Development of A WebGIS Supported Road Traffic Accident Data Management System: A Case Study Of Nairobi County

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Abstract—This research project work seeks to improve road traffic data storage and accessibility through the use of WebGIS by creating a road traffic accident data management system. A case study method was employed with Nairobi County as the study area. An Accident Management System was developed encompassing a database managed by PostgreSQL and a webserver. It has the advantages of having centralized data, readily accessible as opposed to the current status where data access is constricted by office working hours and manual data requisitions that take time to respond to. Simple statistical analyses are afforded by this system for data comparisons, estimations and inferences. The location of accidents usually given in textual formats has been addressed hence viewing of accident locations on maps is possible.

Keywords—Database, Geospatial Information Science, WebGIS.

I. INTRODUCTION

There is a palpable desire and urgency to effectively address the fatalities and serious injuries resulting from road traffic accidents evidenced by the many studies and reports carried out both globally and locally to address them. [1 - 6]. Studies have shown that 90% of the global road traffic accident statistics occur in low and middle income countries like Kenya [7, 8] where over three thousand people are killed as a result of road accidents, with an average of 7 deaths from 35 accidents per day [9]. It has also been shown that the majority of these fatalities and serious injuries occur in the economically active population of 15-59 years [10], thereby curtailing economic activities of affected countries.

The United Nations, the World Health Organization, the African Development Bank, United Kingdom’s Transport Research Laboratory, African Transport Policy Program, Kenya Road Safety Network, Institutions of higher learning and individual researchers among many others have dedicated considerable financial resources and time to find ways of mitigating the Road Traffic Accident problem.

In the year 2004, the then president, His Excellency President Mwai Kibaki, acknowledged that over 3000 Kenyans got killed on the Kenyan roads every year, most of them between the ages of 15 and 44 years. He asserted his government appreciated that road traffic injuries were a major public health problem amenable to prevention [11]. Calls for concerted efforts for effective and sustainable prevention have been made at national and global fora to address this state of affairs. This did lead to a number of measures as a redress to the road traffic accidents menace.

Globally the United Nations, in its Sixty-fourth session, Agenda item 46, proclaimed the period 2011–2020 as the “Decade of Action for Road Safety, with a goal to stabilize and then reduce the forecast level of road traffic fatalities around the world by increasing activities conducted at the national, regional and global levels”[12].

At national level, the National Transport and Safety Authority (NTSA) was established through Act Number 33 of 2012 to minimize loss of life through road accidents and a raft of rules introduced via amendment of section 12 of Cap 403 of the laws of Kenya to address road traffic accident crashes in the country. These included [13]: Overlapping, obstruction, driving on pavement or through a petrol station to avoid traffic, contravention attracting a fine of Kshs 100,000 - 300,000 or one year in jail or both, over speeding which attracts a fine of Kshs 10,000 or 3 months imprisonment or both, careless Driving having a penalty of Ksh 500,000 or 10 years imprisonment or both. If it leads to death, the penalty is Life Imprisonment, driving under influence of alcohol which has a fine of Ksh 500, 000 or ten years in jail or both, PSV Operators to adhere to the uniforms’ and badges’ rules, Motor Cycle operators to carry one passenger only and the passenger and rider must be in reflective vests and helmets – infringement attracts a fine of Kshs 10,000 and in default 12 months imprisonment.

These efforts were supplemented by Sessional paper No. 10 of 2012 on Kenya Vision 2030 [14] which outlined a national road safety program targeting reduction of incidences of road crashes and their impact on the Kenyan Economy and suggested computerized information maintenance management systems program to manage roads, bridges and pavement.

Still the numbers remain unacceptably high both globally and at national level. For the Kenyan case, road crashes have been shown to be steadily increasing year after year [9]. Acknowledging the fact that the majority of the fatalities and serious injuries occur in the economically active population of 15-59 years [10], the need to attempt to prevent road accidents...
by viable means becomes increasingly important. There has to be much better than the react-to-crisis basis way of tackling infrastructure issues [15] that is the norm in the country. Better methods of assembling and managing road traffic accident data than the current practices which rely on un-harmonized manual technologies that are slow and in the long run expensive need to be put in place.

