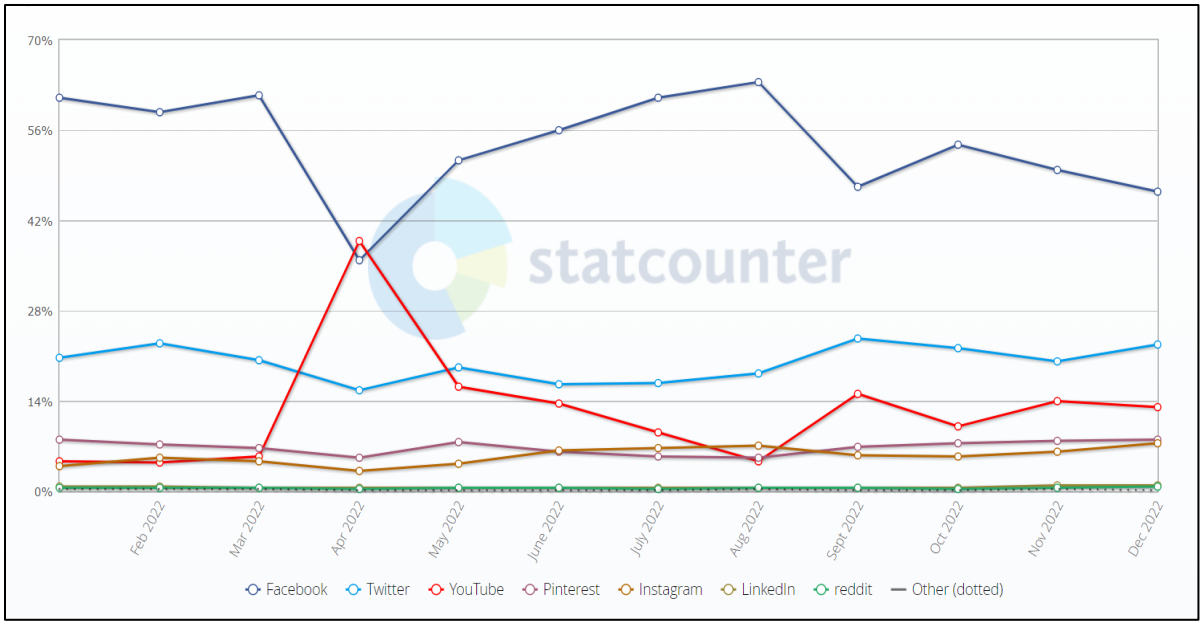

Figure 3: Source: Social Media Stats Kenya (2022)

2.6 Extraction of incidences from Social Media platforms.

Social media platforms enable efficient road incidents detection by allowing users to produce geotagged content known as geosocial media content (Shishuo Xu et al, 2022). There are several software's and methodologies of identifying keywords for real time detection of incidents (Yiming Gu et al, 2016). The use of social media as sensors for detection of road incidences using Application Programming Interface (API) and algorithms has been developed and is used as a layer for accessing the data of an executing application. Consequently, platforms like twitter provides free access to their data through REST API through which users can query by keyword and location (Georgakis et al, 2018). The connection is made through Python with a geolocation filter. The filtered data is scrapped and processed through tokenization and classification. Machine language has also been appropriated in classification of the tweets using SVM (Support Vector Machine) (Georgakis et al, 2018). Another method of scrapping incidences is by using Natural Language Processing (NLP) and syntactic analysis and Semi-Naïve-Bayes classifier (Y. Gu et al, 2016).

2.7 Web applications vs Mobile Apps

Technologies for both web and mobile apps have evolved rapidly. Any application that may run on a handheld or mobile device (like a smartphone or tablet) with a function of providing a service to its users is categorized as a mobile application. A Mobile App is fundamentally for a particular

mobile platform, and a simple installation on the respective device is allotted. They're majorly built for prime performance and a pleasant user experience; also, access to a large range of API's will put no restriction on App usage. Since mobile apps are platform-specific, it's costlier to make. They're built using specific languages and integrated development environments. Online web app is reached through mobile devices' web browsers; they're also termed as progressive web apps. The coding remains the identical across all platforms. Separate installation of applications isn't necessary within the case of web apps. Mobile apps are expensive to keep up and update, may face challenges in approval by app store, and consumes more phone battery power and space. The web applications need internet to figure, have low development cost and holds a standard code base across all platforms, they don't require to be downloaded or installed, they're easy to keep up and are quicker and easier to create. The solution applied web application thanks to the advantages outlined.

2.8 Conceptual framework.

The approach to this project entails first detailing the existing gap by evaluating the existing web-based systems for road incident reporting. The creation of the system will include a conceptual model known as System Development Life Cycle, often used in project management. It entails policies and procedures for developing or modifying systems throughout their life cycles (Kneuper, 2017). The life cycle processes include planning, creating, testing, deployment and maintenance of the system. The waterfall system design method was used to develop the system. The system development processes include system analysis, requirements gathering, design, development, testing and implementation (Adenowo et al, 2013). It is in testing and implementation that the third objective will be achieved, by showing the integration of the social media platforms and web based system for incident reporting.

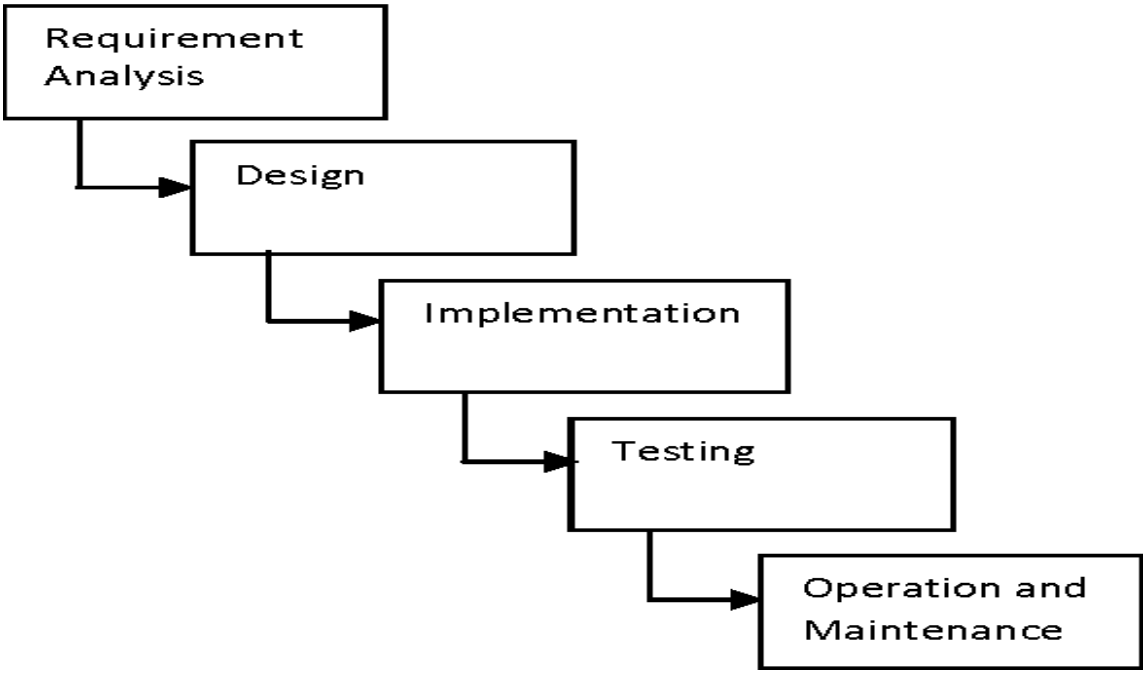

Figure 4: Waterfall methodology (Pfleeger et al, 2010)

2.9 Feasibility Study

The feasibility study is entails the assessment of the practicability of the proposed plan or solution. This was done through review of relevant literature on existing systems related to incidence reporting systems. The study was done to evaluate the proposed solution and system.

2.10 Conclusion

The literature review outlined shows that safety on the roads is essential and it remains a course for worry in many countries. Though there have been improvements in reporting road incidences, there is no way of tracking there is no efficient management of all the reported cases. The informed the design of the application. The integration of social media data to enrich the existing applications for capturing the road incidences add value. The utilization and availability of internet and web resources has enhanced the literacy of citizens and therefore contributing to big data, VGI and crowdsourcing. The combination of geospatial technology with social media enhances the visibility of the incidences and quick resolution.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

Nairobi Region is one of the KeNHA network regions. The region covers 25,320 Sq.km and a population of approx. 7,932,648. (2019 Census). It also covers KeNHA road network of approx. 1,855km. The region boarders South Rift, Central, Lower Eastern, Coast regions and Tanzania. The study area was selected because of the rate of incidences and the usage of social media to report cases. The selected region has high internet penetration and mobile network accessibility. The region also had over 14,000 reported cases of incidents by police. (NTSA, 2022)

