FACTORS THAT INFLUENCE THE INCIDENCES OF ROAD ACCIDENTS IN KENYA: A SURVEY OF BLACK SPOTS ALONG MOMBASA-MALABA ROAD

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ABSTRACT

High morbidity, disability, mortality and economic cost and burden arising out of road traffic accidents (RTAs) are a major public concern globally and more specifically to growing economy as Kenya. The disproportionate 80 percent of all RTAs with unusually high fatality of 24.1 percent in developing countries points to a systematic failure in the management of road construction standards and safety performance and measures in Road Transport Systems. Annually Kenya experiences one of the highest fatality rates in the world at 34.4 percent that brings economic cost to 11 percent of GDP. Additionally there are over 80 accidents prone sections (black spots) on a 788 kilometres highway. This situation draws attention and calls for a change to minimise the damage. The influence of road geometrical variables on road accidents at black spots remains unclear at present. The existing road safety information is not based on scientific findings and is therefore subjective and not reliable. The aim of this study was to unravel the causes of road accidents and influence of road design and standards on incidence of road accidents and road safety with the sole objective of finding a lasting solution to road carnage in Kenya. Descriptive statistics was employed to describe factors that causes occurrence of incidence of RTA sin. Kenya Road networks with focus to black spots along Mombasa–Malaba road.The study found that that incidence of fatal road traffic accidents frequently occur mainly in the designated black spots in Kenya. It was also established that the nature of the incidence of accidents that occur within the black spot, morbidity affected the victims the most. The study established that road surface conditions greatly influence incidence of road accidents in black spots. In addition, the study established that, to a moderate extent road conditions, vision, speeding, bad breaks or tyres, and trees along the roads correlated with the factors that influence incidence of traffic road accidents. Primarily the study concluded that driving behaviours such as speeding were the major reasons associated with incidence of road traffic accident. Secondly, the study established that drivers' personal characteristics influence incidence of road accidents. Thirdly, the study determined that road surface conditions influence incidence of road traffic accidents in black spots along Mombasa-Malaba road. The study recommended that Stakeholders in the transport and communication sector should establish a well-coordinated and funded road safety research and development programme(s) in Kenya to provide the information needed for necessary decision-making process in road safety measures. This will assist in coming up with essential stop gap measures and road improvement/rehabilitation to eliminate or reduce incidence of road traffic accidents in designated black spots in Kenya as well as other major road network.

Key Words: *road accidents, Kenya, black spots, Mombasa-Malaba road*

INTRODUCTION

Globally Road Traffic Accidents (RTAs) are claiming about 1.2 million lives and nearly 50 million injuries annually (Manyara, 2013) and mortality, morbidity, disabilities and economic costs and burden arising out of them make RTAs a major public health concern that attracted the United Nations' (UN) attention. In Kenya, annually, about three thousand (3000) people die in road crashes (Ogendi*et al*; 2013) majority of whom are between 15-44 years of age; an economically productive group of our population, in spite of the government's road safety measures put in place (Odera*et al.* 2013, Muchene 2013 &Asingo&Mitullah, 2013).In fact, there are about eighty (80) accident prone sections, referred to as black spots, on the key highway of our paved road network (Odera*et al.* 2013).

An estimated 13 million deaths (fatalities) and about 20-50 injuries (morbidity) and disabilities occur annually worldwide through road accidents (WHO, 2013), accounting for 23 percent of all injury deaths globally in the year 2012 (Muchene, 2013). The problem of road accidents apparently has not yet grabbed the attention of governments to marshal the will to arrest situation of these high mortality and morbidity with the attendant economic costs and burden approximating to 1 to 2 percent of annual Gross Net Product (GNP) in the developing countries (Ogendi*et al.* 2013). Surprisingly, Kenya lost about U.S. dollar 500million which translated to 11percent of its GNP in the year 2013, due to road accidents (Manyara, 2013&Muchene, 2013).

Road design has been viewed as one of the main causes of road accident. According to data provided by the Federal Motor Carrier Safety Administration (FMCSA), there are generally over 5,000,000 police-reported accidents each year. While these accidents can occur for a wide variety of reasons, each year some of the accidents are the result of improperly maintained or poorly designed roads (Odera et al. 2013). Issues like narrow roads, steep curves, slope of the roads, blind corners, improper illumination, improper traffic junctions (without signals), and lack of speed signboards are found to be the major road design issues that causes accidents. At some places there are even parking lots on the roadside becoming reasons for road accidents (Mitullah, 2004).

