Potentials of GNSS and GSM Technology in Road Traffic and Speed Management in Kenya

*Charles Kigen[1] and Zedekiah Onyando[2]

[1]Moi University Department of Natural Resources P. O. Box 3900-30100 Eldoret

[2]Department of Biology, Masinde Muliro University of Science and Technology P. O. Box 190 – 50100 Kakamega

Email: charleskigen@gmail.com and zedekiah.onyando@gmail.com

*Corresponding author

Acronyms / Abbreviations

GNSS	Global Satellite Navigation System
GPS	Global Positioning System
GSM	Global System for Mobile
MOA	Matatu Owners Association
NTSA	National Transport and Safety Authority
PSV	Public Service Vehicles
RRW	Random Road Watch
SACCO	Savings and Credit Co-operative Society
SIM	Subscriber Identity Module

Table of Contents

Abstract

Road safety is a concern worldwide and more so in African countries including Kenya due to a number of factors comprising weak enforcement of road traffic regulations, inadequate road safety policy and technology application. Kenya's regulations on speed is enforced through application of speed limiters in public vehicles and police checks using mobile speed cameras mounted at strategic sections of the roads. However, these measures have many shortcomings that do not deter motorist from speeding above the set limits. This paper proposes the use of Global Satellite Navigation System (GNSS) and Global System for Mobile (GSM) communication technologies for better road traffic safety management and speed enforcement. The application of GNSS and GSM technology amongst other benefits are independence from the vehicle systems, they are cheap, they function round the clock, require personnel at command and monitoring centres only and the information collected can easily be shared by all road and transport industry stakeholders. Additionally, road traffic and safety information can be updated from the command center and motorist advised to take appropriate action. Further, the data collected can be analysed and used in transport industry taxation and policy formulation leading to informed decision making resulting in sustainable management of road traffic and safety. The GNSS and GSM technologies have high potentials in speed enforcement and traffic management and its application should be explored in Kenya.

Key words: road traffic, GNSS, GSM, safety, NTSA

Introduction

Road safety and traffic management is a concern in both developed and developing countries where different mechanisms have been put in place to address the issue. The human suffering and economic losses caused by road traffic accidents necessitated regulation of traffic speed through imposition of speed limits, erection of bumps and rumble strips, use of vehicle speed limiters and construction of road by-passes. The imposed speed limits are meant to safeguard human life and ensure smooth flow of road traffic. Road traffic and speed control measures around the world are different and are more advanced in the developed and developing countries.

The measures applied in the developing countries such as Kenya are not effective enough to enforce the statutory speed limits due to a number of factors including weak enforcement of regulations, corruption among law enforcers, tampering with speed limiters and lack of enough personnel to mount and man the speed cameras. The statistics collected by the NTSA (National Transport and Safety Authority) indicate that the measures put in place are not as effective as intended since the trend in road traffic deaths has not improved a situation that can be changed by use of GNSS and GSM.

The application of GNSS and GSM technology in road traffic and speed management has a great potential of improving the current situation in Kenya. There are numerous benefits associated with this technology among them being elimination of speed limiter manipulation, reduction in corruption cases, it is cost effective, road situation information can be sent to motorists and the government will be in a position to collect taxes from the PSV (Public Service Vehicles) investors. Additionally, the insurance industry will easily access vehicle driver behaviour, vehicle condition and vehicle speed information.

Road traffic speed and safety management

Road traffic speed forms the central focus of road safety management. Various road reports and research materials have established that there is a strong relationship between speed and both the number of crashes and the severity. An effective enforcement of road traffic speed is the solution to the reduction in the number of accidents, injuries and severities and associated number of deaths. The speed enforcement requires multi pronged approaches which complement each other. The best combination of measures is determined by the prevailing circumstances which are different with countries depending regulations put in place. Wegman & Aarts (2006) proposed an integrated, systematic and stepwise approach to speed management by setting the speed limits on particular sections of the roads, informing

the public about the speed limits through use of consistent road signage, use of engineering measures such as speed bumps and rumble strips at particular sections of the roads like near schools and hospitals and police enforcement to control the traffic speed. An integrated road safety system specifies possible road safety measures and how different road safety measures comprising road design, setting speed limits are applicable. The speed enforcements relations to one another in a logical and order of application in particular situations described clearly is equally important.