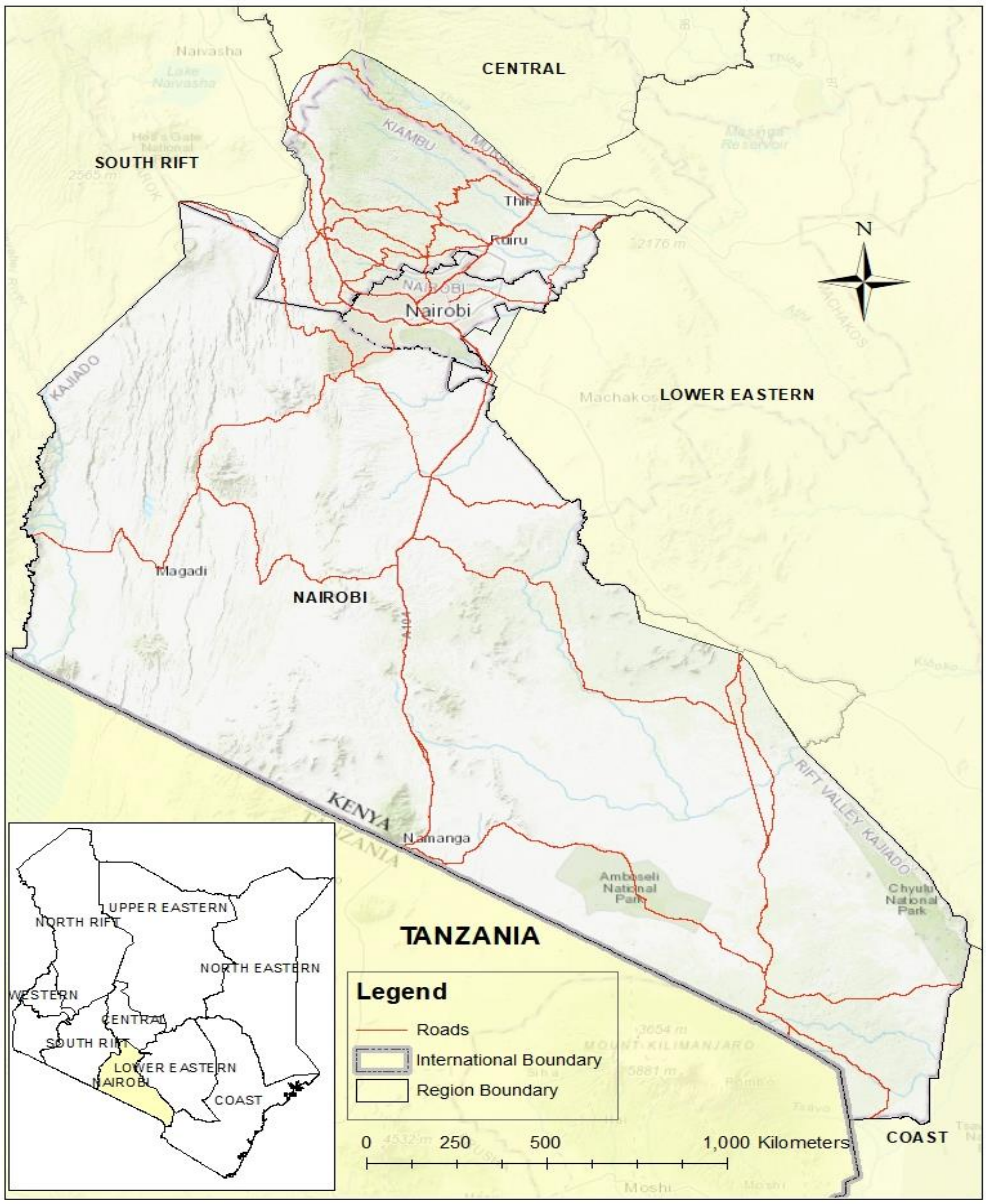

Figure 5: Study area

3.4 Data Collection

Spatial information acquired was processed as relayed in Table 3.1 after being standardized. The latter aided in the integration into the studies system hence smooth manipulation. The spatial information acquired were in numerous structures and systems. Therefore, they were transformed into a uniform projection system the usage of Esri ArcGIS software. Esri ArcGIS permits for numerous spatial information formats to be operated on.

Table 2: Datasets and sources

Data Source	Data Type	Data Format	Data Processing
KeNHA	Road network, KeNHA Regions, KeNHA Offices	Vector shapefiles	Clipped with the study area.
Kenya Roads Board	Road Condition Survey data	Vector shapefiles	Clipped with the study area.
SOK	County Administrative boundaries	Vector shapefiles	Extraction of the study area counties.
MOH	Health institutions	Vector shapefiles	Extraction of the study area health facilities.
Field data collection/ google earth	Police Stations Coordinates	Csv / kml file format	Data was plotted to overlay with the study area.
Field data collection/ social media data	Incidents data	Feature layer	Data was overlaid with other layers in the system.

3.5 Methodology

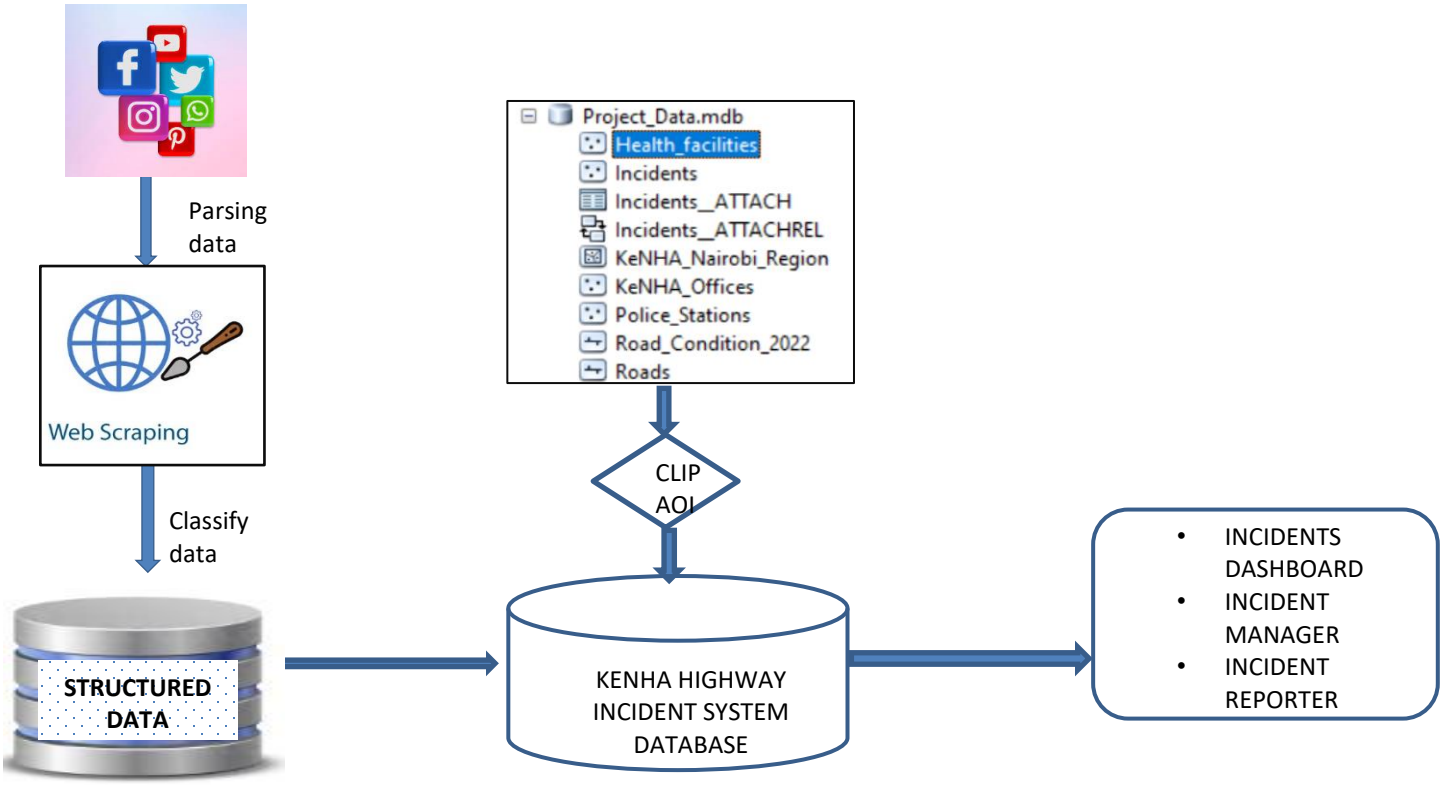

Figure 6: methodology workflow chart

The spatial data obtained from various sources were loaded into ArcGIS software. The roads included the KeNHA road network class A,B and S from the counties within the study area mainly Nairobi, Kiambu and Kajiado. The health facilities were filtered to include only facilities that can handle cases of incidences fatalities. These include; Health Centre, Dispensary and Hospitals. The police stations include fully fledged station with a command centre with capability of intervention and mobilization in case an incident is reported within their jurisdiction. The incidences feature layer is an empty layer which is configured to collect the reported cases in the field. The layer was configured with a schema to capture categories of incidences such as accidents, hazards, roadworks and road condition.

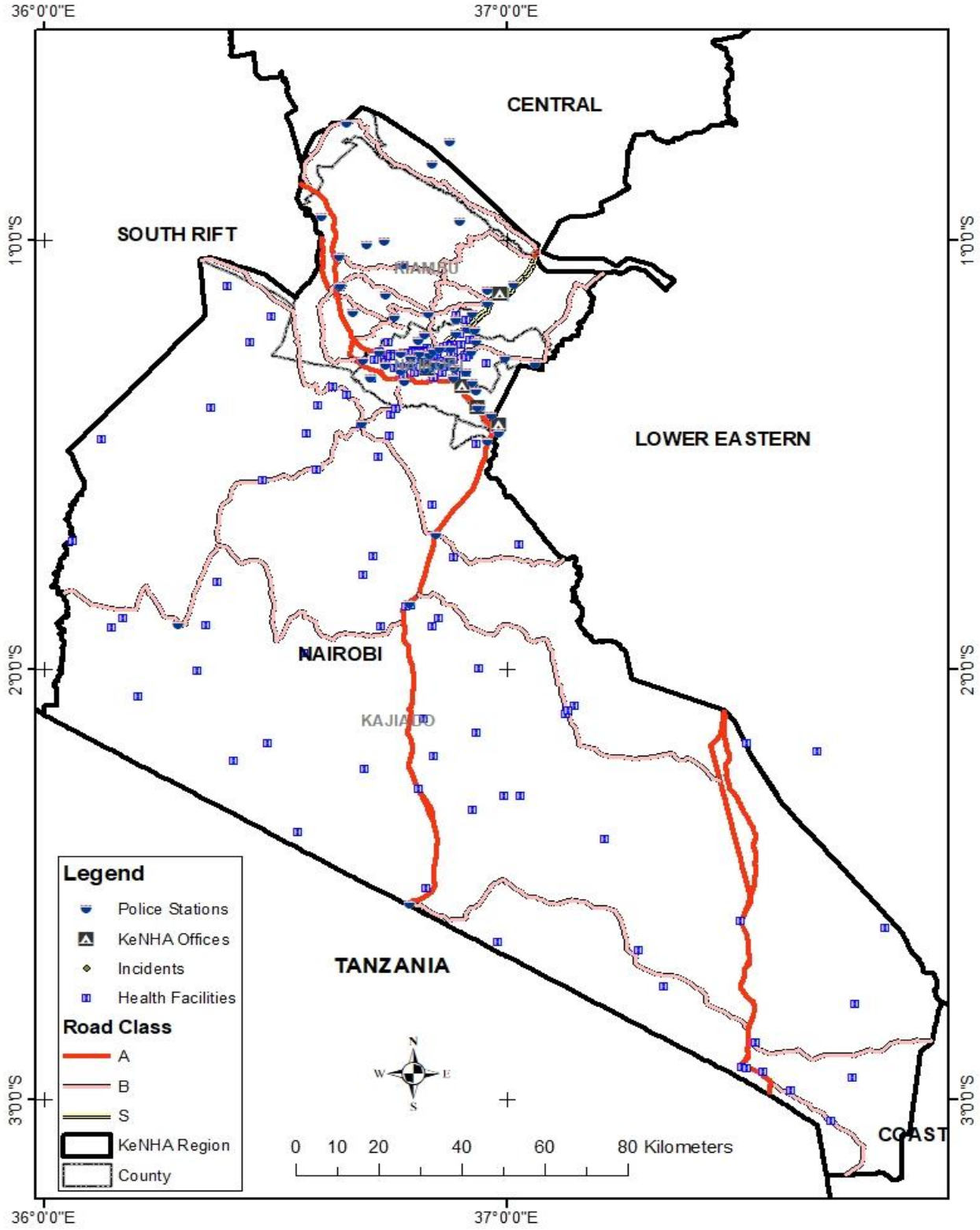

Figure 7: Study Area Datasets

3.5.1: Esri ArcGIS Enterprise

ArcGIS Enterprise is the base software system that facilitates GIS. It powers mapping and visualization, analytics, and data management. It is the backbone for running the Esri suite of applications and other custom applications. The collaboration and flexibility of the system components enable the organization and sharing of work from any device, anywhere at any time. The flexibility capabilities support tracking real-time data, performing big data analysis, data science workflows among other functionalities. The system architecture comprises of ArcGIS desktop, mobile, portal, server, online, explorer and web browser.

