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INTEGRATION OF GIS, GPS, GSM AND REMOTE SENSING, (3GR) FOR ROAD ACCIDENT REPORTING AND MANAGEMENT

C.O. ADEOFUN[1] AND *J.A OYEDEPO[2]

[1]Department of Environmental Management and Toxicology,
[2]Environmental Resources and Conservation Research Programme,
Institute of Food Security, Environmental Resources and Agricultural Research
Federal University of Agriculture, Abeokuta Nigeria
***Corresponding author:** johnoyedepo@yahoo.com

ABSTRACT

Abeokuta metropolis is gradually developing into a mega city in Nigeria. At the moment the municipality spans 4 local government areas and the sprawl has just started. Along with the city expansion is the increase of vehicular movements and concomitant vehicular accidents. There is therefore a need for development of an accident, reporting data collection, referencing, management and analysis system, for Abeokuta city. Consequently, the paper looks at a GIS based integration of spatial technologies for near real time reporting and management of road traffic accident in the city. In the study, an accident database management system was developed to store urban traffic accident data, and analyze these data in terms of their attribute and spatial characteristics in order to exploit the reasons for accidents, the hot spots and rank the urban area with various degrees of danger. Foremost, the study established a road network in ArcGIS for Abeokuta metropolis. Next, locations of fatal and minor road traffic accidents data within the metropolis in the last five years were geo-referenced with the aid of GPS and the attributes were developed into a database. Reasons for road accidents were analysed in order to summarize major factors related to the accidents. Finally a hazard map was created to show the accident hot spots and degree of danger with respect to road accident in the city. The paper particularly explains the method of using Mobile phones to report accidents by eye witnesses while using the GPS to reference the accident locations. The incorporation of GIS map along with some monitoring systems like the Personal Digital Assistants (PDAs) was identified as pedestal for the development of real-time or near-real time accident reporting and management system.

Keywords: 3GR, GPS, GIS, Remote sensing, Accident database, Abeokuta

INTRODUCTION

Over the years, auto crash has became a major concern in Nigeria. Available records reveal that between 1960 to 2006 an estimate of over 967,618 road accidents have occurred leading to the loss of 292,703 lives and a total of 1,159,642 causalities (Nnadi, 2011). As part of the effort to reduce road accidents, the Federal Government of Nigeria re-established the Federal Road Safety Commission (FRSC) in 1988. Notwithstanding, it is still useful to incorporate newer strategies that will further assist the commission to effectively manage and respond to vehicular accidents on the roads.

Since, Geographic Information System (GIS) is a computer system for capturing, storing,

querying, analyzing and displaying geographic data, new paradigm for the organization of transport information and road auto crashes has been proposed (Abdalla, 2004**)** through integration of Global System of Mobile telecommunication (GSM) and the three spatial technologies; Geographic Information System , Global Positioning System and Remote Sensing (GIS, GPS and RS) in a 3GR model. The integration of the four technologies will aid near real-time reporting of road accidents and will enhance rapid response. GIS is a powerful computing tool for managing large amounts of heterogeneous data. while GSM takes care of the reporting, GPS and the real time remote sensing can guide rescue team to the very spot of the crash while GIS can also be effectively used to store up the incidents, identify black spots on roads in view of providing warning and guidance, to road users (Waters, 1999) The application of GIS in transportation problems dates from the 1960s and is typically referred to as GIS-T (Goodchild, 2000). Similarly, the integration of GPS and GIS as reported in several studies (Quiroga, 2000; Taylor, *et al.,* 2000; Xue, *et al.,* 2002 and Uno *et al.,* 2009) provide a useful tool for transport management. But the association of remote sensing, spatial databases (GIS), GPS and telecommunication systems, (GSM) in order to support real-time decision-making described as *telegeoprocessing* (Xue, *et al*., 2002) as. appears relatively better in road accident reporting and management.

Derekenaris *et al*. (2001) described the result of integrating GSM with GPS, and GIS as system that offers solution to the problem of ambulance management and emergency incident handling in the prefecture of Attica in Greece. According to them, using efficient data structures for the implementation of routing analysis, the time performance of the shortest-path algorithm for an ambulance can be enhanced and incorporating the efficient algorithm within the GIS will increase the system's viability. Thill (2000) also noted that mobile computing devices like PDAs can aid the Web-based GIS applications to facilitate data acquisition and information dissemination. Thus making the application of telegeoprocessing very promising as already demonstrated through several piecewise applications.