Research has established that different measures can be effective in controlling speed. Mountain (2004) compared speed and safety effects of engineering measures and enforcement by fixed speed cameras. Using a study design that controlled trends in crashes, regression-to-the mean effects and changes in traffic volume, they found that engineering schemes including vertical deflections (speed bumps, cushions) prevented 44% of personal injury crashes. Moreover, they found that engineering schemes with horizontal features resulted in a decrease of 29% in personal injury crashes and speed cameras reduced the personal injury crashes by 22%. The idea behind an integrated speed management approach is to seek for the best possible synergies between the various individual measures as isolated measures will have a durable impact.

Effective speed enforcement is dependent on the regulations put in place, the infrastructure in place and the level of apprehension of offenders among others. These factors are different with countries and is generally accepted that the levels of speed limits enforcement are varied. The critical factor in speed enforcement is that it prevents motorists from speeding a term described as general deterrence. This risk of apprehension can only be increased by enforcement of speeding measures on busy roads, at most likely time of over-speeding, over a long time, creating public awareness and police checks conducted randomly.

Road traffic speed enforcement and their efficiency

a) Stationary enforcement

Stationary enforcement is also known as physical policing and involves checking of drivers alongside the roads and the offenders identified. This method makes use of manned surveillance and apprehension units where offenders are stopped. The advantages of this method are the speed violator is given immediate feedback and increases the apprehension of other motorists. However, it has drawbacks which comprise of high labour demand, has a small chance of apprehension, is applicable only during certain times and it might not be

possible to identify traffic speed limit violators. Zaidel (2001) criticizes conventional manpower-using methods of police enforcement of speed as being selective, sporadic, inconsistent, and in the end, being rather expensive and ineffective. A specific example of stationary enforcement is the Network-Wide Random Enforcement or Random Road Watch (RRW). This technique randomly schedules enforcement with the aim of realizing long-term widespread coverage of a road network. Newstead et al., (2001) evaluated an RRW programme in Australia and established that it reduced fatal crashes by 31% and had little effect on less severe crashes. The effects became larger as time increased after the programme introduction.

b) Speed cameras

A second method of speed detection is use of speed cameras to detect offenders and send them a fine or notification by mail. The speed cameras can be automated or manned in a visible or hidden location, stationary or mobile where it can be used in several locations. Speed cameras can be used fulltime at fixed locations (fixed cameras) or can be rotated over different locations (mobile cameras). This technique is appropriate in section of the roads where motorists are most like to over-speed and when the volume of road traffic is high to make physical policing challenging. Elvik &Vaa (2004) estimated that automatic camera enforcement results in a crash reduction of 15 to 20%.

The effectiveness of the speed control methods depend on many factors among them being the enforcement effort, the public awareness level and the initial road safety level. Elvik & Vaa (2004) presented findings of a number of studies of the effectiveness of different speed camera techniques (table 1).The research was done on rural, urban and highways using different methods. The effect on road crashes reduction ranged from 11% to a high of 33 % in New Zealand highways and rural roads in the United Kingdom respectively.

Table 1: Effectiveness of speed camera techniques (SafetyNet, 2009)

Road type	**Method type**	**Effect on crashes**	**Study and country**
Urban	Fixed speed cameras	Minus 28%, all crashes	Elvik & Vaa (2004) Meta-analysis worldwide
Rural	Fixed speed cameras	Minus 18%, all crashes(*corrected estimate, not mentioned in original	Elvik & Vaa (2004) Meta-analysis

		report)	worldwide
Urban	Fixed speed cameras	Minus 22%, personal injury collisions	Gains et al., (2005) UK
Urban	Mobile speed cameras	Minus 22%, personal injury collisions	Gains et al., (2005) UK
Rural	Fixed speed cameras	Minus 33%, personal injury collisions	Gains et al., (2005) UK
Rural	Mobile speed cameras	Minus15%, personal injury collisions	Gains et al., (2005) UK
Rural	Fixed speed cameras	Minus 20%, injury crashes	Elvik (1997) Norway
Rural	Mobile hidden speed cameras	Minus 21%, injury crashes involving a motor vehicle	Goldenbeld & Van Schagen (2006) Netherlands
Highways	Mobile speed cameras	Minus 25%, daytime unsafe speed related crashes	Chen (2000) Canada
Highways	Hidden speed cameras (*extra effect above visible cameras)	Minus 11%, all crashes	Keall et al. , (2001) New Zealand