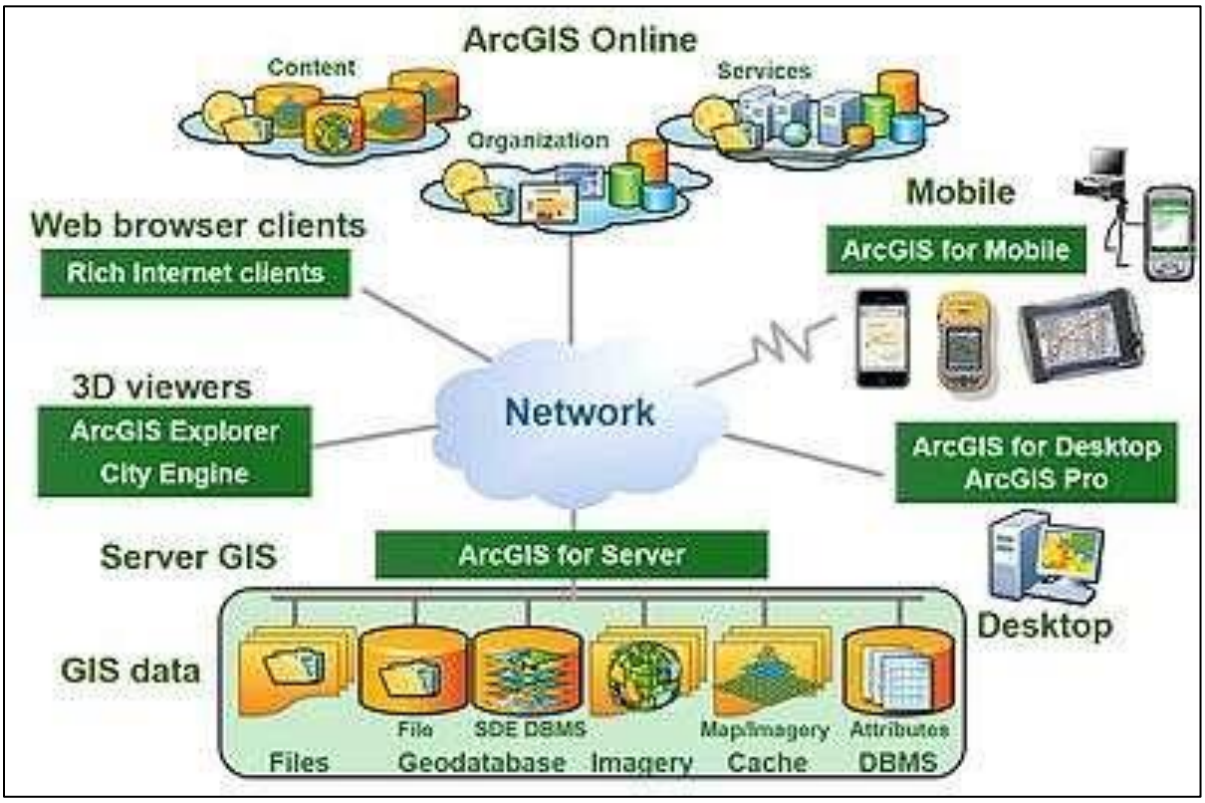

Figure 8:ArcGIS Enterprise Architecture (Esri.com)

The ArcGIS system also comprises of designed apps to extend the use of maps and apps across a platform of products. The ArcGIS Enterprise provides open source Instant Apps which are configurable Apps templates that allow users to build web apps from web maps, scenes, and groups without having to write code. These apps can be downloaded, configured and hosted in other web servers. The configurable apps have several benefits among cost saving, time saving, control and flexibility.

The apps include the data collection and editing. Among the apps include crowdsource reporter, crowdsource manager and dashboard. These apps contain open source code and are downloadable and customizable to suit the user needs. They can also be hosted either in the ArcGIS platform or other websites.

3.5.2 ESRI Crowdsource Reporter

Crowdsource Reporter is a configurable application template that allows users to submit issues or observations. It is configured in the new web application designed in this project to facilitate the graphical user interface where users can report the road incidents. One or more maps are provided by the application, and they can be used to report an issue or an observation. Users have the option to submit new reports anonymously, review previously submitted reports, and leave comments and cast votes on other users' observations or reports. Additionally, customers are able to track the progress of issues or observations they have reported by logging in using their ArcGIS credentials. The application has been used for surveys, AED reports, participatory budgeting, Mosquito service requests and Vision Zero. In general, the existing systems and applications lack follow-up, conversion, slow updates and data access, tracking resolution of reported incidents and positional accuracy.

3.6: System Design and Configuration.

The system of collecting road incidents was based on the information from the data and information gathering. The report contains the particulars of the road incident and is stowed at the backend in the server. The users can report and view the incidents posted by other users and the status of the incidents reported. The backend user login to server and is able to manage the data and update features such as status and assigning of the reported incident to the relevant department. The dashboard contains the filter and explores the dataset to see what types of observations have been submitted. The architecture of the system shows the various components of the system based on the gathered information.

The incident report is used by the public or staff to submit road incidents to the system. The incident manager is used to triage submitted incidences and update the status of each as needed. It

is also used to assign staff to the incidences. The system requires ArcGIS account login to manage an incident. The incident dashboard is used to view and monitor the submitted incidences.

3.6.1 System design

The system was designed to reduce the information flow and the time reporting to responding to an incident. The user or public report an incident, the reporter informs the manager of new incidences reported. The manager then using the system finds the nearest KeNHA officer, hospital and police station. The manager alerts the police about the exact location of the incident. The KeNHA staffs dispatches a team for follow-up and resolution of incidents and submit report which is used to update the status. The user/ public then able to view the status of the reported incidence in the system.

3.6.1 .1 Data modelling

The application development required to define and analyse data requirements needed to support the processes of the system. The physical data mode captured key entities that were used for the data modelling.

Table 3: Data modelling

Incidence	This entity represent the incidence reported and its attributes
Incidence type	Classifies the incidents types such as accidents, hazards, road condition, road works, and obstacles among others.
Users	The users involved in reporting the cases and the access rights in the system
Incidence Status	This categorizes the status of the incidences into submitted, received, in progress and completed

3.7 System implementation

The incident reporting system was designed and implemented using the methodology described earlier. The personnel involved the author guided by the supervisor. The software products used in the implementation of the project are; ArcGIS desktop used to prepare the datasets used in the project. The ArcGIS portal was used as the web platform to publish and host the system. The

ArcGIS crowdsource reporter configurable app was used to develop the system. The hardware components include the laptop and PC. The components of the web based incident reporting system include the web maps developed in the ArcGIS portal platform.

3.8 KeNHA web based incident reporting system.

The application was developed using the ArcGIS portal. The shapefiles were zipped and uploaded in the portal and was saved under a folder KeNHA Incident Reporter.

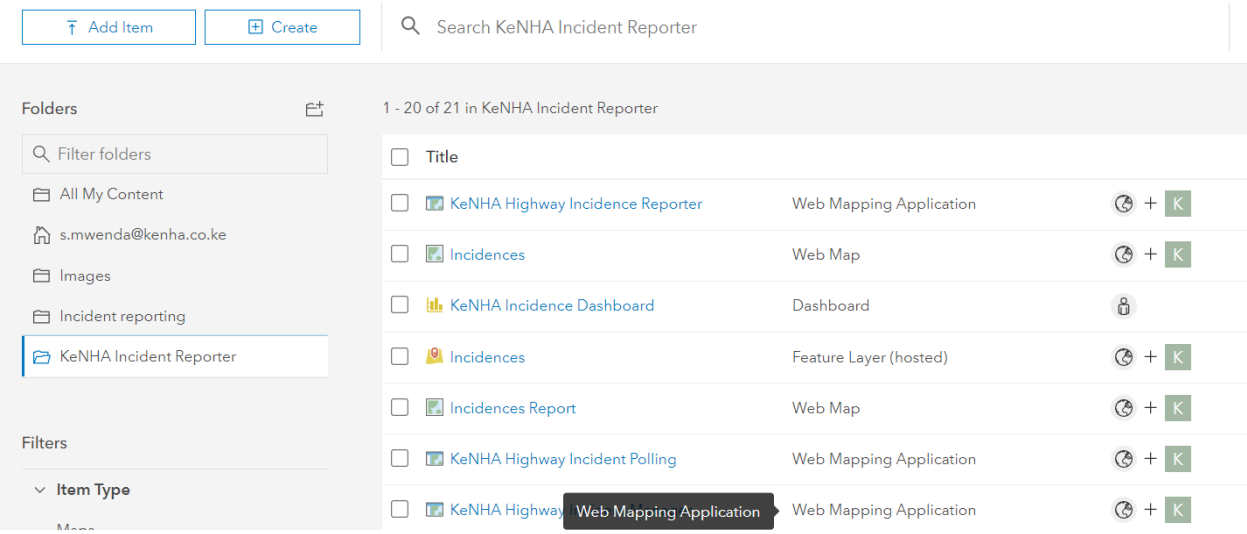

Figure 9:ArcGIS portal interface.

The web maps were prepared by adding the layers in the map viewer and symbolized accordingly. The map for incidents that allows the public to report was created. The pop-up for each layer were configured. The fields which were used to present details of submitted report and the editable parameters were set. The visibility options were set to restrict display of layers visible through the application. This was repeated for incident manager web map. The domains of the layers were set as illustrated in figure 3.8.

A group was created where the maps will be shared with Crowdsource reporter. The group is also the source of the content displayed in the application. Content and layers, apps, maps intended for the public were shared with everyone.