The main advantages of integrating GSM with GPS and GIS include the capacity to collect, every second and from anywhere in the urban road network and report any mishap in real time. Positional and other traffic data can also be stored automatically and used in real-time operations while the ability to display this spatial data in a GIS environment makes room for easy analysis, and integration with other relevant data (Taylor *et al.,* 2000). The main disadvantages of this new concept, which according to Uno *et al.,* (2009) will be overcome in the next few years with the recurrent advances in computing and telecommunications technologies, include the enormity of the amount of data to process, the cost of data transaction (especially for real-time observations), and data bias.

In this context, this work aims to contribute to the development of Telegeoprocessing especially in accident management by providing prototypes for GPS/GIS integration with GSM and PDA application, in order to enhance real-time data acquisition and diffusion. In this paper, an attempt is made by taking into account factors causing accidents for predicting the accident prone points (hot spots) on the road. The paper also highlights the integration of Global System of Mobile telecommunication (GSM) with Global Positioning System, Geographical Information

Systems and Satellite remote sensing to rescue accident victims on the road. In case of accidents the accident spot is located geospatially and then, the ambulance may be guided through the shortest route to the accident spots and hence forth to the nearest hospital. Suggestions of possible ambulance locations were also made on accident hot spot maps.

METHODOLOGY

Study area

Abeokuta is the largest city in, and capital of Ogun State in southwest Nigeria and is situated in a window described by 7° 22' N; 3° 28'E/7.16083; 3.34833on upper left corner and 7°10N and 3° 44' E at the lower left corner. Abeokuta is situated along Ogun River; which served as the main transport route to Lagos at the early period of the city establishment in 1825 (Wikipedia, 2010). Abeokuta is 64 miles north of Lagos by railway, or 81 miles by water and less than 100 km by road., Abeokuta city had a human population of 593,140 as of 2005.

Data types and data collection

The data types collected were mainly of secondary source. A high resolution satellite remote sensing data acquired in 2006, purchased and geo-referenced for the study. GPS was used to obtain the coordinates of the position identified as accident prone and records of auto crash were incorporated to the GPS coordinates.

Data Capture

The road map of Abeokuta was captured directly from a High resolution satellite (IKONOS) image of the city acquired in December 2006. The image was first registered using coordinates of known locations of the city identified from the image and were digitized out "on-screen". Physical inspection of the roads was conducted to determine among other attributes, the motorability conditions, the type and the volume of vehicles plying the roads.

GIS Database Development:

It was necessary to build a GIS database that keeps track of accidents. This is because accident database is the building block for accident reduction and prevention. The operation of accident investigation procedures hinges on the existence of a reliable database and clearly defined technical procedures. A database was developed for the roads in GIS and the records of road accidents in the last 3 years was incorporated into the developed data base. The essential data necessary for evaluating accident prone zones were collected. The key elements of an accident database are an accurate location reference, basic Information describing the accident, its victims, the events leading up to the accidents, a collision sketch showing the paths of the vehicles and road users involved and information about the accident site and circumstances (road condition, weather etc). It should be noted that an Accident Management System (AMS) consist of a database that incorporates both spatial data and non-spatial data. It usually involve the following:

- Database frame; which involves collecting data and building database.
- Preventive Analysis; location of the hot spots with the available database.
- Remedial Activity such as rescue of victims and removal of causal factors.

Data Analysis

The accidents and road types were analysed based on causative factors and conditions respectively. This was done to enable identification of the most frequent causes of road accidents and the hot spots where road acci-

dents have the highest probability to occur.

Preventive Analysis

As part of measures to manage accidents and to prevent future occurrences preventive analysis was carry out following the highlighted steps below.

- Locations for ambulance points were identified
- Phone booths for calling accident assistance numbers in case of emergencies were positioned on the maps so as to reduce communication gap and thus quicken the remedial measures.
- Analysis to indicate road expansion to accommodate rescue vehicles was conducted
- These analyses were developed into remedial measures.

RESULTS AND DISCUSSION

The road network city at the centre (circled) in Figure 1 is poor due to the compact nature of the houses. Compared to the city outskirts, vehicular accidents around the city centers may be limited to motorbike crashes and may not be as rampant or as fatal as it is at the outskirt. This is simply due to many barriers such as buildings and natural obstructions like rock outcrops which may serve as speed break for cars and bigger vehicles. However, there is a very high probability of vehicles running into pedestrians and traders who often display their wares on the road.