The effectiveness of the method used depends on the intended objectives. The use of visible cameras with signage is best to warn motorist approaching intersection or a school or a hospital to slow down Gains (2004). Once passed the section with imposed speed limits, drivers are tempted to speed up. The use of hidden cameras with warning signs on the other hand make road traffic speed checks less predictable and drivers keep to speed limit Keal et al., (2001)since they do not know which section of the road are the cameras mounted.

c) Average speed control

The Average speed control method is also called ‘section control’ or ‘point-to-point’ control. It works by measuring average speed at intervals in the enforcement section. The Average speed control systems measure the average speed over a road section. The vehicle is identified when entering the enforcement section, and again when leaving it and the average speed calculated between the two points. The chance of being caught is 100% as the system works on a 24 hr basis in the seven days of the week. This speed control method is still fairly new, not yet widely applied and not yet evaluated on a substantial scale. In Austria, Stefan

(2006) evaluated the use of average speed control on an 80 km/h motorway which after two years of operation reduced injury crashes by 33.3% and fatal and serious injuries by 48.8%.

Road traffic and Safety management in Kenya

The Kenyan government is concerned about the road traffic safety situation. The road traffic accidents (RTAs) have impacts on all spheres of life ranging from health, social and to economic aspects of the affected persons and the country at large. The road traffic accidents deaths and serious injuries statistics shows a worrying trend between 2004 – 2014 (figure 1). During the 10 years more than 200,000 road traffic casualties were recorded with more than 30,991 people having lost their lives while 82,321 were seriously injured with economic losses of more than Ksh. 310 billion in 2014 (Cheseret and Otieno, 2016).

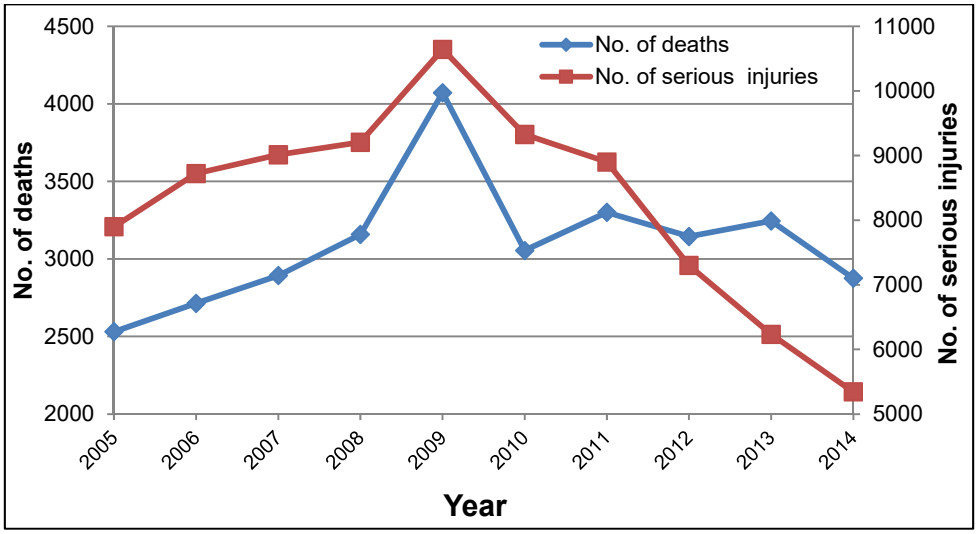

Figure 1: The road traffic deaths and serious injuries from 2005 - 2014

The Kenya Traffic Act (1953) (GoK, 2014) has been revised several times with the most recent in 2014 on Chapter 403 that consolidated the law relating to the traffic on the road. Part V section 42 of the Act addresses speed of motor vehicles and (1) states that "No person shall drive, or, being the owner or person in charge of a vehicle, cause or permit any other person to drive, a vehicle on a road at a speed greater than such speed as may be prescribed as the maximum speed for that class of vehicle", while (3) states that "No person shall drive, or, being the owner or person in charge of a vehicle, cause or permit any other person to drive, any vehicle at a speed exceeding fifty kilometers per hour or any road within the boundaries of any trading centre, township, municipality or city: Provided that the