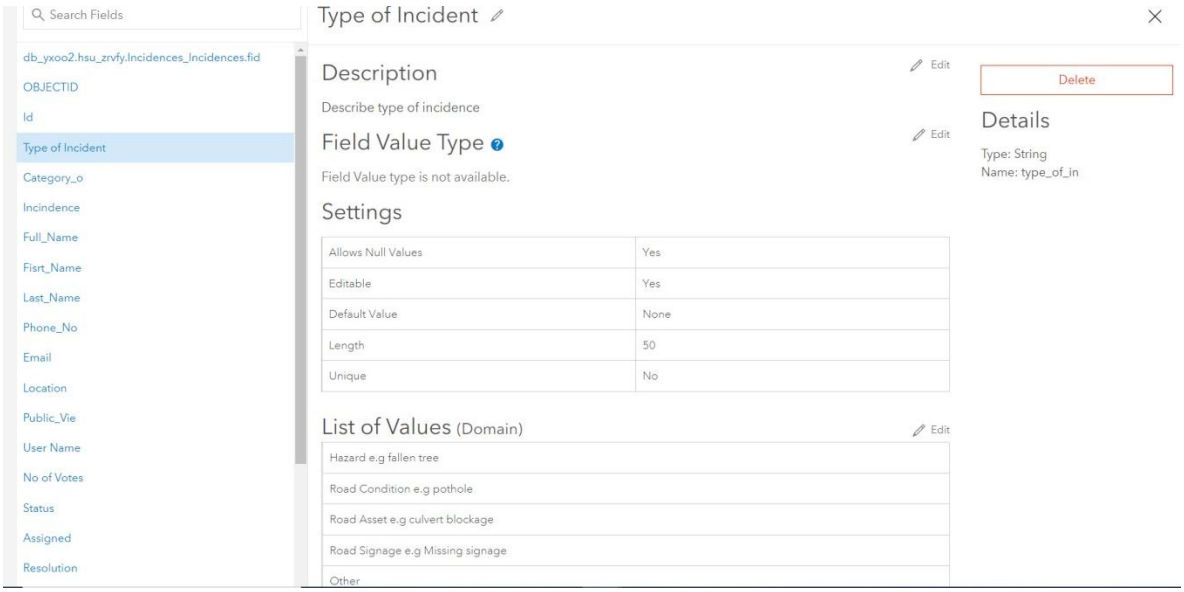

Figure 10:Setting domain values for layer

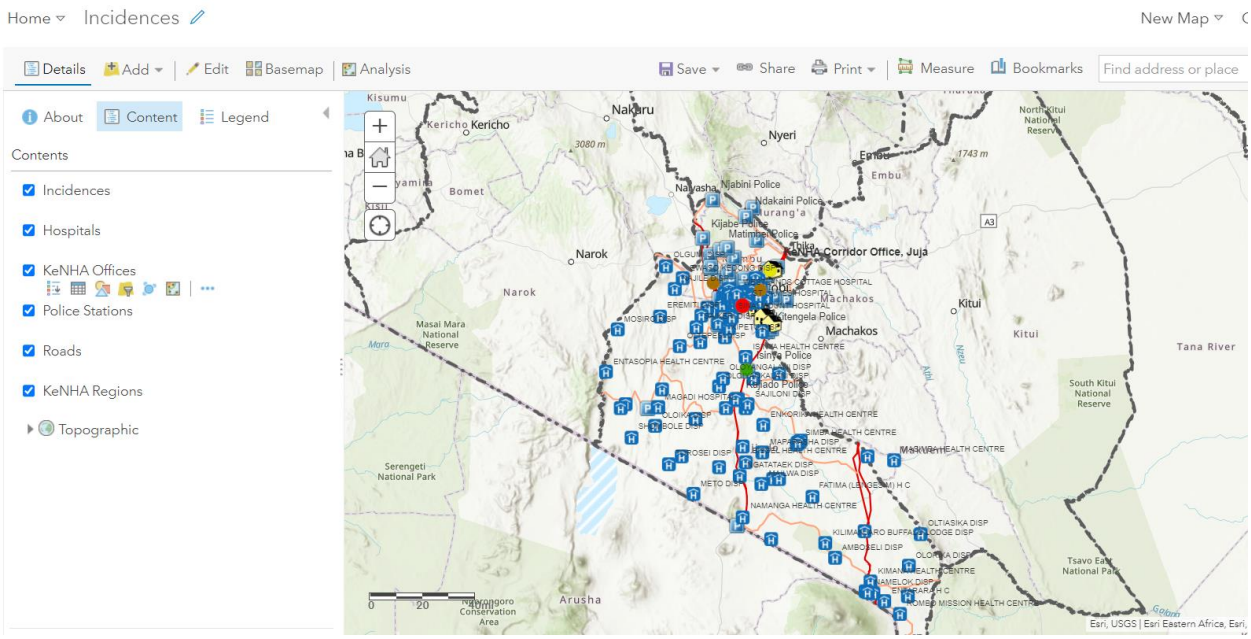

Figure 11: Incidences web map.

The crowdsource reporter app was created using the create configurable apps from the content and then navigating to the crowdsource reporter app

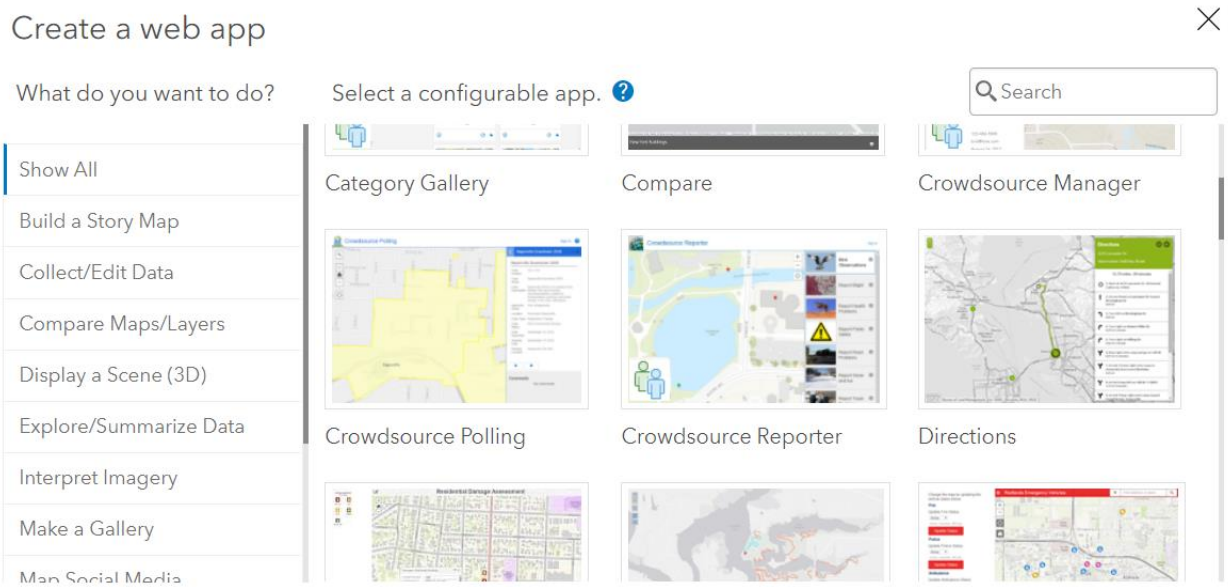

Figure 12: Create crowdsource web application.

The application is configured and the settings were defined on the general tab. The group containing the maps to display in the application were selected. The group must contain at least one editable feature layer such as the incident layer. The title and subtitle of the application were set. The logos and colours of the application using the parameter on the themes tab of the application configuration were set. The sign in options were set to allow users access the application. The options were configured to include Guest, twitter and ArcGIS Account holders' login. This was to enable the public access the system and report an incident. The users who authenticate with ArcGIS account have access to a list of all the reports they have submitted, including those which aren't publicly visible elsewhere in the application, through the menu under their username. The search, form and report were configured accordingly as illustrated below. The configurations for the crowdsource manager and dashboard were set accordingly.

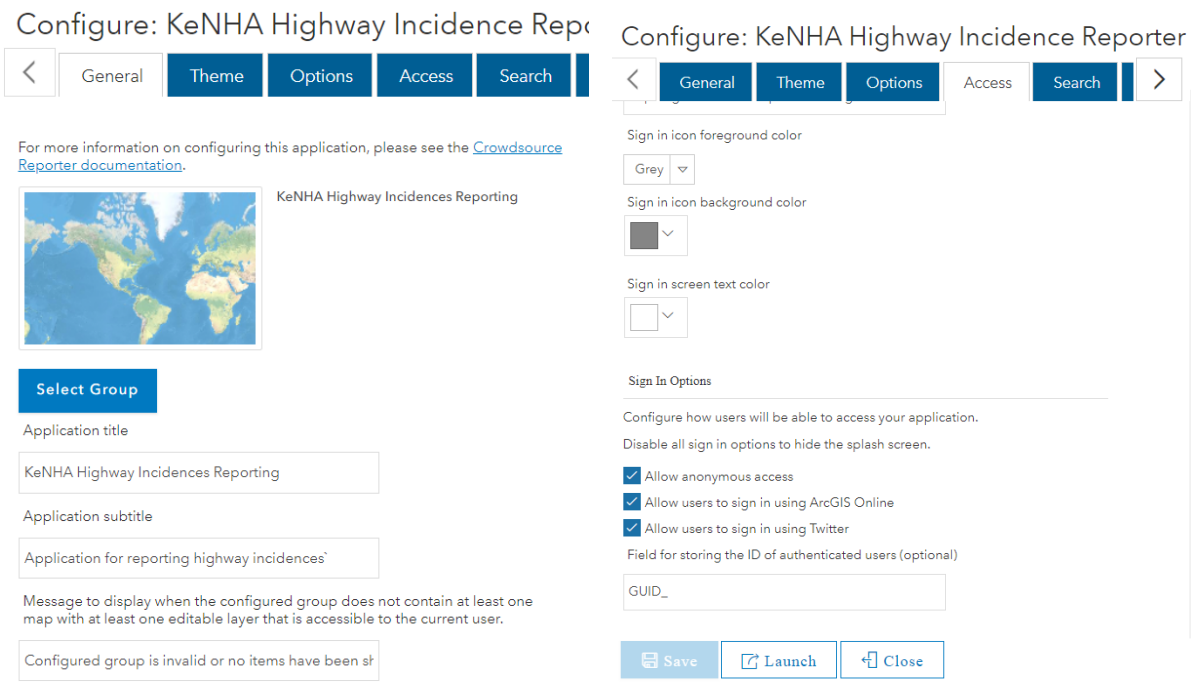

Figure 13: Configuration of the Incident reporter.