There are about over 80 accident prone sections (black spots) on Mombasa-Malaba Highway, with Mombasa-Nairobi trunk having 28 black spots which translate to 35 percent (Ruyters, 1994) and other paved road networks also have their share of the problem both in rural and urban locations they traverse (Jacobs 1976 &Ruyters*et al* 2004). This disproportionate occurrence of road traffic crashes and fatalities at particular black spots is a major cause of concern in academia, public and Government circles (Ogendi*et al*, 2013 &Mitullah, 2004) that needs empirical research data collection and analysis to fix in Kenya and the rest of developing countries (Manyara 2013 & Jacobs 1976).

STATEMENT OF THE PROBLEM

The influence of road design factors on road accidents at black spots remains unclear at present. The existing road safety information is not based on scientific findings and is therefore subjective and not reliable. High morbidity, disability, mortality and economic costs and burden arising out of road accidents are a major public health concern globally and more specifically to a growing economy as Kenya. The disproportionate 80 percent of all road traffic accidents, with unusually high fatality rate of 24.1 percent in developing countries points to a systematic failure in the management of road construction standards and safety programmes or measures in road transport systems. The circumstances or “causes” of any one single accident on a roadway are multi-factorial, involving human, vehicular, environment and road design variables. It is unclear which road geometric variables, separately or in combination, cause accidents at the black spots and/or correlate separately or in combination or interaction with other independent variables to predispose accidents on Kenyan road network. The influence of road design and standards on accidents and road safety therefore needs to be investigated.

GENERAL OBJECTIVE

The aim of this study is to investigate the influence of road design on the incidences of road accidents on Kenyan highways.

SPECIFIC OBJECTIVES

1. To describe the incidences of road accidents on Kenyan highways.
2. To describe factors that influences the incidences of road accidents in Kenya.
3. To establish impact of road design on incidences of road accidents in Kenya.

EMPIRICAL REVIEW

Road Accidents

Many researchers have tried to find out the causes of traffic road accidents in countries the world over. The research reports compiled on road traffic accidents forms the base of literature on road safety studies. Some of these researches on road accidents are carried out by government agencies, international organizations such as the UN, individual scholars and researchers. This section reviews the already available information on road traffic accidents as the causes of road safety problems from an environmental and governance point of view.

Verberckt (1987) suggests that environmental issues do not influence modal choice in passenger transport. He identifies speed, frequency of service, costs, comfort and accessibility to a place as the major determinants of modal choice in passenger transport. He further suggests that railway transport is the most environmentally friendly mode of transport, yet, as long as economic system allows people to freely choose a mode of transport, only a marginal proportion of them will voluntarily use trains in the interest of the environment.

As argued by Verberckt, the modal choice in passenger transport identifies speed as one of the factors in play. Speed has causal effects in road accidents and in fact it is of major concern in road safety programmes of many countries. This study will attempt to identify the environmental and law enforcement governance issues which influence the need for speeding on roads and the need for all concerned parties to take cognisance of these issues to enhance road safety on our roads.

Manyara(2013), states that Kenya in recent times experiences one of the highest fatality rates and economic burdens/costs with little emphases placed on the problem of road accidents save half-hearted safety measures that police have challenges enforcing. In fact, road accidents will be third-leading cause of injury deaths world over by 2020, 50-60 percent being young males in the 15 - 44 age groups(UN 2015).There has been paucity in scientific research on the correlation of road geometric elements to road accidents since John Cohen's study carried out in Kenya in 1973 (Ogendi et al. 2012).

The cost of road traffic accidents to global economy is enormous, close to US$ 500 billion annually (WHO, 2013) of which US$ 100 billion is lost in developing and transition countries of Eastern Europe (WHO, 2013). Kenya's economic cost is well in excess of US$ 50 million exclusive of actual loss of life which translates to 11 percent of its gross domestic product (GDP) when compared to 1-2 percent of all developing countries (Manyara, 2013). The country loses US$4 billion annually in fatalities while the costs of medical treatment and care are shouldered by friends, relatives and family and this put together result in huge burdens to the community and dramatic damaging effects on the families' standards of living and education of the orphans and the affected (Manyara, 2013).

This economic cost and burden can be expressed as (Burden/Cost) B/C ratio (Odero, 2012) and in terms of percentage of GDP annually. The percentage of economic cost of the GDP has exponentially increased from 5 percent of GDP in 1980 to 11 percentof GDP in 2012 (Manyara, 2013) and there is no let-up in the trend in foreseeable future.

Road Accidents and Safety

Worldwide, road accidents are emerging as a leading cause of deaths, injuries and disabilities (Razzak&Luby, 2008 &Tercero*et al*. 2009) of monumental proportion that has jolted the United Nations to craft UN global plan of action of making roads safer 2011-2020 (UN, 2015). Although the scourge of road accidents seems a curse of developing countries, which the developed worlds of North America and European Union have contained, empirical researches and data on road accidents need to be analysed to awaken the governments of the developing countries to the nature of this imminent epidemic (Manyara, 2013).The circumstances obtaining in the occurrence of any one single accident on the motor way are multi-factorial event probably involving combinations of other variables besides road engineering design parameters and drivers' competences and behaviours (Odero, 2012).