highway authority shall erect and maintain traffic signs as prescribed so as plainly to indicate to drivers entering or leaving such roads or areas where the fifty kilometer per hour speed limit restriction begins and ends". It further give the Cabinet Secretary powers to impose lower speed limits as considered necessary by reason of repairs, reconstruction, hazards or damage to the road for public safety or prevent damage to the road.

The penalties prescribed in section 43 of the Act in relation to failure to comply with section 42 are a fine not exceeding one hundred thousand Kenya shillings, suspension of driving license for one month and three months for the first and second convictions respectively. Further, the Act on the witness states that, "A person charged with the offence of driving a motor vehicle of any class or description on a road at a speed greater than the maximum speed allowed shall not be liable to be convicted solely on the evidence of one witness to the effect that in the opinion of the witness the person charged was driving the vehicle at such greater speed".

Other traffic speed and road safety management are captured in NTSA documents. An example is the National Transport and Safety Authority 2014-2018 draft strategic plan that has included objectives of reduction of yearly road traffic deaths from 3000 to below 2000 people and reduce number of road crash serious injuries per annum. It also has a strategic objective of establishing and implementing efficient and effective road traffic regulations enforcement mechanism through among others acquisition and installation of traffic speed cameras.

Other players in road traffic and speed management

Other stakeholders in Kenya's road traffic and safety management include the international community such as World Health Organization which funded Bloomberg Philanthropies Global Safety Programme which focused on promoting helmet-wearing among the drivers and passengers of motorcycle taxis, commonly known as "boda-boda", as well as on preventing speeding on the main highways. The Matatu Owners Association (MOA) has also been actively involved in the road traffic and safety management. The organization initiated a road safety awareness campaign dubbed "Arrive Alive Program" or "Safiri Salama" in 2004 supported by a local insurance company. The focus of the program was on the owners of the public service vehicles to keep their vehicles road worthy and provide favourable working conditions for the driver and crew.

Challenges of road traffic and safety management

In the past, the transport industry stakeholders blamed the state of poor roads in Kenya as the major cause of accidents. But with the improvement of road infrastructure and establishment of road traffic management legal and institutional frameworks serous road accidents continue to be reported. The Traffic department of Kenya Police blames careless driving, incompetence, over speeding, drunk driving and a myriad of other vices that render them prone to causing accidents.

The Traffic Police on the other hand, while charged with enforcing the Traffic Act, have on numerous occasions been blamed for promoting corruption. While the Kenyan Police was reported as the most corrupt institution in Kenya by the East African Bribery Index Report, it's the traffic arm of this organization that tops the list (TIK, 2011). Asingo (2004) explained that laxity by traffic police to enforce traffic rules is due to massive corruption and that the traffic police are also ill equipped to enforce some of the traffic rules and work under extremely difficult conditions. Although there are quite a number of road safety intervention measures in place, a major challenge is the lack of political concern and priority to effect the necessary changes in the road transport system (Khayesi, 1999).

The biggest challenge in traffic speed management in Kenya especially in the PSV industry is the manipulation of speed limiters. Many cases of interference with speed limiters have been reported and the offenders prosecuted. The manipulation is done in such a way that the concerned vehicle speedometer does not go beyond 80km/hr but in actual sense the PSV is speeding well above the limits. Other cases of speed limit non-compliance include malfunctioning speed limiters or switching the speed limiters on and off as desired by the vehicle drivers. This challenges makes road traffic speed enforcement a challenging task which can be improved by use of GNSS and GSM based traffic speed monitoring.