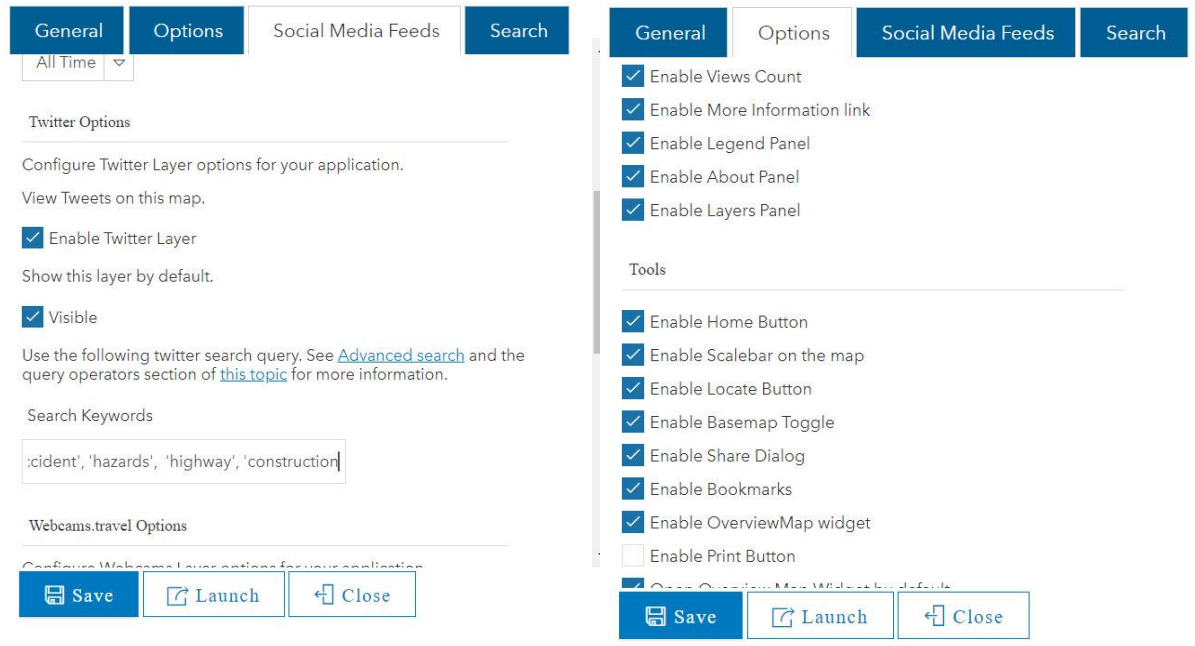

Figure 14: configuration of social media scrapping map

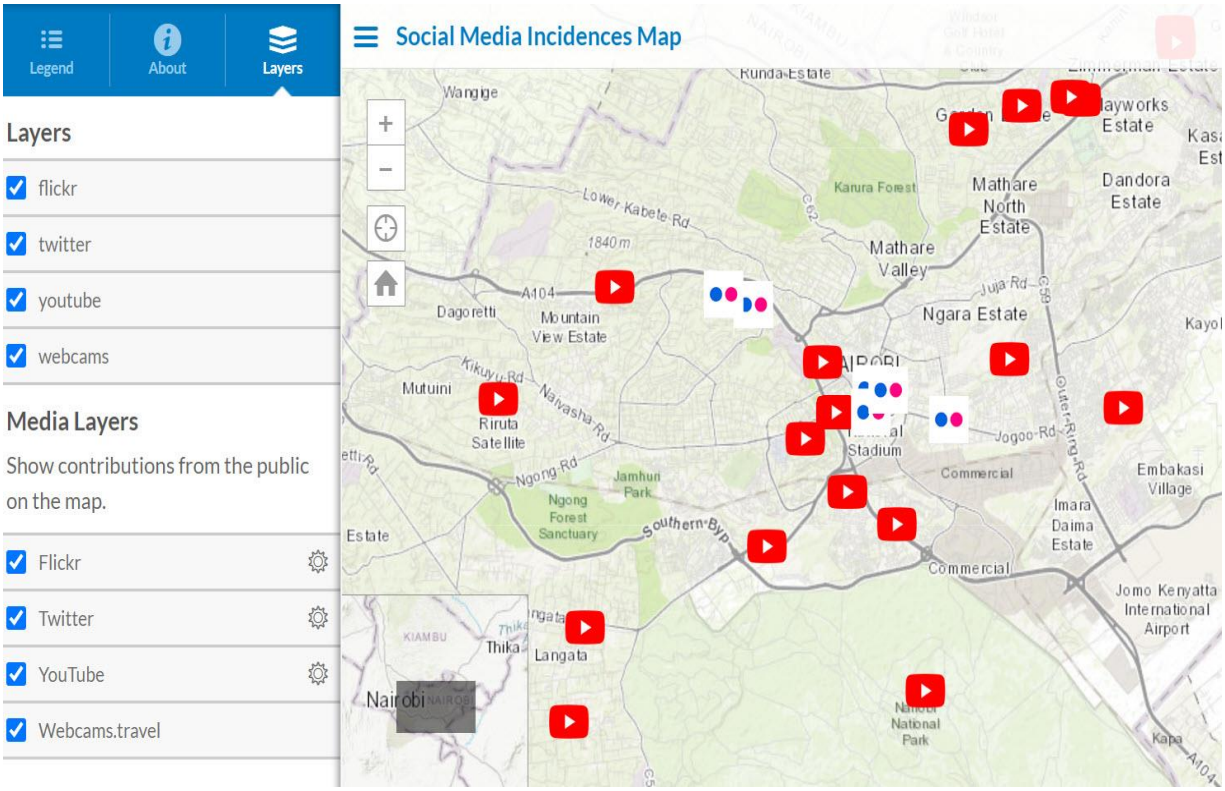

Figure 15: Social media map interface

The web based incident reporter was saved after configuration and ready for launch. The interface allows users to access the application and report incidences. Users can access the application as guests, login using twitter or the ArcGIS login. However, to access the layers and editing is only enabled for ArcGIS named users for security. After login a window for reporting incidences appears as illustrated in figure 3.14

Figure 16: web-based incident reporter login page.

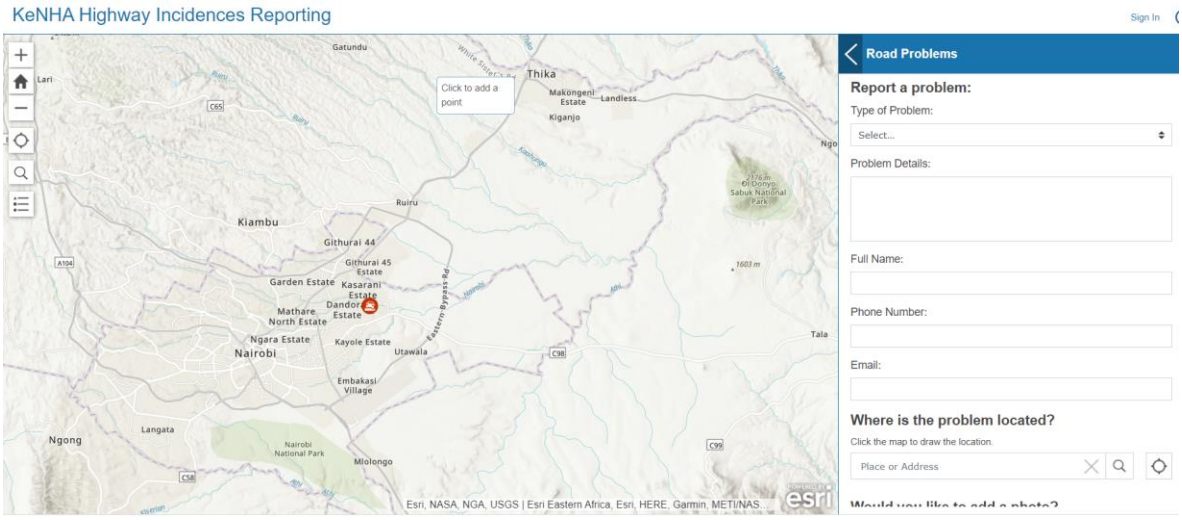

Figure 17: incident report interface

The incidents manager is used to triage submitted problem reports and update the status of each report as needed

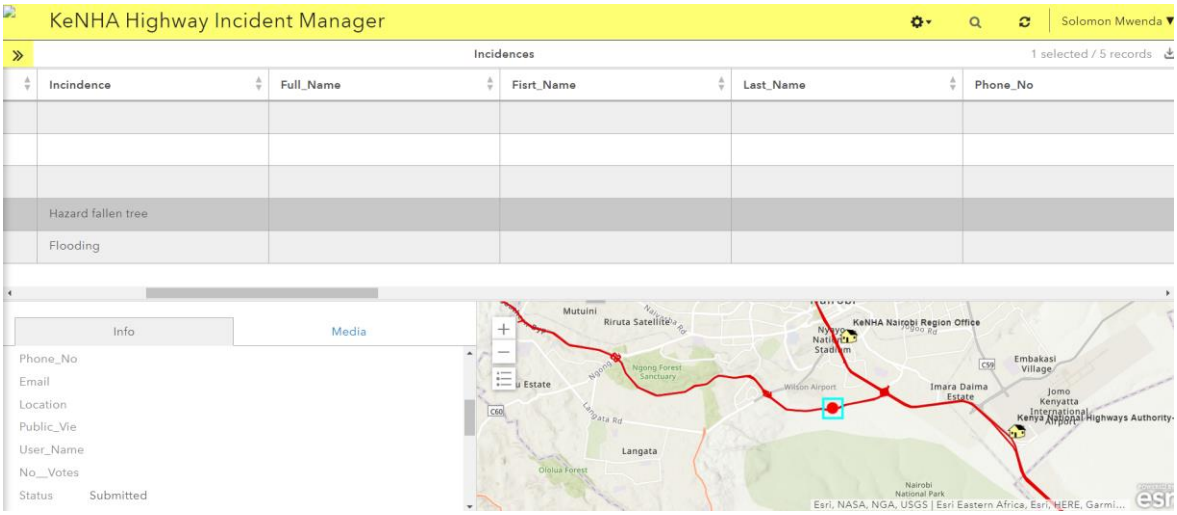

Figure 18: Incident manager interface

The incident dashboard is used to monitor the incidences submitted for an overview and summary report of the incidences.