The road traffic accidents as a parameter has its own measurable dependent variables such as a total number of accidents per thousand vehicle kilometres per year, number of deaths per 100,000 population per year, death per 10,000 vehicle kilometre and as U.S. dollar per annum, or percentage of Gross Domestic Product, Burden-Cost Ratio (Manyara, 2013). Studies elsewhere have related variables of road accidents to independent variables such as human, road design geometry, environment and vehicles (Ruyters*et al.* 1994)

Notwithstanding that road accidents cannot completely be eliminated or prevented, suitable traffic engineering and management have reduced accident rates in U.S. and Canada by 35 percent and 65 percent respectively (Manyara, 2013). The existing circumstances of road geometric and road condition variables of our highways or other classes of roads in relation to stipulated international standards obtaining in Europe, Canada or U.S. remains not well understood from empirical researches (Ruyters*et al*. 1994).The road traffic accidents are assumed to be "curses" of which blame targets the drivers for incompetence in handling or controlling of vehicle, drink-driving and not heeding traffic rules, regulations and safety measures (Ogendi*et al.* 2013).

Incidence of Road Accidents

There is a disproportionate prevalence and incidences of accidents between developed and developing countries, along the highways of road networks, times of day, days of the week and in sectors or classes of road users (Ogendi, *et al.* 2013).For instance, 80 percent of all road accidents globally occur in developing countries (Ogendi, *et al* 2013). Incidences or prevalence of road accidents are influenced by vehicular variables or parameters such as volume of traffic, traffic flows and other parameters such as road geometry, road conditions, environment and other physical factors like terrain and weather patterns (Lee & Mannering, 2002). Notably, traffic volume, traffic flow and population growth have put untold pressures on drivers and other road users beyond the geometric design variables of the road networks in developing countries Kenya inclusive. Elsewhere studies have revealed that incident rate of accidents measured either as total number of accident per kilometre-length of road per 24 hours day or total accidents per kilometre road - per year are lower in developed than developing countries.

In United States and Canada, the incidences of road accidents on the road networks have been reduced by 35 percent and 65 percent respectively through implementation of robust road safety measures including the construction of new highways and expansion of existing roads in accordance with stipulated standards of empirically safer road geometry and conditions (Torregrosa*et al.*, 2012).

In African region, the average annual fatality rate now stands at 20.1 deaths per 100,000 populations for developing countries and at 24.1 deaths per 100,000 populations compared to 8.7 deaths per 100,000 populations in developed countries (Manyara, 2013).Comparatively, Kenya has one of the highest fatality rates of 34.4 deaths per 100,000 populations in the world (WHO, 2013). Developing countries are known to experience largest mortality and fatality of about 85 percent deaths compared to a paltry 4 percent ascribed to developed world's global rate fatality,annually (Ogendi*et al.* 2013).

The morbidity (injuries and disabilities) due to Road Traffic Accidents (RTAs) is disproportionately higher, 90 percent of the 50 million fatalities, which occur annually worldwide;occur in the developed countries (WHO, 2012). Although morbidity is about ten times the fatality in the preventable road accidents that occur globally (Muchene, 2011), developed nations of North America and Europe have contained incidences of road accidents and by extension morbidity and mortality, through vehicular designs and road geometric designs specifically suited to needs of road users in complete contrast to developing countries such as where vehicles and roads designs are solely tailored to vehicle drivers' instincts or whims (Ogendi*et al.* 2013).

World Health Organisation (WHO) projects that RTAs shall be the third significant cause of injury deaths worldwide by 2020 (WHO, 2013) and has impressed upon UN to embark on Global plan of action for safer road towards that end. The vulnerability of populations or sections of it using public or private transports on road ways varies from one country to another between classes of roads, locality to locality and along sections of the highway (Jacobs, 1976). Evidently, vulnerability tends to be clustered along accident prone sections (black spots) of highways, amongst specific or particular classes of road users on highways or urban centres and to specific times or hours of the day or days of the week (Manyara, 2013) and is attenuated by wet weather conditions, land use and terrain which affect the road geometry and conditions on road networks in Kenya and world over (Ruyters*et al.* 1994).