Application of GNSS and GSM Technology

Successful enforcement of road traffic regulations is key to ensuring safe road use by all. The realization by drivers that the chances of apprehension are high contributes significantly in deterring speeding beyond the recommended limits. The application of GNSS and GSM technology provides a good opportunity of speed limit enforcement in road traffic speed and safety management. This technology makes use of GNSS to provide location, speed and direction of movement data and GSM for sending data transmission to a remote server. The data transmission requires use of SIM (Subscriber Identity Module) unique for each vehicle. The received data is then analysed using computers and output made available

to the transport industry stakeholders. The system should be programmed such that it the registered vehicle speed is beyond the regulatory limits, initiate an automatic message generation and send to GPS (Global Positioning System) unit on board the vehicle, NTSA, traffic police, the insurance company and the vehicle owner and the PSV Savings and Credit Co-operative Society (SACCO).

GNSS and GSM

The Global Navigation Satellite System (GNSS) is a constellation of satellites providing signals from space transmitting positioning and timing data at global level thus giving the location coordinates of a vehicle fitted with a GPS tracking unit. The GPS units are independent of vehicle systems either passive or active with the former performing the function of receiving and recording satellite signals only. The active GPS units apart from receiving and storing the satellite signal also transmit the same data to a remote server through GSM (Global System for Mobile Communication) technology. Further, the same GSM can receive instructions to manipulate the vehicle as desired if it is connected to the vehicle control systems. The data sent and stored in the remote server can be retrieved through connection with a computer or other devices for analysis.

Principles of the System Operation

The proposed GNSS and GSM system layout figure 2 has the source of the signal, the signal reception and transmission, the database and processing and the output. The GNSS satellite transmission pattern sends at least four signals to all locations on earth at all times. The signal strength depends on the level of obstruction from clouds, tree cover and buildings. The GPS unit has to receive signals from at least three satellites to give coordinates of vehicle location point on the earth's surface. A warning message normally accompanies a weak signal that can be strengthened by using antennae if the GPS unit is inside a vehicle. The location information is given in terms of longitude, latitude and altitude at any given time (Leick, 2003) thus allowing calculation of vehicle speed or time spent at a particular point. This information is recorded automatically in table 2 format in the GPS unit and sent to the external server through GSM where it can be retrieved.

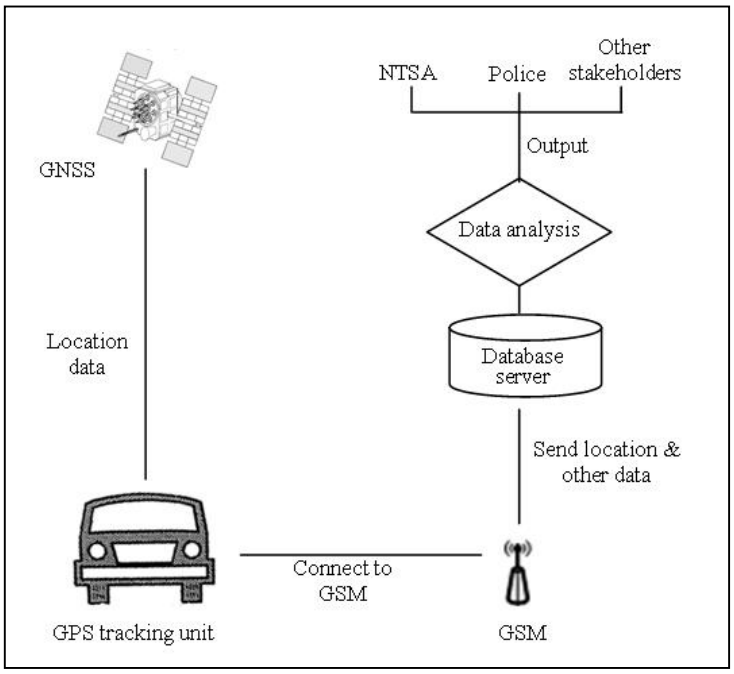

Figure 2: The proposed GNSS and GSM technology (modified from Hasan et al., 2009)

Table 2: Format of information collected and sent by a GPS unit a server

SIM card ID	Latitude	Longitude	Altitude	Speed	Time

A computer connected to the server then processes the speed information received and if it exceeds the set road traffic speed limits it automatically generates a message and send to NTSA, Traffic Police and other stakeholders comprising of vehicle owner and the insurance company as illustrated in figure 2. Additionally useful information can be derived from the data received and include the towns of operations of PSV vehicles and the total distance covered table 3 enabling estimation of gross income which Kenya Revenue Authority is interested for taxation purposes. Other important information connected to road safety is vehicle maintenance that is possible to capture in the same system. The GPS unit will be used to send and update the vehicle maintenance record on the repairs done and by whom.