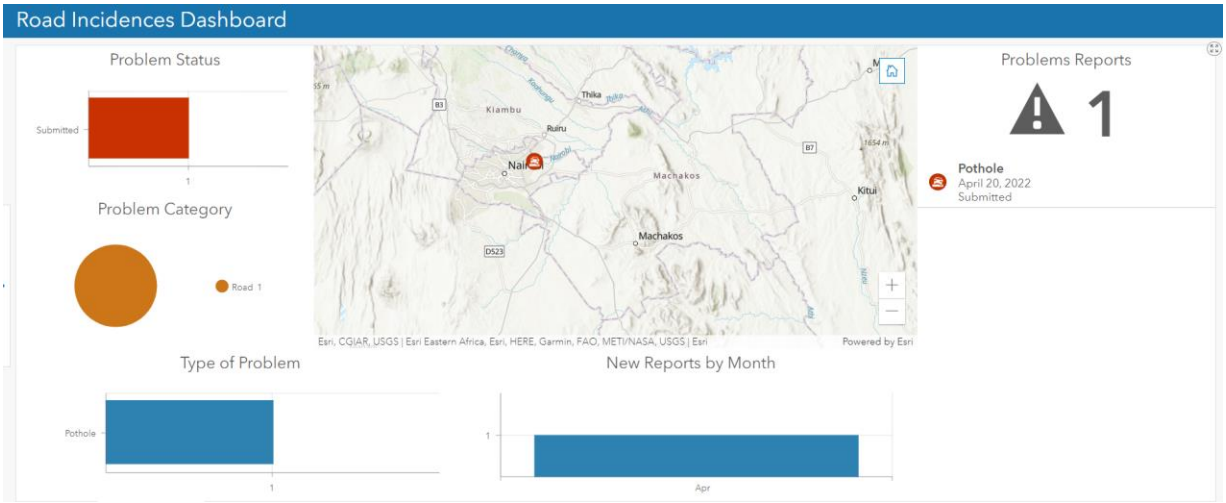

Figure 19: Incidences dashboard interface

3.9: System testing

This involves the testing of the application and involves the stages of unit, functional, system and acceptance testing. The system prototype application was sampled within Nairobi County by staff. The users also represent the population whose feedback would be used before rolling out the system to the public. The testing of the system was to evaluate the functionality of the application, capabilities and user acceptance. The system was tested by the study users. The users were derived from the staff of the Authority who already had smart phone with internet connectivity. The users

represented a portion the target users of the application. The application underwent the user, acceptance and functional tests. The approach involved two fold evaluation designed to conduct adequate evaluation of the system. The first step involved the explanation of the purpose and functions of the application. The second step involved a qualitative evaluation of the system functionality capabilities. The results were assessed and analysed.

CHAPTER 4: ANALYSIS OF RESULTS

This chapter discusses the results of the research. The results are organized by objectives of the research.

4.1 Evaluation existing local web-based incidents reporting systems

According to the literature reviewed, the existing web-based incidents reporting systems evaluated include; open streetmap, Ushahidi, nduru and Ma3Route. The Open StreetMap was laid out to energize the development, advancement and dissemination of free geospatial information and give geospatial information to anyone to utilize and share. The cluttering of data makes it difficult to visualize specific data from the application. The Ushahidi application is a crowdsourcing supported and engages everybody therefore the cluttering of data makes it hard to visualize the incidences. On the other hand, Nduru application is used to report and manage road incident and safety related data. However, the application has no location or mapping capabilities to allow visualization of road incidents and no way to follow up resolution of an incident. Lastly Ma3Route platform that collects transport data and provides users with traffic information, directions and reports. However, the system lacks a clear way to track the resolution of reported incidents.

4.2 Determination of existing social media platforms for road incidents reporting and their integration with GIS.

The determination of potential existing social media platforms for road incidents reporting was carried out by reviewing the social media usage from varied social media platforms like Twitter, and Facebook among others. There were 11.75 million social media users in Kenya in January 2022. Therefore, social media data is one kind of big data which can be harnessed for science data, event data, and transportation data to analyse both physical and real world. The data has the potential to harness real-time and early detection of incidences. This can be integrated into GIS by scraping the social data using a mining model that performs accurate classifications of incidents. Therefore, these were integrated in the GIS platform using API's that import the data for analysis in GIS.

The table below shows extracted data.

Table 4: Data extracted from Social Media

Geo ID	Location Description	Exact Location of Accident / Nearest Landmark	Area	Initial Impact Type
INT_6066	GENERAL WARUINGE ROAD @ NORTH VIEW RD-MURATINA ST-DIGO RD-QUARRY RD	At Pumwani		Pedestrian
28538	A2 PANGANI- KANGUNDO ROAD btwn EASTLEIGH NORTH ACCESS ROAD 5 & UNKNOWN			To Kariobangi
120	NYAYO STADIUM-KAREN RA-DAGORETTI MKT-MUTHIGA btwn CATHOLIC UNIVERSITY OF EASTERN AFRICA ACCESS RD 7 & UNKNOWN	NEAR KITENGELA JUNCTION	Urban	Sideswipe
25050	NYAYO STADIUM-KAREN RA-DAGORETTI MKT-MUTHIGA btwn HILCREST - PLAINS VIEW - MBOGANI ROAD & MARIST LANE			Pedestrian
29693	SOUTHERN BY-PASS btwn 3A-WILSON E/GATE & UNKNOWN	UNKNOWN	Urban	Pedestrian
27683	DONHOLM RA- CITY STADIUM RA-LUSAKA ENT RA- NYAYO STADIUM btwn EASTLANDS CRESCENT - JOGOO POLICE & SERVANTS QUARTERS PHASE 2	Near church army bus stage		Pedestrian
INT_6066	GENERAL WARUINGE ROAD @ NORTH VIEW RD-MURATINA ST-DIGO RD-QUARRY RD			City centre to Thika
29278	IBD MALABA-ELDORET-NAKURU-NAIROBI-VOI-MOMBASA L btwn DONHOLM RA- CITY STADIUM RA-LUSAKA ENT RA- NYAYO STADIUM & SHIMO LA TEWA (LUSAKA-MOMBASA ROAD	OPPOSITE CAPITAL CENTRE	Urban	Rear end
29660	DONHOLM RA- CITY STADIUM RA-LUSAKA ENT RA- NYAYO STADIUM btwn HAMAZA ROAD & HAMAZA ROAD			Pedestrian
INT_18141	GITHURAI 44 ACCESS ROAD 17 @ GITHURAI ACCESS ROADS 37	Towards Kasarani		Pedestrian
8	NYAYO STADIUM-KAREN RA-DAGORETTI MKT-MUTHIGA btwn UNKNOWN & UNKNOWN	Near Langata high school		
19083	A2 PANGANI- KANGUNDO ROAD btwn RUARAKA ACCESS ROAD 17 & UNKNOWN	NEAR MOI AIRBAS STAGE	Rural	Pedestrian
INT_6058	GENERAL WARUINGE ROAD @ GORE STREET			Pedestrian

11305	DONHOLM RA- CITY STADIUM RA- LUSAKA ENT RA- NYAYO STADIUM btwn JOGOO ROAD R1 & RABAI ROAD	Near Likoni junction		Pedestrian
INT_4339	DONHOLM RA- CITY STADIUM RA- LUSAKA ENT RA- NYAYO STADIUM @ EXPRESS LANE	LUSAKA / MACHAKOS ROAD JUNCTION	Urban	Pedestrian
27937	IBD MALABA-ELDORET-NAKURU-NAIROBI-VOI-MOMBASA R btwn A104 KENYATTA AVENUE RA- A104 BELLE VIEW & MUHOHO AVE ACCESS	NEAR SOUTH B FLYOVER	Urban	Pedestrian
23542	DONHOLM RA- CITY STADIUM RA- LUSAKA ENT RA- NYAYO STADIUM btwn INDUSTRIAL AREA ACCESS ROAD 35 & RABAI ROAD	At Rikana		Angle
25864	LIMURU ROAD btwn SECOND PARKLANDS AVENUE & THIRD PARKLANDS AVENUE	NEAR SECOND PARKLANDS AVENUE	Urban	SMV Runoff
25151	NYAYO STADIUM-KAREN RA- DAGORETTI MKT-MUTHIGA btwn MAGADI RD- BOGANI EST-LANGATA RD & NDEGE ROAD	Opposite carnivore		Sideswipe
24981	IBD MALABA-ELDORET-NAKURU-NAIROBI-VOI-MOMBASA L btwn KAPENGURIA ROAD & UPPER KABETE ROAD-FORT SMITH ROAD	NEAR SKY PARK	Urban	Sideswipe
13328	GITHUNGURI ROAD btwn ARCADIA VALLEY ACCESS ROAD & UNKNOWN	AT THE TRADING CENTRE	Urban	Rear end
24485	PANGANI- KARIOKOR- HAILESALASIE- NGONG ROAD- UTHIRU btwn HAILE SELASIE L & TUMBU AVENUE L	NEAR UHURU HIGHWAY ROUNDABOUT	Urban	Pedestrian
29448	IBD MALABA-ELDORET-NAKURU-NAIROBI-VOI-MOMBASA L btwn BELLE VIEW- MATTER HOSPITAL- DUNGA ROAD- WORKSHOP ROAD & UNKNOWN	NEAR IMARA DAIMA	Rural	Rear end
85	THIKA S_HIGHWAY R 2 btwn UNKNOWN & UNKNOWN	NEAR LAMAMBA JUNCTION	Rural	Rear end
INT_6864	IBD MALABA-ELDORET-NAKURU-NAIROBI-VOI-MOMBASA L @ ST. BAKHATA PRI SCH - PRI-HIGHWAY EDUCATIONAL COMPLEX	NEAR STEEL MAKERS	Urban	Rear end
INT_13941	NGECHA ROAD @ REDHILL ROAD	NEAR ROSELYN HEIGHTS AREA	Urban	Turning movement
27937	IBD MALABA-ELDORET-NAKURU-NAIROBI-VOI-MOMBASA R btwn A104 KENYATTA AVENUE RA- A104 BELLE VIEW & MUHOHO AVE ACCESS	AT BELLEVIEW	Rural	Pedestrian

11167	A2 PANGANI- KANGUNDO ROAD btwn COUNCILLOR OPUNDO ROAD-MUGAI KENYATTA ROAD & UNKNOWN	TOWARD GLOBE ROUND ABOUT	Urban	Pedestrian

4.3 Development of a web based GIS application system through which users can report road incidents.

The system was successfully developed. The system was tested and the sample results of the reported cases are shown below.

Table 5: Sample reported cases in the system

Incident Type/ Category	**Status**	**Details**	**Source**	**Location**
Pothole	Submitted	Huge pothole on the right hand side of the road	Public	Hypermart Limited
Roadworks	Submitted	Ongoing roadworks	Public	Roysambu footbridge
Accident	Submitted	Collision	Public	Mombasa Road
Hazard	Submitted	Fallen tree on road	Public	Kangundo Road
Accident	Submitted	Motorbike accident	Public	Thika Town

The user evaluation and assessment was done to determine the usability. According to the survey, the results demonstrate that the target users are ready to adopt the application and that the application meets their needs. The survey was based on the objective to develop a web GIS application system through which users can report road incidents within KeNHA road network in

Nairobi Region leveraging on social media. The survey was carried out to get the feedback of the system usage.