Factors that Influence Road Accidents

The factors that influence road accidents are not clear but are generally referred as causes or determinant variables which are here-in examined. The epitaph that road accidents are "caused" is untrue and unfounded by systematic scientific researches (Manyara, 2013) since they are simply rare and random occurrences or incidences involving a mishap or crashes between one moving vehicle and another object on the road or another vehicle moving in the approaching directionwithin contributing or predisposing circumstances or parameters where the driver has failed to respond or manoeuvre the vehicle in a controllable manner (Ogendi*et al.* 2013).A study in Tanzania established a host of about 31 supposedly predisposing factors that can be collapsed into four independent parameters, vehicular, human, road geometry and road environment (Bhuyan, 2013). Interestingly, empirical studies on "causes" of road crashes, comprising other parameters in exclusion of road geometric and road conditions, have ended up with non-effective road safety rules, regulations and measures (Dehurry*et al.* 2013). The road design that is, road geometry and conditions,greatly have significant influence or impact on incidences of road accidents, frequencies and severity whose magnitudes are evidently aggravated by intervening variables such as terrain (topography), wet weather, traffic volume, drink driving and speeding on highway (Patnalk*et al.* 2013).

The human variables attributable to occurrence of road crash comprises driver's inattention or distraction, fatigue, drink-driving, visibility, speeding and general indiscipline, impairment of judgement and competence of the drivers and other road users (Ogendi*et al.* 2012) besides their knowledge, competence and perception of road networks in their locality (Odero*et al.*2012). However, elsewhere research has shown that over 70 percent of all fatality and serious injuries is attributed to drivers' errors (Ogendi*et al.*2012) which is consistent with 85 percent of crashes as reported by police department, are caused by poor driver's discipline or judgement in Kenya (Manyara, 2013). The driver impairment is a significant variable of road traffic accidents both in developed and in developing countries (Muchene, 2012).

Driver's impairment may be attributed to situations such as being under the influence of alcohol, drug, sleepiness or fatigue and condition of extreme weather, especially wet weather and short hours of day light. In Far East countries, Singapore, Korea and Malaysia, increased illumination and use of head lights by mopeds and cyclists during the day have reduced accidents by 40 percent. Vehicular variables contributing to high incidences, mortality and morbidity in road accident include mechanical failure (failing to brake), flattened tyre treads, bad brakes or tyres, anti-crash devices such as seat belts, air bags, and speed governors (Asingo*et al.* 2014, Manyara 2013&Ogendi*et al.* 2013), vehicle speed, capacity, and sensors monitoringthe driver's performance and behaviour on the road; alcohol-vehicle locks, collapsible steering, secured car doors and wind screens which do not open upon crash (Thomas & Jacobs 1995).These vehicular variableshave been successfully used to reduce road crashes in developed countries of North America and Europe.

Furthermore, vehicular designs can be operated on auto mode where variables of road geometry and conditions are interfaced with in-built devices for auto drive with maximum anti-crash sensor–mechanisms (Muchene, 2012) and further interconnected to roadways surveillance cameras to enable enforcement of traffic rules and safety regulations through computerised systems (O'Neill, 2011).Environmental variables include trees, power posts, terrain, weather conditions, wild animals, land use, encroachment on the road reserve, buildings or built-up or residential areas along the road (Jacobs 1976,Rao& Jacobs 1995) that may alter visibility sight distance, driver judgement and traffic flow that may include a road crash or accident on road or highway (Derry, 2011).

The human, vehicle and environmental parameters may interact into a complex matrix of predisposing circumstances or situations within unexpected spatial and temporal dimensions not cogent to the driver's behaviour, pedestrians or cyclists involved in the road (Muchene, 2011).Road geometry and road condition in road design are dictated by soil texture, structures, rock types, terrain and prevailing weather conditions such that a highway or road is never entirely a straight strip of pavement or travel way but a construction land mark with geometric and condition variables.

The contributory or predisposing circumstances in any single road accident can either act/interact individually and/or in combination as independent variable(s) (Manya, 2013) in correlation with dependent variable in our case the road accident and its variables (Ruyters*et al*. 1994).Elsewhere correlation or multiple regressions between road accident variable(s) and above four independent parameters or their variables have been established in a couple of studies (Lee & Mannering, 2003). Empirical studies carried out in Kenya, Jamaica, Sri Lanka, Malaysia and other countries of developing world in 1972-73 produced data that have been systematically analysed to help draw the road construction and inventory manuals and standards for developing countries of European Union, and Northern America (Ruyters*et al.* 1994).

Road Designs and Maintenance Standards

Studies elsewhere in developed world have reported that only 30percent of road traffic accidents are correlated to road geometric variables and 34 percent RTAs to combination of geometric variables with other parameters (ASHTO, 1968) and majority of accidents correlated to driver and vehicle factors (Anne *et al.* 2010). There is paucity of data or publications establishing correlation or interaction between road geometric and road condition variables with road accidents or its variables in Kenya and elsewhere in developing and developed countries (Muchene, 2011).