Table 3: Vehicle data capture and analysis output

SIM card ID	Name of owner	ID/ Passport	Owner PIN No.	Owner Contact	Ve. Plate Number	Engine No.	Chassis No.	Name of SACCO	Licensed Rout
Insurance company									
Date	Time	Lat	Long	Alt	Speed				
Distance covered	Monthly		Estimated income	Monthly					
	Yearly			Yearly					
	Cumulative			Cumulative					

Table 4 captures the information of vehicle maintenance data including the mechanic′s national identity card number (ID), Personal Identification Numbers (PINs), the cost of both the mechanic and spare parts and PIN number of shop where spare parts are bought and or repairs done.

Table 4: Vehicle maintenance information

Mechanic ID	Mechanic PIN	Repairs done	Cost of labour	Cost of spares	Vehicle Spares shop PIN
Total Cost	Monthly				
	Yearly				
	Cumulative				

Discussion

Road traffic and speed management in Kenya faces many challenges and can be significantly improved by the adoption of the GNSS and GSM technology. The world over, there is a shift to adoption of spatial technological applications to solve various challenges of management including road traffic. Many researchers have proposed the adoption of the same technology though with systems connected to the vehicle controls. The difference with what this system envisions is that the GPS tracking unit will be independence from vehicular systems. The vehicle speed will be solely based on the GNSS signals and transmitted to an external server through the GSM technology. The only requirement is that the GPS tracking unit has to be on board the vehicle and switched on at all times when the vehicle is operational. This system requires use of a SIM card for data transmission to the external server. The issued SIM card will contain the vehicle registration and chassis numbers and other details such as insurance information, details of vehicle owner comprising name, national identity card number, physical address and the contacts. This information eases vehicle management especially when the authorities require the attention of the vehicle owner.

This proposed system has various advantages the first being it deters over-speeding and elimination of vehicle speed limiter manipulation. The GPS tracking unit is independent of vehicle control systems and the chances of controlling vehicle speed recording are drastically reduced as it done by GPS unit. Unlike the current road traffic speed management measures, the proposed system works round the clock thereby monitoring road traffic speed all the time regardless of the weather and location. This will significantly reduce the requirements of more equipment and road traffic enforcement personnel on the road allowing the limited resources to be used elsewhere. Though a monitoring and command center will be established, it will require a limited number of skilled personnel for routine maintenance resulting in cost reduction. Many aspects of the proposed system already exist and some are even available for use without any extra cost such as GSM networks and google maps. Also, the contact between the road traffic regulations enforcers and the offender in relation to vehicle speed will be non-existent a situation that will reduce corruption on the roads.

Moreover, the road traffic information situation on particular sections of the road can be sent through the system to vehicles within that vicinity or heading there. At present, the motorists tend to drive blindly in that they do not know the status of traffic movement or road ahead. Many motorists in most cases are surprised by accidents or closure of roads ahead of them and if information on the road situation ahead is available on time, motorists will take

appropriate action. In Kenya for example, traffic accidents and road closures due to demonstrations have caught motorists unawares which sometimes cause serious traffic jam. Such cases were reported in the coastal region along Mombasa-Nairobi highway where motorists and travelers were stranded for nineteen hours (Nyassy & Ahmed, 2015) and for four hours along the Mai Mahiu – Narok road (Murage, 2016).

Other information that the government can benefit from the system is PSV taxation and generation of useful data that can inform policy formulation. The proposed system apart from recording vehicle speed can estimate the distance covered by the PSV vehicles allowing the government to estimate the gross income generated. Equally relevant safety vehicle management information is the maintenance record which can be sent to the database server using the GPS unit. The information contains the cost of labour and spare parts and the PINs of the concerned individuals and/companies. This information becomes useful in taxation of companies and individuals involved in PSV business consequently increasing government sources of revenue. The insurance industry too will benefit enormously due to ease of availability of vehicle condition data, the vehicle driver behaviour and the vehicle speed history. Regardless of the benefits of the system, its development, rolling out and operations largely depend on the stakeholders who need to come together and agree on way forward.