The survey was carried out using 30 respondents. The survey was carried online due to the COVID restrictions using survey monkey online survey. Out of the total, 27 surveys were filled and 3 were nonresponsive.

The results of the survey are analysed below.

4.4: The impact of the application in dealing with road incidences response in the cases.

The users sampled determine the impact of the application. 80% of the users felt that the application can impact the response of the incidences and dealing with the cases while 20% were negative.

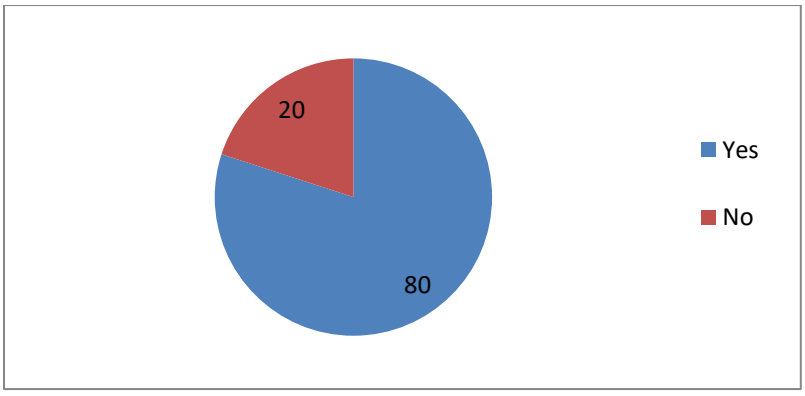

Figure 20: Impact of the application in dealing with incidences.

4.5 The application usage to improve road safety and maintenance

65% of the users felt that the application can be used to improve road safety and maintenance while 35 % felt that the application may not be useful in improving road safety.

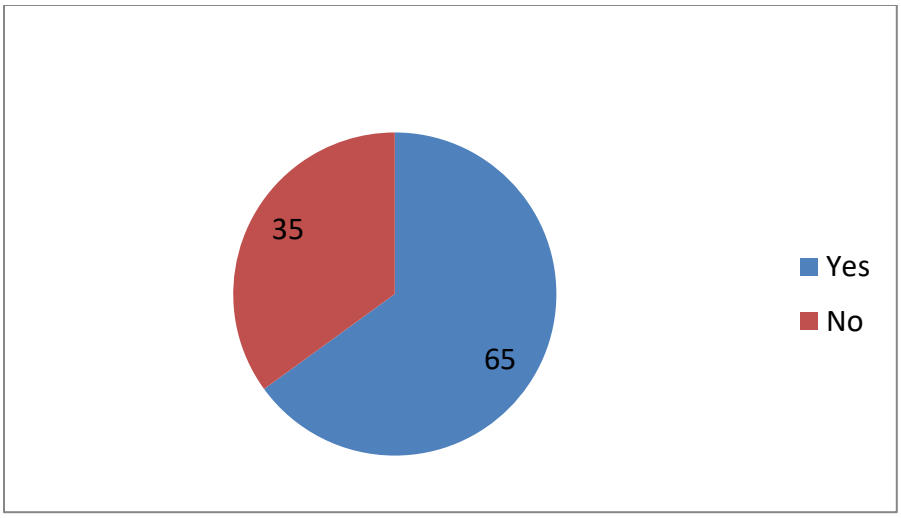

Figure 21: application usage to improve road safety and maintenance

4.6: Willingness to use the application to report road incidences to the Authority

78% of the users were willing to use the application to report cases. However, 22% felt otherwise about using the application to report incidences.

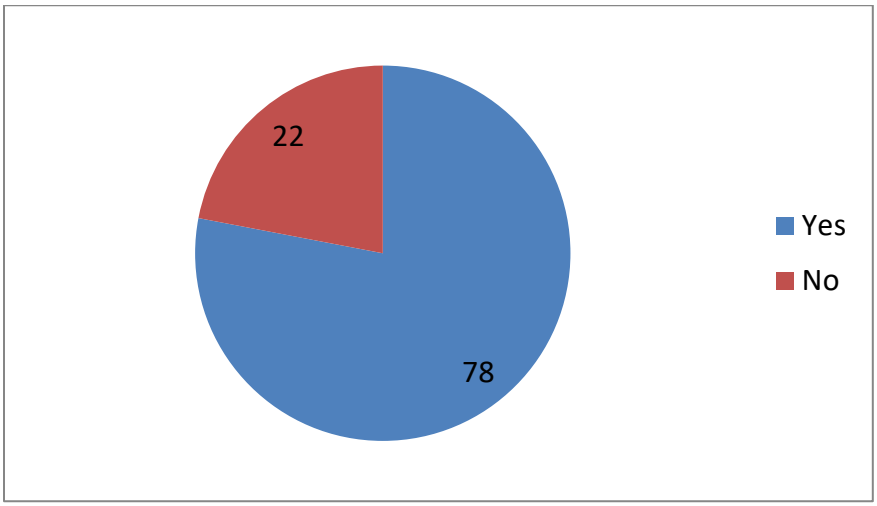

Figure 22: willingness to use the application to report incidences

4.7: Ease of using the application in reporting and submitting report

The users felt that the ease of using the application in reporting and submitting reports were 30% Excellent, 22% Very good, 20% Good, 18% Fair 18% and 10% Bad respectively.

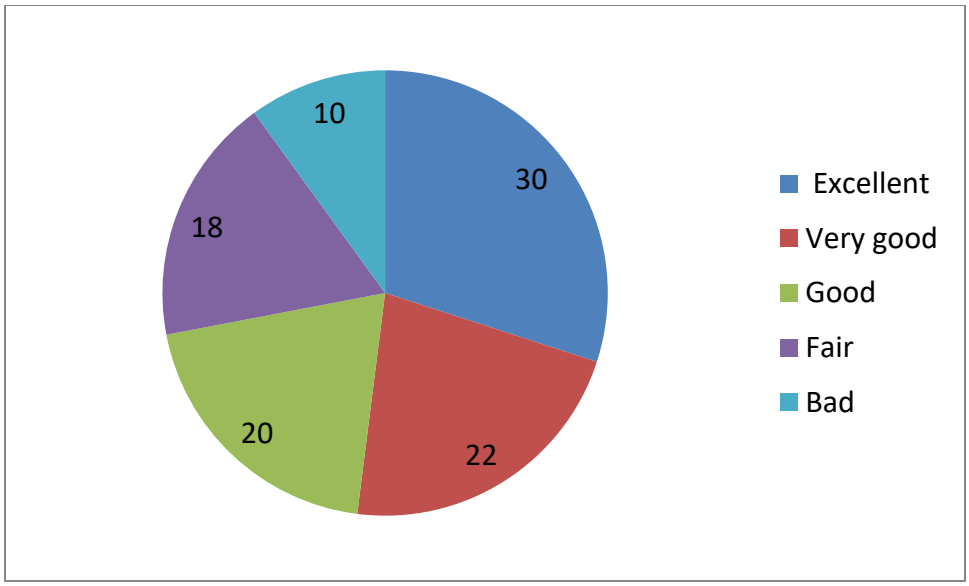

Figure 23: ease of use the application to report incidences

4.8: Aapplication graphical user interface and appearance

The respondents rated the graphical user interface as 35% excellent, 26% very good, 22% good, 15% fair and 2% bad respectively.

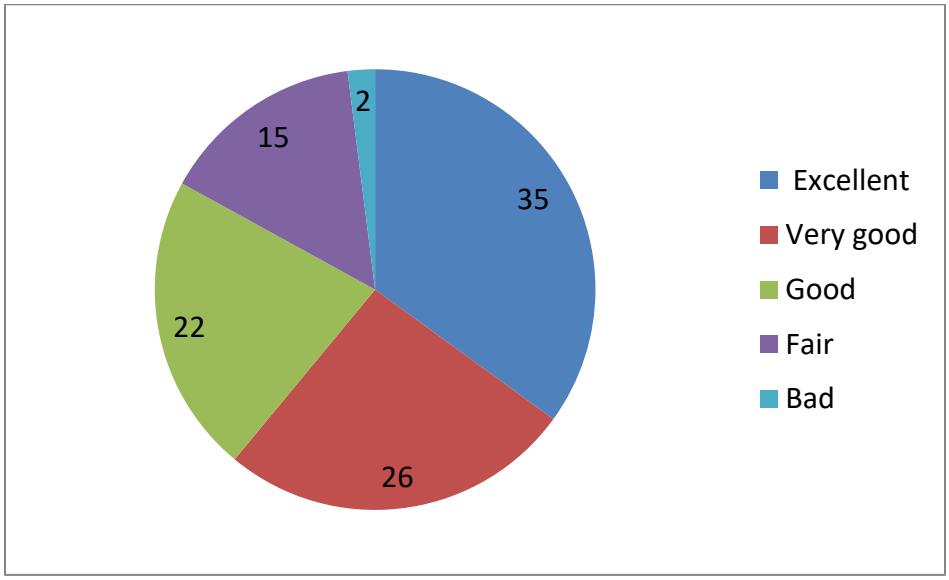

Figure 24: graphical user interface of the application

4.9: Representation of the information on the map

The results of the representation of the reported information on the map stood at 40% excellent, 35% very good, 18% good, 7% fair and none bad respectively.

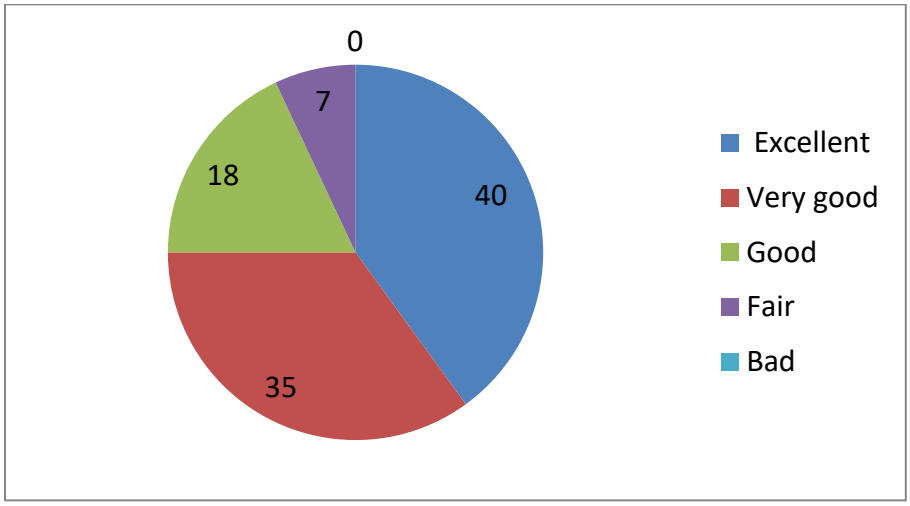

Figure 25: Representation of the information on the map

4.10: Navigation of the user interfaces

The users' responses to the feel of the graphical interfaces are 50% excellent, 40% very good, 8% good, 2% fair and none bad respectively.