At the city outskirts, accident prone segments of the road and accident and hot spots include, the University road near Isolu Village, Ajebo-Abeokuta road by Iyana mortuary, Sagamu-Abeokuta road by NNPC junction, Post-Office-Okeilewo round about area, Ibadan- Abeokuta road by University road junction, and three other spots along the Abeokuta Ibadan road; namely Gbonogun junction, Fajol Area and Asero Estate Junction.

The deadliest spots have been the NNPC junction, Gbonogun junction and the University road. The study identified heavy traffic flow along these identified areas but the most frequent causes of accidents have been the poor road condition along the university road and the sharp bend around Isolu area, high volume of heavy duty trucks (trailers, tippers) which often suffer brake failure due to the topography of the road and the narrowness of its width in Gbonogun junction., NNPC junction is an exception with respect to road condition, the causal however, is the location of two mega filling stations at the junction of the major bye pass to the city (i.e. Abiola way). At Iyana mortuary, the frequent reason for road accident is similar to that of Gbonogun junction; several heavy trucks loaded with quarried rocks also take the roads that form the junction as primary route. Often poor traffic control and brake failure result in fatal vehicular collision. Table 2 presents the accident prone areas, which is translated to accident hotspots on the city road networks in Fig. 2.

In the integrated system, the GSM and the Personal Digital Assistant (PDA) are at the scene of the incident. While the PDA acts like the black box in the aircrafts, by keeping a detailed information of the vehicular movement up till the time of the incident at the same time revealing its location to the probe vehicle through its Bluetooth, the GSM which requires people participation will be utilized to report the accident in real time to the nearest rescue point. To make this functional, phone booths specially designated to emergency reporting are strategically positioned where citizens can utilize them in real-time. The information retrieved

from the PDA will also assist the GIS in spatial analysis for remedial action against future occurrence. Invariably, a detailed information obtained from the PDAs includes a "Mobile system" prototype for traffic data acquisition, a "GeoModelling & Analysis system" prototype to store and manipulate the collected data in a GIS for Transport management (GIS-T) environment. A "Public Information system" aspect of the model is included to disseminate information to the public through a WebGIS application.

In other words, the first part of the model is used to get data from the real system and to telecommunicate the data, in real-time, to the Traffic Management Center. The second part consisting of a geodatabase, in a GIS-T environment is to store, analyze and display the data obtained from the mobile system. This GIS-T is part of the municipal *Database, Modelling and Analysis Platform*, along with a traffic micro-simulation tool and a set of environmental impact models. While the third part is a WebGIS application designed to display occurrences on the traffic network, in real-time. This belongs to the *Public* module of the *Applications for Municipalities* subsystem.

The foregoing produces the city map in figure 4 which shows suggested locations for rescue facilities such as mobile clinics and ambulance positions, and locations for positioning booths for wireless phones.

Table 1: The Records of Auto Crash in Recent Past and the Location of Incidence

Locations	Incidents	Fatal	Major Causal factors
UNAAB road	8	2	Poor road condition, recklessness
Camp-Mechanic village	6	1	Human Error
Odo-Eran junction/Gbonogun	6	1	Human Error Brake failure
Asero estate to Asero garage	6	1	Carelessness
Fajol Obantoko	4	0	recklessness
Iyana-Mortuary	5	1	Human Error
NNPC-junction	6	0	Obstruction/Human error
Post office - Ibara	4	0	Poor road condition

Table 2: Major accident prone areas

Locations	Incidents
UNAAB road by Isolu	8
Gbonogun junction	6
Asero Estate junction	6
NNPC junction	6
Camp-Mechanic village	6