It is with regard to the foregoing that a centralized Road Traffic Accident Data Management System accessible via the World Wide Web (WWW) is given as a solution. This is in line with international practice where systems using GIS have been developed for use in road traffic accidents’ management for improving the efficiency and effectiveness of traffic accident countermeasures [16 & 17].

This paper addresses management of data, which is the cornerstone of all road safety activity and is essential for the diagnosis of the road crash problem and for monitoring road safety efforts [18], resulting from Road Traffic Accidents. Many decisions meant as interventions have been made, which, invariably in the short term, have not proved effective because of the failure to understand and account for variability in these accidents.

II. LITERATURE REVIEW

Studies have shown that frequency of accidents can be addressed by adequately collecting and centrally storing data from road traffic crashes’ in a spatial database for ease of management and most importantly to learn from it. In a report by the Transport Research Laboratory [19], the importance of such a system and its utilization is emphasized. Such a database would capture the road traffic crash situation where all crashes resulting in death and injuries are recorded, adequate detail surrounding the accident incident are inventoried – vehicle, road user, road environment, crash location accurately determined and recorded, and reliable output provided as needed.

Currently road traffic accident related data is managed by various players – mainly the Traffic Police Department, the National Transport and Safety Authority, Kenya Urban Roads Authority and Ministry of Health hold disaggregated data. Other organizations like the National Bureau of Statistics, Kenya Road Safety Network have aggregated data from the former institutions. The implication is that data is available in varying data formats and that accessibility regimes are different for each organization. Data extraction from existing storage is cumbersome at the least and at worst records might be missing all together. Manner of storage is mainly in analogue publications, meaning that retrieval is cumbersome and at worst inaccessible for cases of lost data. Further, locational information in the current data collection and storage – where accidents take place – is very much generalized. No attempt is made at determining and recording the geographical position of traffic incidences. A good indicator of the non-accurate accident location reporting and recording is in the manner of reporting black spots by the Kenya Police Service [20], the National Transport and Safety Authority [21], Kenya Roads Board [22] among others.

This project work sets out to integrate data related to traffic accidents via a spatial database and employ use of communication technologies for a one stop data and information portal and for a wide reach via the WWW. These data is both spatial and descriptive. The system is to ensure readily available data at common standards for decision making support and research purposes. Such a system has been before proposed in earlier research [23].

Thus the main objective of the study was to use the ability of GIS in management of road traffic accident related data by developing a WebGIS Supported Road Traffic Accident Management System for Nairobi County. Specifically, the objectives were;

- To develop a spatial database for road accident incidences in the Nairobi County;
- To develop a web user interface that accesses the database; and
- To construct a logic tier that links the database with the user interface.

The premise of this research is that good accident data management can aid better decision making which in turn would lead better policy formulation, focused road traffic legislation and informed traffic rules enforcement. This would eventually have a positive impact on the numbers in road traffic accident incidences.

The World Health Organization (WHO) recommends [24] road safety management as one of the six pillars that guide national road safety plans and activities over the Decade of Action for Road Safety [12]. This study will therefere aid the country’s move towards meeting its obligation of stabilizing and reducing the increasing trend in road traffic fatalities and injuries by implementing this pillar. The web based road accident data management system will provide a one stop data portal and be accessible to multiple users through the web interface.

As a case study, it provides a learning and evaluation platform on a pilot basis before any nation-wide program is implemented and thus save the country on resources that could be invested in untried counter-measures. This idea of piloting programs is strongly supported by the Transport Research Laboratory, United Kingdom [25] who advances the importance of running road traffic accident countermeasures as pilot schemes so that they are properly evaluated and reported on before acted upon on a wider scale.

The road traffic accident data management system will have the following benefits: It will help the national government decide on Safety Policy supported by scientific evidence e.g. the night travel ban; It would guide national and county government authorities to reach appropriate decisions such as campaigns on drink –driving, child safety education; It would help identify design problems on the transportation network; It would be a one stop shop for road accident related data; It would help determine the true burden of Road Traffic Accidents; Highlight the inaccuracies and incompleteness of...
current traffic accident data; and it would aid in the achievement of the Millennium Development Goals of reducing child mortality and reduction of extreme poverty and hunger by reducing the number of road traffic accident fatalities which involve children and family bread earners.