Odera*et al.* (2012) reported that only 17 percent of road accidents are contributed by human and road environment while 83 percent is contributed by road design, and maintenance standards, vehicular factors, safety measures among other factors . These findings, taken together, point to road design being a probable inherent variable responsible for high incidences of road crashes and carnage along black spots on the highways. All roads and highways are designed, executed and maintained to take into account vehicles, drivers (human) the roadway and environmental parameters that may compromise road safety and induce road crashes. Road geometry has a couple of variables that affect both the traffic speed, flow and road safety of motorway or highway (Derry, 2011). The variables include carriage width in metres, curvatures whether horizontal, transition and vertical measured in degrees, shoulder width and type, road margin or road side features and border lines.

The cross-sectional road geometric elements such as travel way (carriageway), shoulder, medians, verges, borders and pavements have typical or characteristic width dimensions. From empirical research, non-adherence to standards, recommendations, guidelines or codes is known to have serious impacts on the safety of road network or highway on a country's road transport system (Jacobs 1974, Ruyters*et al.* 1994&Muchene, 2011). However, it is unclear whether road design and standards in developing countries, where high incidences of road accidents occur, comply with or have modified these standards. The standards of European Union countries, Canada and United States are acceptable all over the world (Jacobs 1974, Jacobs 1976, RaoRuyters*et al.* 1994 &Jacobs 1995).

Pavements, travel lanes and shoulder width dimensions are known to range from 6.0 to 12.0 metres, 2.75 to 3.75 metres and 0.6 to 3.75 metres respectively against stipulated standard of 11.5 to 12.0 metres for highway pavements in Europe (Jacobs 1976&Ruyters*et al.* 1994). Width dimensions of elements have been associated or correlated to high incidence of accidents, their frequency and severity if reduced or modified for whatever reason, during the construction of roads (Lee & Mannering, 2002). Narrow pavements, shoulders, lanes and verges or median have been associated with high incidences of accidents or unsafe roadways (Rao*et al.* 1995, Asingo&Mitullah 2004&Muchene 2011).

Kenya has approximately11, 197 kilometres of paved or bituminous roads, which translate to only 7 percentof 160,886 kilometre of road network. Globally, standard pavement width ranges from 11.5 to 12.0 metres for multilane highway and 6 – 12 metres for undivided rural roads but shoulder width may range from 0.6 to 3.75metres. Emergency lanes on highways serve as a shoulder for vehicles to pull off or to stall. Roads with narrow shoulders or without shoulders experience high incidences of RTAswhereas those with narrow pavements or travel ways are associated with high incidences of road crashes and collisions(Thomas & Jacobs 1995, Asingo 2004, Muchene 2011).

Horizontal curvatures are mainly on the level terrain of land whose radius influences the incidence of road crashes or accidents. However, horizontal curves of short radii are associated with highest incidences, frequency and severity of RTAs on highways and road networks and those with elevation of less than 2percent experience more than 3 per cent increase in road crash risks (Thomas& Jacobs 1995&Mudena, 2011). However curvatures are associated with low wet skid resistance and reduced sight distances which could be the explanatory variables for high incidences of RTAs on roadways(Roberts *et al.* 2003, Asingo2004 &Mudena 2011,)in spite of them keeping drivers alert. Vertical curves are commonly rampant on sections of road networks or highways that traverse critical topography with hilly terrain. Existence of vertical curves serenely comprises the stopping, decision and passing sight distance of the road increasing the likelihood of road crashes on carriageway besides frequent incidence of heavy trucks or vehicles stalling or slowing down speed (Ruyters*et al.* 1994). Vehicles experience difficulties when climbing vertical curves or steep slopes hence an additional climbing lane for heavy vehicles (Jacobs 1974, Ruyters*et al.* 1994, & Thomas & Jacobs, 1995, Muchene 2011). Transitional curves are associated with high incidences of crash, if the drivers of vehicle engage high speed, due to centrifugal force created by the curved section (Ruyters*et al.* 1995). The effects of road curvatures on skid resistance and sight distance are aggravated by wet weather conditions, speeding and traffic flow (Jacobs 1976, Ruyters*et al.* 1994, Asiyo 2004 &Muchene 2011).

Verges are spaces of the roadway land between the shoulder and the barriers created to prevent errant vehicles from crashing on obstacles and enable safe recovery (Jacobs 1976, Thomas & Jacobs 1995). Verges overgrown with shrubs, tall grass and bushes decrease visibility of drivers who look into the distance at junctions, thus increasing chances of road accidents and making the road unsafe (Ruyters*et al.* 1994 &Torregrosa*et al.* 2012). The widths of verges have influence of occurrence on road crashes. Narrow verges experience higher incidences of road crashes.