Conclusion and Recommendations

The efforts made by the government of Kenya to manage road traffic speed and safety are commendable. They have attained a certain level of success though more effort is needed to bring down the number of road traffic accident deaths, injuries and damage to property. The benefits of adopting GNSS and GSM technology are beneficial to warrant its application in the Kenyan transport industry management. This paper therefore recommends use of GNSS and GSM technology in road traffic and safety management in Kenya.

Reference

Asingo, O. P. (2004). *The Institutional and Organizational Structure of Public Road Transport in Kenya.* Discussion Paper No. 050/2004. Institute of Policy Analysis and Research, Nairobi, Kenya.

Cheseret D. & Otieno D. (Jan 2016). Road Traffic Deaths – Newsplex. *Daily Nation*. Retrieved from http://www.nation.co.ke

Gains, A., Heydecker, B., Shrewsbury, J. & Robertson, S. (2004). *The national safety camera programme.* Three-year evaluation report. PA Consulting Group, London.

Government of Kenya (2014). Revised Traffic Act Cap 403. Nairobi, Government Printer.

Hasan, K. S., Rahman, M., Haque, A. L., Rahman, M. A., Rahman T. & Rasheed, M. M. (2009). Cost effective GPS-GPRS based object tracking system. Proceedings of the International Multi Conference of Engineers and Computer Scientists, Vol I IMECS, March 18 - 20, 2009, Hong Kong.

Khayesi, M. (1997). Analysis of Terms and Condition of Work in Matatu Industry in Kenya: A Study of Nairobi, Thika and Ruiru Towns. Research report submitted to the Institute for Development Studies, University of Nairobi.

Leick, A. (2003). *GPS Satellite Surveying* (3rd ed.). New York: John Wiley and Sons.

Mountain, L., Hirst, W. and Maher, M. (2004). A detailed evaluation of the impact of speed cameras on safety. *Traffic Engineering and Control*, 45, 280-287.

Murage, G. (2016). Protesters block Mai Mahiu-Narok road after speeding bus kills cows. *The Star*. Retrieved from http://www.the-star.co.ke

Newstead, S. V., Cameron, M. H. & Leggett, L. M. W. (2001). The crash reduction effectiveness of a network-wide traffic police deployment system. *Accident Analysis and Prevention*, 33(3), 393-406.

Nyassy D. T. and Ahmed M. (Nov 2015). Travellers' tale of 19-hour agony in Mombasa-Nairobi highway traffic gridlock. *Daily Nation*. Retrieved from http://www.nation.co.ke

SafetyNet. (2009). Speed Enforcement, retrieved on 4th Jan 2016 from http://www.ec.earopa.eu

Stefan, C. (2006). *Section control – automatic speed enforcement in the Kaisermühlen tunnel (Vienna, A22 Motorway).* Austrian Road Safety Board (KvF), Vienna.

Transparency International-Kenya. (2011). *The East African bribery index 2011 report*. Technical report, Transparency International-Kenya

Wegman, F. & Aarts, L. (eds) (2006). *Advancing sustainable safety*. SWOV Institute for Road Safety Research, Leidschendam. Retrieved from http://www.sustainablesafety.nl

Zaidel, D. (2000). *Total Speeding Management (TSM) - a different way for Controlling Speeding,* paper presented at the 13th ICTCT-workshop, ICTCT, Corfu, Greece.

Main Author Boidata

Mr. Charles Kigen Msc, Bsc

Environment Lecturer Moi University, Eldoret Kenya

Mr. Charles Kigen is a registered and licensed Environmental Impact Assessment and Audit Lead Expert with National Environment Authority in Kenya and is actively involved in environment and mapping consultancy. He is also a lecturer of Environment in Moi University Kenya teaching among other courses risk analysis and environmental management, geographical information system and environmental impact assessment and audit.

Over the last five years he has been involved in numerous environment, health and safety issues as a researcher in the university and consultant with impressive accomplishments.