It is the opinion of the researcher that the current way of managing information surrounding accident occurrences is not adequate. Hence the choice of WebGIS as a management tool in this research. The application of GIS in data management has grown since the 1960s because of its great appeal in integrating all kinds of information and applications with a geographic (spatial) component into one manageable system, hence, allowing for the creation of a complete picture of a situation. Spatial and other kinds of information are brought within a single system allowing for manipulation and display of geographical knowledge in new and exciting ways. Further, the ability to separate information in layers and combine it with others gives GIS great potential as research and decision-making tool [26].

This ability of data layering has been greatly used in incident and traffic management systems with high efficiency, with GIS’ capability of integrating data feeds and sharing dashboard views exploited [27]. This feature makes it ideal for getting a comprehensive depiction of the present road traffic accident situations. For instance, traffic operations managers can observe traffic jams and other such information so that they can quickly respond to the situation. They can also share their views with the public through websites and update the drivers on any information like road conditions, travel conditions, etc.

GIS, being a computerized system, facilitates data entry, data analysis and data presentation [27]. Such data is usually organized in a database, a repository of data, designed to support efficient data storage, retrieval and maintenance. Data in a database is stored in various forms including tabular, hierarchical and graphical forms [28]. It is the tabular form, referred to as relational database that was exploited in this research. Here data is stored in a simple but versatile way in two dimensional tables, also called relations. The relation columns have attributes while its rows (tuples) contain information about the attributes.

Various researches have shown that for an accident database, the needed data for an ideal Road Traffic Accident Data Management System would include vehicles and people involved in accidents, the location of the accidents, time and environment/weather conditions existing during the accident incident, the cause of the accident and the consequences of the accident. This information relating to an ideal accident database was gathered from various research studies done [29, 30].

Studies and applications in the use of GIS in Road Traffic Accident Management have been done successfully elsewhere where road traffic accidents were as prevalent and discorncing as in Nairobi County. A prototype Geographic Information System and Road Accident View System (GIS-RAVS) [31] was developed in Malaysia to reduce the number of traffic accidents. The system was developed to afford data entry and querying. Access of the system was via desktop computers.

Agoki [32] studied the characteristics of road traffic accidents in the country in order to develop accident predictive models for Kenya. The study was evidently addressing the alarming number of traffic accidents on the roads.

Mwatela [23] used GIS to analyze causes of RTAs in Kenya. An actual database was not created but advanced the benefits of road crash database which would allow for analyses of RTAs and facilitate fast retrieval of information. He acknowledges that GIS has the advantage of affording easy system updates when there is need.

W. Odero, M. Khayesi and P. M. Heda [9] studied road traffic fatality trends in Kenya and showed that traffic crashes and the resulting casualties were on an increasing trend. These conditions were replicated in the then Nairobi, Rift Valley, Coast and Eastern Provinces because of high concentration of human population, high road network density and connectivity. In their discussion, they highlighted the incompleteness and inaccuracies of available data on road traffic accidents. The recommendation of the study was that “accurate and reliable traffic injury data can help inform decision makers, stakeholders and the public about the magnitude of the problem and intervention options that have proven effectiveness”.

In a research carried out by E. K. Reshma and S.U. Sharif [33], the results did show the existence and location of black spots on roads in South Bangalore, India. Proper data collection and storage for accurate road accident data sets was recommended.

In a study detailing the characteristics and availability of fatal road-crash databases worldwide [30] it was learned that webGIS enabled accident management systems had been established elsewhere and that in such regimes the number of road traffic crashes were considerably lower when contrasted with countries where road accident data management was not managed properly, such as Kenyan.