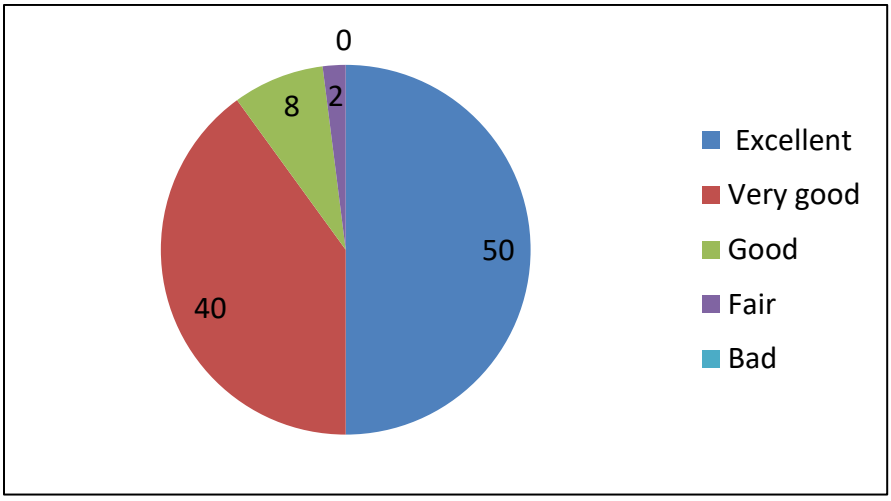

Figure 26: Navigation of the user interfaces

CHAPTER 5: CONCLUSION AND RECOMENDATIONS

5.1 Conclusions

The first objective was achieved, showing that the existing local web-based for road incidents reporting systems which were reviewed determined that there was a gap since they lacked follow-up, conversion, slow updates and data access and tracking resolution of reported incidents. The second objective, which was also the main objective of the research was to develop a Web GIS based Application for Real-time Highway Incident Reporting system for KeNHA Nairobi Region leveraging on social media, that will contributes to road safety by improving reporting and response as well as improving the dissemination and analysis of information arising from the incidents. The web based app was successfully developed and deployed for testing and it worked. The third objective was achieved as the research also determined that the integration of existing social media platforms for road incidents reporting with GIS is crucial for reporting cases due to the increased usage of social media and internet accessibility to users. The integration of the web GIS application system with social media makes it possible for users can report road incidents within KeNHA road network in Nairobi Region using their social media like twitter without creating accounts in the application. This increases accessibility and confidence in users in the application. The system was easy to use since it only requires internet connection and does require the user to install the application.

5.2 Recommendation

The recommendations that can be drawn for the research is to implement the system at the Authority which will enhance the incidents management, the application if used will assist the Authority to manage the reported cases by enabling the managers to visualize and respond to the cases in a timely and efficient manner. This will improve the road safety and save time for road users. The collected data can also be shared with the police as stakeholders for easy workflow since the data in the system integrate the health facilities which can reduce fatalities on the roads by responding timely and taking the casualties to the nearest health facility. The application can also be replicated to other road agencies since some users may not differentiate the roads assigned to the authorities. The reports can also inform design and black spots mapping to warn the road users of the road condition. The data can also be used to inform road maintenance planning. There is also need to set up field verification team to verify reported cases.

5.23 Suggestions for further research

The automation and integration of systems in an organization for seamless workflow is crucial in the current technology development. Therefore the application can be further integrated into the workflows and automation of the Authority. The research can be done to determine and automatically detect reported cases using the various social media platform and integrate the data into the system. Furthermore the research can also be extended to integrate traffic data and analysis tools to enable road users reroute to their destinations using the shortest route. The application can also be improved to automatically detect incidences on the road from cameras and high resolution images captured on the road by satellites. The system can also be up scaled to include both mobile and web applications. There is also a need to develop a mechanism to verify the reported cases due to ambiguity of some data from social media.

REFERENCES

1) Adenowo, A.A., & Adenowo, B.A. (2013). Software Engineering Methodologies: A Review of the Waterfall Model and Object- Oriented Approach.
2) Attard, M, Haklay, M and Cristina C. (2016). The Potential of Volunteered Geographic Information (VGI) in Future Transport Systems. Urban Planning Vol1 (4) 6 -19.
3) Attard, M., Haklay, M., & Capineri, C. (2016). *The potential of volunteered geographic information (VGI) in future transport systems: Article*. Urban Planning. Retrieved February 18, 2022, from https://www.cogitatiopress.com/urbanplanning/article/view/612?internal-redirect
4) Chen, Y. (2017). "Twitter or chatter? Involving social media data analysis in traffic incident management," in Transportation Research Board 96th Annual Meeting (Washington DC), 1–20.
5) Crowdsource reporter. Crowdsource Reporter | ArcGIS Solutions. (n.d.). Retrieved May 6, 2022, from https://solutions.arcgis.com/local-government/help/crowdsource-reporter/
6) Daniel Sui, Sarah A Elwood, Michael Goodchild (2013). Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice
7) Gatitu, J. N., Kabubo, C. K., & Ajwang, P. (2020). Approaches on Mitigating Variation Orders in Road Construction Industry in Kenya: The Case of Kenya National Highways Authority (KeNHA). *Engineering, Technology & Applied Science Research*, 10(5), 6195-6199.
8) Goodchild, M.F. (2007). "Citizens as sensors: the world of volunteered geography". GeoJournal. 69 (4): 211–221.
9) Gu, Y., Qian, Z. S., & Chen, F. (2016). From Twitter to detector: Real-time traffic incident detection using social media data. *Transportation research part C: emerging technologies*, 67, 321-342.
10) Hutchinson, Emma, Kovats, Sari. (, 2017) "EBOOK: Environment, Health and Sustainable Development" , EBOOK: Environment, Health and Sustainable Development
11) Joseph Kamau Muguro, Minoru Sasaki, Kojiro Matsushita & Waweru Njeri | Ahmed Haj Darwish (Reviewing editor) (2020) Trend analysis and fatality causes in Kenyan roads: A review of road traffic accident data between 2015 and 2020, Cogent Engineering, 7:1, DOI: 10.1080/23311916.2020.1797981

12) Kneuper, R. (2017). Sixty years of software development life cycle models. *IEEE Annals of the History of Computing*, 39(3), 41-54.
13) Ma3route(2016). About ma3route.https://www.ma3route.com/,Retrieved June 08, 2017
14) Ma3Route. (n.d.). Retrieved February 18, 2022, from https://www.ma3route.com/
15) Mitchell, A., & Page, D. (2013). The role of news on facebook. Pew Res.J. Proj. 1–24. Available online at: http://mediaimpact.issuelab.org/resources/16225/16225.pdfNASCIO (2010).
16) Ngicabe,J.K. (2016). Development of a mobile application for road incident reporting in Kenya (Thesis). Strathmore University.Retrieved from http://su-plus.strathmore.edu/handle/11071/4908
17) Ndung'u, S. M. (2020). *Integration Of Road Design Information With Carrymap For Mobile Access* (Doctoral dissertation, University of Nairobi).
18) NTSA (2020). Road Safety Policy Guidelines For Government Ministries, Departments And Agencies (Mdas) In Kenya
19) Sicular S. Gartner's big data definition consists of three parts, not to be confused with three "V's", vol. 27. Stanford: Gartner, Inc; 2013.
20) Souleyrette, R., Strauss, T., Pawlovich, M., and Estochen, B. (1998). GIS-ALAS: The Integration and Analysis of Highway Crash Data in a GIS Environment. Integrating the transportation Business Using GIS. Proceedings of the 1998 Geographic Information Systems for Transportation (GIS-T) Symposium, (pp. 411-415). Salt Lake City, Utah.
21) StatCounter Global Stats. (n.d.). Retrieved April 23, 2022, from https://gs.statcounter.com/social-media-stats/all/kenya.
22) UNCTAD. (2018, December). *Road safety - considerations in support of the 2030 Agenda for Sustainable Development*. UNCTAD. Retrieved February 18, 2022, from https://unctad.org/webflyer/road-safety-considerations-support-2030-agenda-sustainable-development
23) UNECE. (2016, February 19). *Options for the establishment of a UN Road Safety Fund - UNECE*. http://www.unece.org/. Retrieved February 18, 2022, from https://unece.org/fileadmin/DAM/trans/doc/2016/itc/Options_for_a_UN_Fund_For_Road_Safety_draft.pdf
24) WHO (2020). Global Status Report on Road Safety Time for Action.

25) WHO. (2018, June 17). *GLOBAL STATUS REPORT ON ROAD SAFETY*. www.who.int. Retrieved February 18, 2022, from https://www.who.int/violence_injury_prevention/road_safety_status/report/executive_summary_en.pdf?ua=1

26) Y. Gu, Z. Qian and F. Chen, "From Twitter to detector: Real-time traffic incident detection using social media data," Transportation Research Part C: Emerging Technologies, vol. 67, pp. 321 342, 2016.

Appendix A
Questionnaire

This is a questionnaire designed to collect user data based on the KeNHA highway incident reporting application.

1. Have you used any web application in reporting road incidences?

   Yes

No.

2. Have you used social media to report an incident before?

   Yes

   No.

3. If yes, which of the following applications have you used?
   - Twitter
   - Facebook
   - Waze
   - Ma3Route
   - Nduru

4. Do you think that the application will impact the road incidences response in dealing with the cases?
   Yes
   No.

5. In your opinion, do you think that this web application will improve road safety and maintenance?
   Yes
   No.

6. Would you be willing to use such an application to report road incidences to the Authority?
   Yes
   No.

7. How would you rate the application's ease of use in terms of accessibility and submitting report?
   - Excellent
   - Very good

- Good
- Fair
- Bad

8. How would you rate the application graphical user interface and appearance?
    - Excellent
    - Very good
    - Good
    - Fair
    - Bad
9. How would you rate the representation of the information on the map?
    - Excellent
    - Very good
    - Good
    - Fair
    - Bad
10. How would you rate the navigation of the interface?
    - Excellent
    - Very good
    - Good
    - Fair
    - Bad