Proper access management through access junctions, bicycle and cyclist facilities, signage, road markings and pedestrian crossings facilitate traffic flow without delays or impede traffic, reduce visibility and sight distances and conflicts on the road. The access facilities reduce incidences of road crashes, fatalities and delays in travelling. A study in an Indian highway found that, the highest number of road crashes occurred at access junction entries to the highway and steep slopes of the flyovers (Rao*et al.* 2004). However, well-managed access facilities such as bicycle or cyclist lanes and pedestrian crossing reduce vehicle-vehicle or vehicle-pedestrian conflicts on the highway (Muchene 2011,Ogendi*et al.* 2012&Manyara 2013). However, the doubling of access points from 10 to 20 per kilometre, and ofdriveways from 20 to 40 per kilometre increase road crash rates by about 30 percent and 30 to 60 percent in existing urban corridors, respectively (Bendale, 2005).

In the towns and cities, traffic on roads are regulated or controlled with traffic lights and signs and/or signals (Ogendi*et al.* 2012). Road signs and sign boards are used as virtual information instructing or guiding the drivers on the decisions and manoeuvres on the section of road ahead. However, the gravel surface and road bumps are included on the highway to draw attention to drivers who have not been keen on road signs and sign boards

(Osueke&Okorie, 2012). As a road design variable, signage may be expressed as the number of signboards per kilometre on road (Muchene, 2012)

The condition of road surface has important influences or effects on speed, manoeuvres and traffic flow on sections of the road or highway. The road conditions as a variable may be measured and expressed in units of surface friction coefficient, skid resistance and polished stone value (PSV) to quantify the roughness and friction on the road surface as well as its texture (Ruyters*et al.* 1994). The road micro texture, macro texture, friction and skid resistance are variables of road surface conditions which have significant impact on road safety or its failure that results in road crashes. The skid resistance and surface friction coefficient of road surface increase following the opening of the road for traffic then remain constant and gradually decrease with passage of time with increased incidences or risks of crash on the road (Muchene, 2012). Highest accident rates on the black spots coincide with reduced skid resistance on the section of the road or where there is likely to be change in the speed or direction on the highway (Rao*et al.* 2004).Skid resistance is severely compromised by wet weather, steep slope greater than 8percent and curvatures on the hilly terrain (Ruyters*et al.* 1994, Jacobs 1976).

Sight distance is the length of roadway visible to a driver. Road geometric variable of alignment of the highway besides the terrain, weather, and land use has significant influence on the sight distances: Passing Sight Distance, (PSD), Decision Sight Distance (DSD) and Stopping Sight Distance (SSD). The aforesaid sight distances are geometric variables, if maintained prevent drivers from hitting vehicles or obstacles on the roadway, which could be explanatory variables or contributory variables to high incidences of road crashes or accidents on the roads (Thomas & Jacobs 1995 &Muchene, 2012).The vertical, horizontal and transitional curvatures severely reduce the sight distance, as light or illumination from vehicles or object into driver eyesight travels in a straight line (rectilinear property of light), making it impossible for the driver to sight a stalled or an in-coming vehicle on the roadway. These sight distances are expressed in metres of the road length; of which stopping sight distance and passing sight distance are 85 kilometres and 180 kilometres ahead, respectively. Decision sight distance varies from driver to driver, from road alignment to another and importantly dictates the driver's skill and competence in making appropriate judgements and manoeuvres on the highway to avoid incidence of frequent crashes (Chandraratna*et al.* 2006, Muchene 2012&Manyara 2013). However the sight distances are severely reduced by alignment of the road, terrain, curvatures, illumination and wet weather conditions. Severity of RTAs is associated with night travels due to reduced visibility and sight distances at night.

Safety Measures on Road Accidents

Several safety measures and counter measures have been planned and instituted to curb incidences of road carnage, road crashes and to reduce the mortality, morbidity and economic cost and burden (Peter & Roberts, 2009). These safety measures have worked effectively to reduce incidences of road accidents by 35 percent in US and 65 percent in Canada (WHO, 2012). However they are only specific to obtaining circumstances or situations in one country but cannot be applied to other countries wholesomely (Bhuyan, 2003) as they have failed to bear the intended effects in developing countries (Anne *et al*, 2010). UN Global Plan for the Decade of Action for Road Safety 2011-20 imputes the need to raise the inherent safety and protective quality of road networks for the benefits of all road users at risk of road crashes (WHO, 2015, UN 2015, Muchene, 2012) through encouraging governments to set targets of eliminating high-risk roads by 2020, developing safe new infrastructure which meets the mobility and access; and identifying hazardous road sections or locations that are accident prone (black spots) or have exclusive numbers of severity of crashes occurring and taking corrective measures (Derry, 2011).