Other studies have been done at both undergraduate higher levels that address aspects of road accident incidences. For instance, Nabende [34], then a student at the University of Nairobi studied factors contributing to Bodaboda taxi related traffic accidents in Kakamega Municipality, Kenya. Chitere and Kibua N. Thomas in their article ‘Efforts to Improve Road Safety in Kenya looked at achievements and limitations of reforms in the Matatu Industry [35]. Nyangweso [36] studied the existence of black spots on Nairobi roads. Kipnegetich [18] carried out a study on application of GIS Mapping and Analysis in mapping of road traffic accident incidences on Nakuru – Eldoret Highway road.

On accident reporting, the National Transport and Safety Authority (NTSA) avails daily accident reports in excel and pdf formats on enforcement, though the reports are not daily as envisioned. Kenya Urban Roads Authority also occasionally reports on accidents [21 & 22].
Thuo [37] designed a system to manage the entire traffic environment in the Central Business District in Nairobi. While the system was GIS aided, there is no evidence that it was availed to users via the WWW. Thus whereas it could be deployed to address road traffic accidents, knowledge of its existence was confined to a small group of people and its usage limited to people exposed to GIS software and in particular in ArcGIS.

A ‘Road Safety Seminar’ held in the Republic of Tanzania in the year 2009 organized by the United Nations Economic Commission for Africa discussed “A Way Forward for Reducing Accident Fatalities by Half by 2015” [2]. Road Traffic Accident Data Management was discussed and a recommendation made for participating states to harmonize their road safety data to ensure comparability.

III. METHODS AND MATERIALS

Experimental survey method was employed where case study option was adopted, with Nairobi County, the study area, considered a true representative sample of the population country Kenya with regard road traffic accidents.

A. STUDY AREA

The country’s political, social, cultural and economic capital is located within the boundaries of the County. It is one of the forty seven (47) counties created as administrative units provided by the Constitution of Kenya, 2010. It is bordered by Kiambu County in the North and North West, Machakos County in the East and South East and Kajiado County in the south and south east. It is administratively divided into three sub-counties with a total of seventeen constituencies. The study area is depicted in Fig. 1 below.

Fig. 1 Study Area

It has a population of 3,138,369 against the country’s population of 38,610,097 (approximately 8% of total population). This population is mainly comprised of migrants from other counties with male to female ratio of 0.51:0.49.

Nairobi County was chosen because of its high population density and extensive road infrastructure composing of all road classes in the country and a high number of registered vehicles.

B. METHODS AND MATERIALS

The methodology adopted for this research to develop a webGIS enabled road traffic accident data management system using open source tools is illustrated in Fig. 2. The initial action was data collection and preparation. Then a relational database was created comprising of both spatial and non-spatial data composed of Nairobi road network data, Nairobi County Boundary, boundaries of neighboring counties, accident statistics, country and county population statistics, police stations and health facilities.

Acknowledging that the development of a road traffic accident data management system entailed data needs identification, data collection and harmonization, database creation, client layer creation and logic layer development, implementation was phased out as shown in Fig. 3 below.

Fig. 2 Research Methodology
Having identified the data requirements from previous researches, the next action was road accident data collection and preparation. These data both spatial and non-spatial, comprised of Nairobi road network data, Nairobi County Boundary, boundaries of neighboring counties, accident statistics, country and county population statistics, police stations and health facilities. All spatial data was projected into Universal Transverse Mercator projection on Arc 1960 Ellipsoid using DNRGarmin, a free source program for datum transformations. Then this data was prepared and assembled in Quantum GIS (QGIS), an open source GIS program.

Accident Statistics, Hospitals and Police Stations data were provided without spatial information. To address this shortcoming, their locations were inferred from Google Earth Imagery where location was marked and saved as Keyhole Markup Language (KML) files. These were then loaded in QGIS and converted to shape-files and attributed accordingly. An illustration is given in Table 1 of Hospitals Data and location inference as described above of one of the hospital facilities in Fig. 5.

<table>
<thead>
<tr>
<th>Code</th>
<th>Facility Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>19550</td>
<td>Meridian Medical Centre</td>
<td>Medical Clinic</td>
</tr>
<tr>
<td>19463</td>
<td>Kenya National Hospital</td>
<td>Referral</td>
</tr>
<tr>
<td>13091</td>
<td>Mid Hill Medical Clinic</td>
<td>Hospital</td>
</tr>
</tbody>
</table>

In a similar manner, spatial information was assigned to hospital, police station and reported accident locations. As a result of this, it was possible to overlay these datasets on the roads data set as shown in Fig. 6.