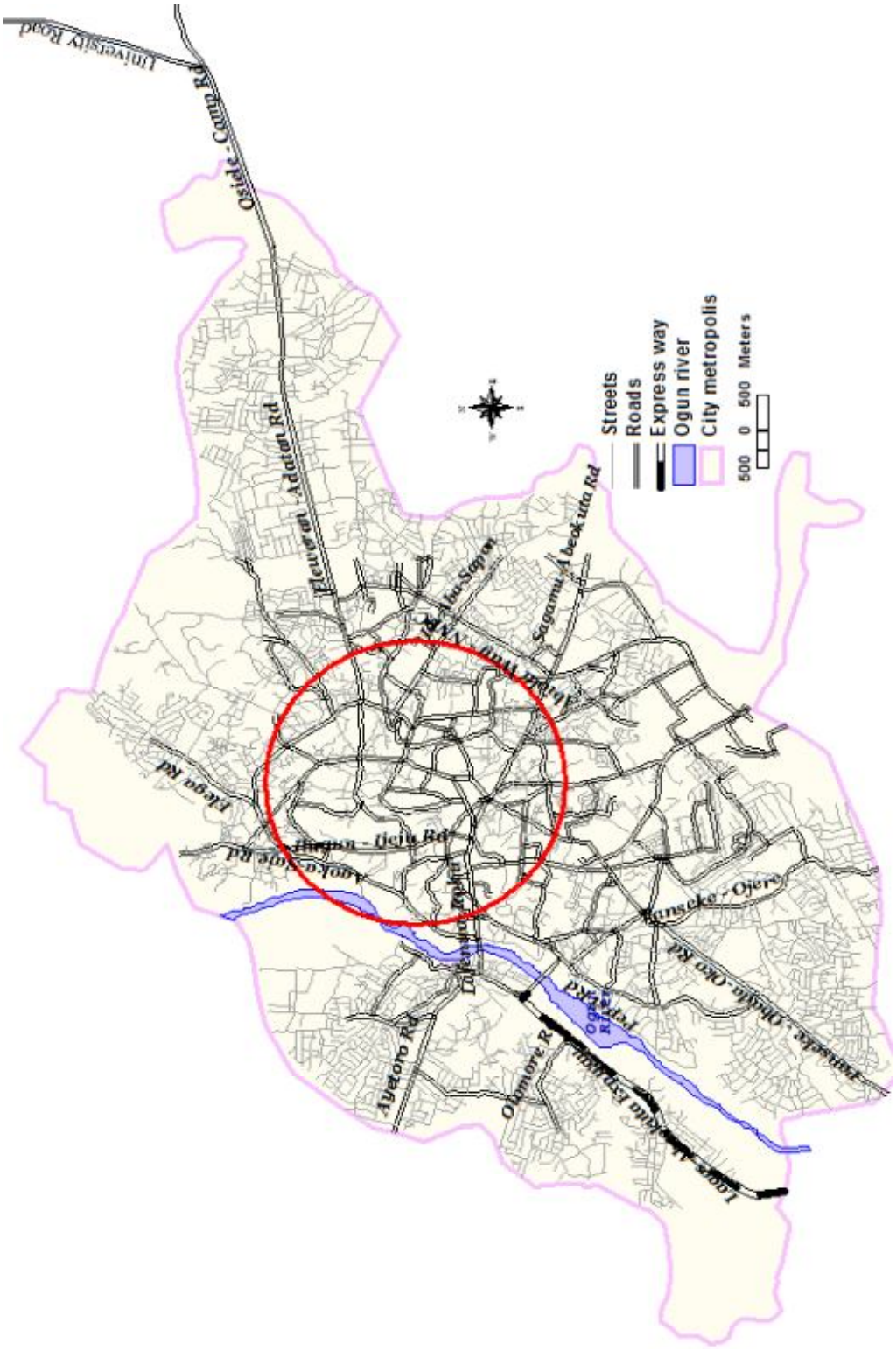


Fig. 1: The road network of Abeokuta city.