In developed countries road safety measures, advanced by Professor Jonathan Haddon in 1971, have belatedly been implemented to reduce road carnage and crashes (Ruyters*et al.* 1994) on highways or motorways while the governments in developing world's still waffle with non-empirically obtained solutions to specific road traffic problems (Muchene, 2012). RTAs or injuries and fatalities have been addressed from vehicular and road geometric designs that cater for the human limitations and challenges on the traffic flow on the road networks. Vehicles with drivers' biometric data and sensors monitoring their behaviours on the road are designed with safety controlling or regulating mechanisms to eliminate human errors, drink-driving and fatal crashes (Bendan 2005, Ogendi*et al.* 2005 &Chandraratma*et al.* 2006). The impact of safety measures heartedly put in place need to be assessed and revamped by research based findings specifically suited to the road geometric designs and road condition designs on the black spots in the Kenyan roadways (Asingo&Mitullah, 2009).

The object of road safety engineering is essentially to reduce the frequency and severity of road crashes (Hassan &Aty, 2012) by application of road traffic engineering principles, sound analysis of empirical data, coupled with understanding of road-user behaviours and cost effective ways of reducing economic burden/cost of road crashes casualties and fatalities on road networks (Elvok, 2015). All these are achievable at stages of planning, designing execution and maintenance of new roads and developments of safety improvements for existing roads (Hassan &Aty, 2012).

Developed worlds of North America and European Union have successfully reduced road accidents through implementation of principles of road safety and standards of road construction and inventory manuals founded on scientific research and analysis on road accidents and road parameters (Jacobs, 1976). Safety measures or programmes were empirically predicated on three components and/or parameters, driver's behaviour, vehicular and road way-geometry and/or its environment, in combination, all acting as "cause" of road accidents (Chandralna, 2006). Vehicular and human variables have been predominantly taken into consideration in the design of safety measures with the limitations and possibilities of human capacity in mind (Bon *et al.* 2010).

THEORETICAL FRAMEWORK FOR ROAD TRAFFIC ACCIDENTS

In theories of accident causation there are several major theories each of which has some explanatory and in predictive values understanding the causal factors of road traffic accidents (RTAs). The initial theories of accident causations were developed by Heinrich (1932) a safety engineer and pioneer in the field of Industrial accident safety are the domino theory and the human factors theory.

The Domino theory

The domino theory of accident causation was one of the earliest developed by H.W. Heinrich (1932). The theory posits that injuries result from a series of factors, one an accident of which is an accident. According to Heinrich's domino theory, an accident is one factor in a sequence that may lead to an injury. In the scientific approach of this theory there are five factors in the sequence of events leading to an accident; the mistakes in social environment, the faults/carelessness of a person, unsafe acts/performance, mechanical or physical hazard, the accident and the injury. The critical issue of Heinrich's domino theory is that , the factors preceding the accident and mostly the unsafe act or the physical hazard should receive the most attention and those responsible be concerned with the proximate causes of all accidents.

The emphasy here is that accidents and not injuries or property damage be the points of concern in accident situations. The scientific views of the domino theory as postulated by Heinrich have some relevance in this study of road traffic accidents on the accident black spots. The domino theory factors on the sequence of events leading to accidents applicable in this study includes; the mistakes in social environment in form of road side activities affecting motor flows, the faults/carelessness of persons in form of poor pedestrian road usage, unsafe acts/performances in forms of driver over speeding, accidents occurrences due to pedestrian-motor conflicts and injuries occurring from those accidents. This study applies these views in analysing the causal effects of RTAs.

The human factors theory

Heinrich posed this model in terms of a single domino leading to an accident. The human factors theory premise is that human errors cause accidents. The structure of human factors theory is a cause/effect format one. This theory of accident causation attributes accidents to a chain of events ultimately caused by human error. It consists of three broad factors that lead to human errors categorised as overload, inappropriate worker responses, and inappropriate activities. In overload the work is deemed to be beyond the capability of the worker on physical/psychological factors. There is the influence by environmental factors, internal factors and situational factors. In the case of inappropriate worker responses, there are hazards, safety measures/workers faults and compatibility of workstations that are deemed to cause accidents. On the case of inappropriate activities there is lack of training and misjudgement of risks as the causal effects of accidents. In summary, the aspects human factors theory by Heinrich attributes accidents to human errors. These human errors are influenced by capability of the workers (driver/law enforcers), the environmental conditions (roads infrastructure /road pedestrian facilities), hazards (lack of safety measures/facilities), lack of training/ misjudgement of risks (driver over speeding and road safety unawareness). These views in the human factors theory are relevant and are applied in this study.