A relational database was then created using PostgreSQL Relational Database Management System (RDMS) with PostGIS extension to handle spatial data. To achieve this goal, entities and their relationships were identified as illustrated in Fig. 7:
Twenty entities and their attributes including six relations with spatial data - Roads, Railline, Hospitals, Police Stations, Roundabouts, and County Boundary were identified and used to create a database using PostgreSQL with PostGIS extension.

The spatial field was achieved by use of QGIS 2.0.1 where shape-files for these entities were created and attributed. Then by use of the Shp2pgsql (Command line data loader packaged with PostGIS for importing of standard ESRI Shapefiles and DBFs) tool that is supported in the PostGIS extension, the shape-files were loaded into the database.

The spatial reference used was the Clarke 1880 Ellipsoid, UTM projection, Zone 37 South. Its code the database is EPSG 21037.

By use of table creation statement, tables were created using the Structured Query Language (SQL) that is packaged with PostgreSQL.

A logic layer was then created. This entailed the acquisition of a virtual hosting account with capabilities to support spatial databases and with GIS tools for administrative interface, development of PHP scripts and tables to provide the link between the data tier and the presentation tier (server-side scripting). A remote server was acquired from AcuGIS Support at http://cpanel.geospatialresource.com.

The considerations for choosing this host were that it had to be available with no or little downtime, that it supported PostgreSQL spatial databases and that it afforded support of GIS tools including conversion of shapefiles to PostgreSQL and Geoserver. Indeed the acquired host had all these and more as evidenced in Fig. 4 below.

Tools that enabled the achievement of this phase included Filezilla for uploading files to the webserver, Web scripting language Pre Processor Hyper Text (PHP), NetBean v8.0 text editor, and Geoserver for delivering of geo-associated database records.

For universal access of the database, a user interface was created. In this phase, a website was built using Hyper Text Mark Up Language (HTML), Case Styling Sheets 3 (CSS3) for HTML formatting, Client-side OpenLayers to display map data on the web, and Gimp v2.8.2 for manipulating imagery.

IV. RESULTS AND ANALYSIS

A. RESULTS

A Road Traffic Accident Data Management System (AMSYS) was created for the purpose of managing road traffic accident data. The system is made up of a spatial database, a logic layer composed of PHP scripts and a user interface for viewing the data, uploading and downloading. Fig.8 illustrates how the disparate parts of the system are interlinked.

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occurrences, a query section where the database can be queried for past crashes and related data with several user selectable options provided.

For data viewing, a user can query data based on several factors, including accident victims – driver, pedestrian, passenger; age and gender – minor, adult, male or female among other factors. An instance of Driver Fatality table is provided in Table 2.

The system also affords map displays for visualization of accident sites – Fig. 11 - which can aid in revealing accident prone roads.

For user input, the system has a provision for road traffic accident reporting. A data collection form is provided with fields that require filling out as indicated in Fig. 10.

### Table 2 Data View of Driver Fatalities

<table>
<thead>
<tr>
<th>No.</th>
<th>Accident Code</th>
<th>Adult Male</th>
<th>Adult Female</th>
<th>Minor Male</th>
<th>Minor Female</th>
<th>Death Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RTA2010012</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>On Site</td>
</tr>
<tr>
<td>2</td>
<td>RTA2010022</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>On Site</td>
</tr>
<tr>
<td>3</td>
<td>RTA2010032</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>On Site</td>
</tr>
<tr>
<td>4</td>
<td>RTA2010043</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>In Hospital</td>
</tr>
<tr>
<td>5</td>
<td>RTA2010052</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>On Site</td>
</tr>
<tr>
<td>6</td>
<td>RTA2010062</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>In Hospital</td>
</tr>
<tr>
<td>7</td>
<td>RTA2010072</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>On Site</td>
</tr>
</tbody>
</table>

### B. ANALYSIS

The AMSYS developed is a ready-to-use solution for addressing the country’s Road Traffic Accident Data Management. It provides a public website on the WWW which provides end-to-end experience for data users from data access to data analysis to sharing/dissemination. Further point and line displays are possible where lines represent the road network and points the accident locations as the system is a highly visual one. The road traffic accident management system provides for the publishing of accident statistics which can be found by people in a single place.