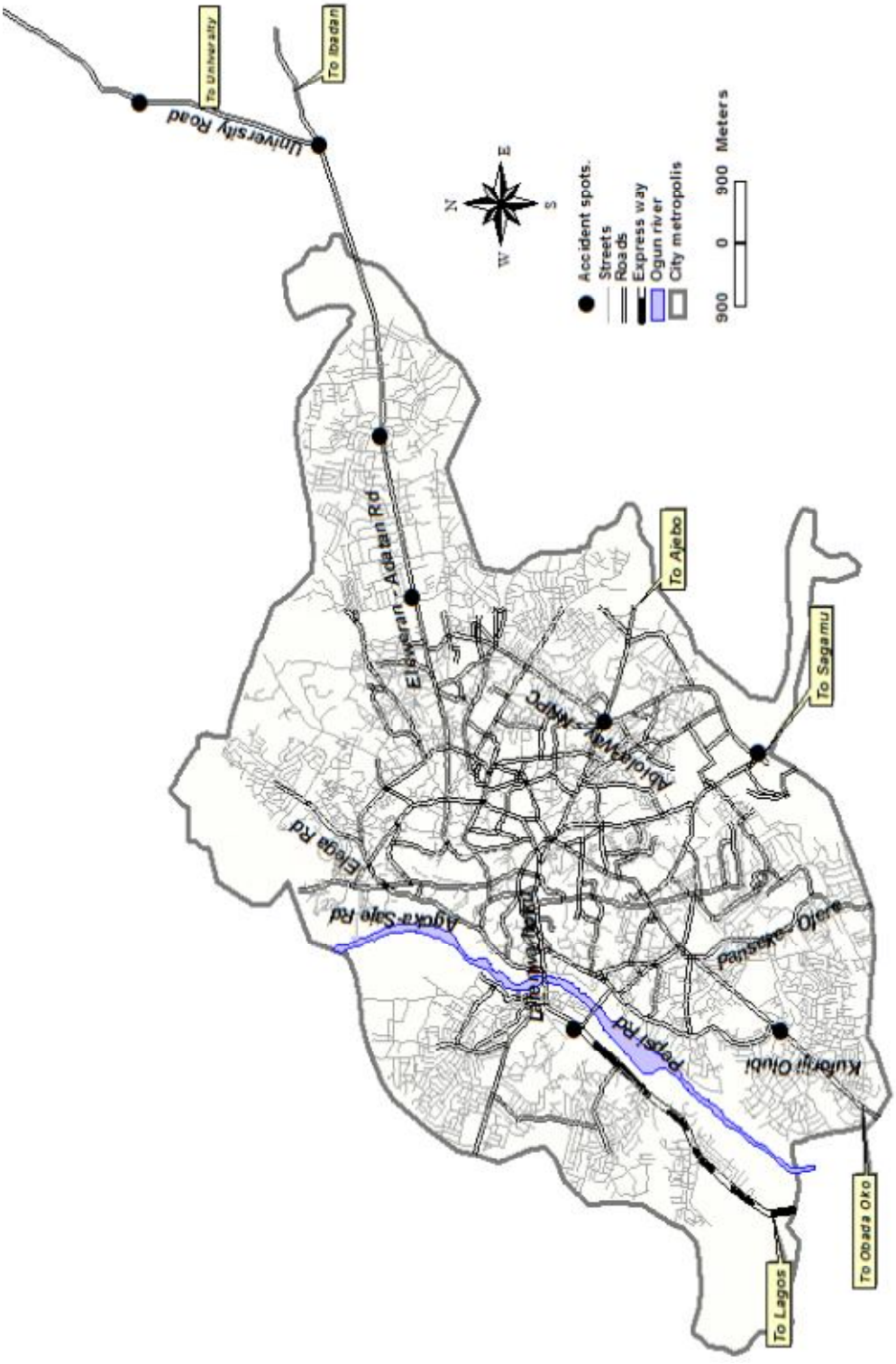


Fig. 2 Accident prone locations within Abeokuta city

Real world

Accident Data acquisition, through PDAs and eye witnesses

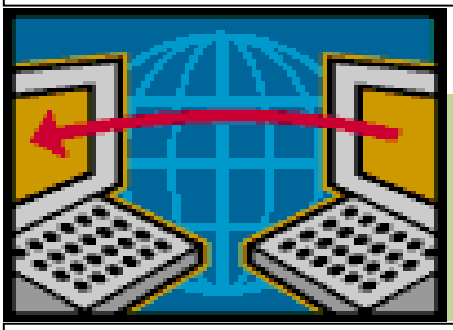
Communications using wireless phones in booths

1 Mobile segment of the 3GR system

Accident database collation, spatial analysis, routing analysis for ambulances

GPS equipped Accident probe vehicles, guided by route analysis and PDA Bluetooth at accident scenes

2 GIS Modeling and Analysis segment of the 3GR system



Communication through the web-GIS to provide warning for other road users about deadly spots and causes of accidents