Boxplots are provided to give information about means of...
various accident data groupings. From the boxplots’ centers’, spreads and shapes (skewness), one can infer patterns in the road traffic accident data. For example one can learn about driver fatality means of different epochs of time from which conclusions can be drawn on the efficacy of interventions put in place to address the road traffic accident menace.

From pie charts one can learn quickly get information from the data, which would otherwise take a lot of time spent in perusing through documents. For instance, one can easily tell that vehicles are being driven by minors on Kenyan roads from the Driver Injury pie chart in Fig. 13 and that their numbers are substantial.

Accident occurrence location (Fig. 13) has been inferred from Google Maps based on the textual description accompanying accident statistics. It is understood that capacities for position determination may be absent or weak in the key institutions dealing with road traffic accident data. Because such capacities often require years to develop and do have an attendant high equipment cost, alternative approaches are essential in order to address the problem of accurate accident location determination. Thus the researcher suggests that strategies that build off existing trends within society be exploited to fix this challenge. One such trend is the use of smart mobile phones which come packaged with position determining GPS abilities. Smart phone usage is prevalent in Kenya. Thus it may be prudent to train specific people on use of smart phones to collect accident location information.

Accident reporting has been made easy by making it possible for any person witnessing road traffic accident occurrence to report via the WWW. This is opposed to the current practice where only serious accidents are required by law to be reported and recorded by authorities. This afforded opportunity would lead to a greater number of the accident incidences being reported. Of course the onus lies with the responsible authorities to qualify the authenticity of such reports.

Accident occurrence location (Fig. 13) has been inferred from Google maps based on the textual description accompanying accident statistics. This is still an issue as position determination, in the least, requires mechanical devices with ability to determine position and with some skills to use such devices for position determination.
The continued proper documentation of such data for updating of the system is justified on economic, scientific and social process grounds. Such documentation would result in a considerable amount of readily available structured road traffic spatial and attribute data that can be used in policy formulation and further research. In contrast, the current situation is characterized by various road traffic accident data repositories with varied data access regimes at different acquisition costs. All these result in data access time lags and associated availability uncertainties that make research in this field very unappealing.

All the foregoing are good grounds for discussion, determination and adoption of common standards in data collection. It is suggested that issues to be discussed to further include the standards needed for spatial data representation, application programming interfaces for spatial data processing, semantic issues on what metadata, domain-specific vocabulary are needed for data to be appropriately interpreted and institutional issues such as what agreements, trust, skills, reorganization are necessary for organizations to coordinate effectively in the generation and use of road traffic accident data.

This would be greatly advanced by cooperation between stakeholders as this is critical to the effectiveness of such a system. This would ensure that there is better and more systematic information available for the updating and integrity of AMSYS database. The researcher is of the view that counties develop such systems (where applicable) in conjunction with the national government so that the county systems would in turn feed the national one.

V. CONCLUSIONS

The AMSYS platform documents the set of procedures necessary to store and query road accident data. Through the developed system, it has been shown that Nairobi County road traffic accident data can be better managed using WebGIS. This can be achieved by replacing the existing patchwork of fragmented individual and uncoordinated efforts by stakeholders with the one-stop system. The system has the ability to stimulate harmonized and synchronized deployment of resources, otherwise disparate, to feed into efforts towards reduction of road accidents on our roads.

This is an achievable exercise that requires minimal financial commitment considering the availability of a wide array of open source tools to implement its operation while its usage does not require specialized training as is the case for GIS programs. The acquisition of data required to populate the system does not entail extraneous efforts and resources as institutions are already in place with clear mandates and responsibilities.

The researcher envisons a situation where after systematic data collection over a number of years, users will be able to make, with confidence from the system, sound and reliable inferences for unbiased policy directions. Researchers will also have a ready data portal available round-the-clock while the community at large would be informed.

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