3 Public awareness segment of the 3GR system

Fig. 4: Proposed model for the 3GR in accident reporting and response model

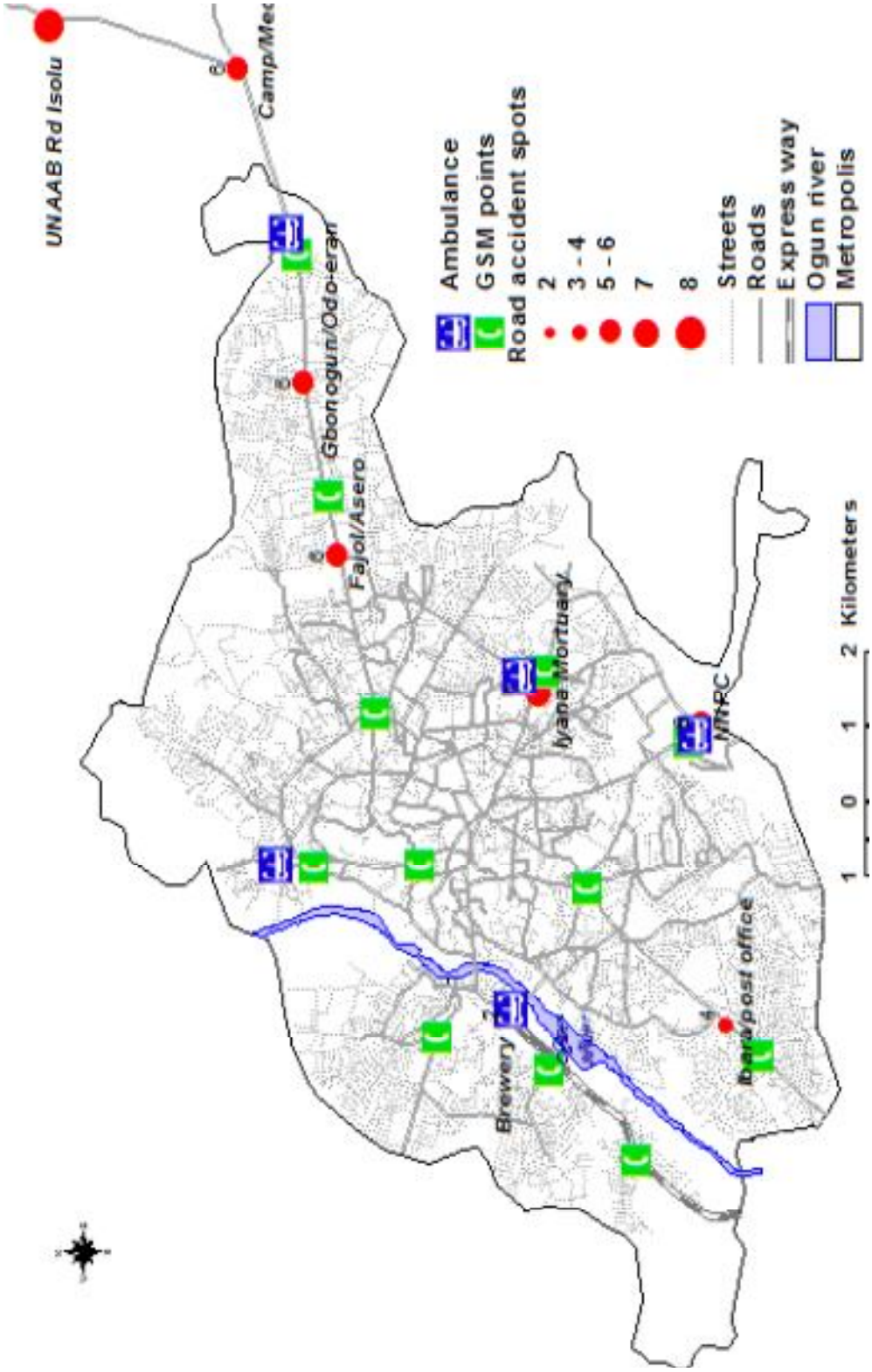


Fig 5: Map showing location of GSM for public use and location of Ambulance

CONCLUSION

This paper gives overview of how accident management system could be implemented in near real-time to reduce loss of lives and increase effective prevention of more accidents occurrence. System's analysis could be more refined by adding more key factors that determine accident hot spots, shortest rescue routes and other possible solutions. The system is also good in identifying causes of accidents such as poor road condition absence of and non compliance to road signs along a routes. It is also good in providing a continuous accurate stream of information to the drivers and other road users through information dissemination via WebGIS. The model provides sufficient advanced warning that allow drivers to make decisions about their route choices and associated lane or direction changes.

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