The accident/incident theory

The accident/incident theory of accident causation is an extension of the human factors theory. It introduces such new elements as ergonomic traps which are the compatible workstations, tools or expectations. It also includes the decision to err which is the conscious/unconscious (personal failure) and the systems failures (management failure). These aspects of accident/incident theory on personal failures and systems failures as the causal effects of traffic accidents are very relevant in this study. The decision of vehicle drivers to err and over speed with no regard to set rules and regulations on speeding, these are personal failures which this theory addresses in accident causation. When traffic law enforcers fail to strictly enforce the traffic rules and regulations, these are system/management failures alluded to in this theory. This theory was helpful in this study.

RESEARCH GAP

In undertaking a study of so complex a phenomenon as occurrence of road traffic accidents, it is seldom that the "cause" of RTAs is very simple but more often than not a combination of circumstances playing function, in which human, vehicle and road, are important as independent variables (Jacob, 1976)

In any country, the key to safer road traffic lies in the design of proper road geometry conditions in accordance with traffic volumes, flows and structures, standards and principles of safety (Roberts 2004, Jacobs, 1976&Ruyters, 1994). Through construction of ultra-modern highways of proper road design, developed countries of Canada, USA and Europe have observed considerable reduction in the number of accident rates and economic burden compared with developing countries especially Kenya (Jacob, 1976, Cohen, 1973 &Ruyters, 1974).

The disproportionate 80 percent of all road traffic accidents, with unusually high fatality rate of 24.1 percent in developing countries (Jacobs, 1976 &Ruyters*et al.* 2004), points to a systematic failure in the management of road construction standards and safety programmes or measures in road transport systems. Annually, Kenya experiences one of the highest accidents rates in world, which bring economic costs of 11 percent of GDP exclusive of fatalities (Manyara, 2013). Additionally there are over 80 accident prone sections (black spots) on a 788 kilometre highway which is exactly 50 percent of all black spots mapped in the whole republic of Kenya. This scenario raises eyebrows and call for a change to minimise the damage and losses.

The influence of road geometrical variables on road accidents at black spots remains unclear at present. The existing road safety information is not based on scientific findings (Ruyters*et al*. 2004) and is therefore subjective and not reliable. Kenya's high fatality rates are 34.4 percent due to road accidents and 4 deaths per 100,000 population could be due to lack of proper road design standards or inability to always apply them in the planning, execution and maintenance of road construction works. It is unclear which road geometric variables, separately or in combination, cause accidents at the black spots and/or correlate separately or in combination or interaction with other independent variables to predispose accidents on

Kenyan road network. The influence of road design and standards on accidents and road safety needs to be investigated.

However, if the multi-functionality of the relationship of road accident is taken into account (Haddon, 1971, Jacob, 1976 &Odero*et al*. 2012), correlation, multiple regression analysis and/or logistic regression analysis could be employed to establish and quantitate the relationship between one dependant variable of road accidents and one or more independent variables of road design elements and/or other parameters as cogent statistical tools or techniques (Muchene, 2012, Jacobs, 1976 &Ruyters, *et al*. 1994). The relationships could then be expressed in simple mathematical representations or equations as:-

(a) (i) For simple correlation $y= f(x)$

(ii) $y =f (x_1 +x_2 + x_3 +x_4)$ for multiple regression

(b) $y = f \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix}$ for logistic regression

Where, x_1, x_2, x_3, and x_4 are independent variables and the "y" being the dependent variable. In the entire equations, "y" is a function (f) of independent variables of the road accidents along either the black spots or the entire road network in Kenya.

Studies elsewhere have reported lack of "hard" evidence about the relationship between road designs and road accidents or road safety (Khayesi, 2010) partly because these findings were compounded or obscured by a variety of variables such as driver, vehicle, traffic flow, regulations and risk increasing circumstances and/or the relationship between road safety or its failure and road features were not understood quantitatively (Jacobs, 1976,&Ruyters, *et al*. 1994) for lack of appropriate statistical analysis techniques.However, no studies have reported existence of causality between the above independent variables and incidences ofRTAs so far in Kenya. The word "cause" is but misnomer referring to predisposing or contributory parameters or variables. Essentially, such contributory parameters of construction must be operationalized into specific variables, measurable in quantitative units whose relations with road accidents may be established by statistical tests, or tools of analysis.

RESEARCH METHODOLOGY

A descriptive survey design was adopted in this study. The study was carriedout around accidental prone sections (black spots) along the Great North Road on the Kenya-portion that spears northward towards Cairo through vast terrain of bush, hilly slopes, valleys and swampland in a warm tropical-Equatorial climate of East Africa.

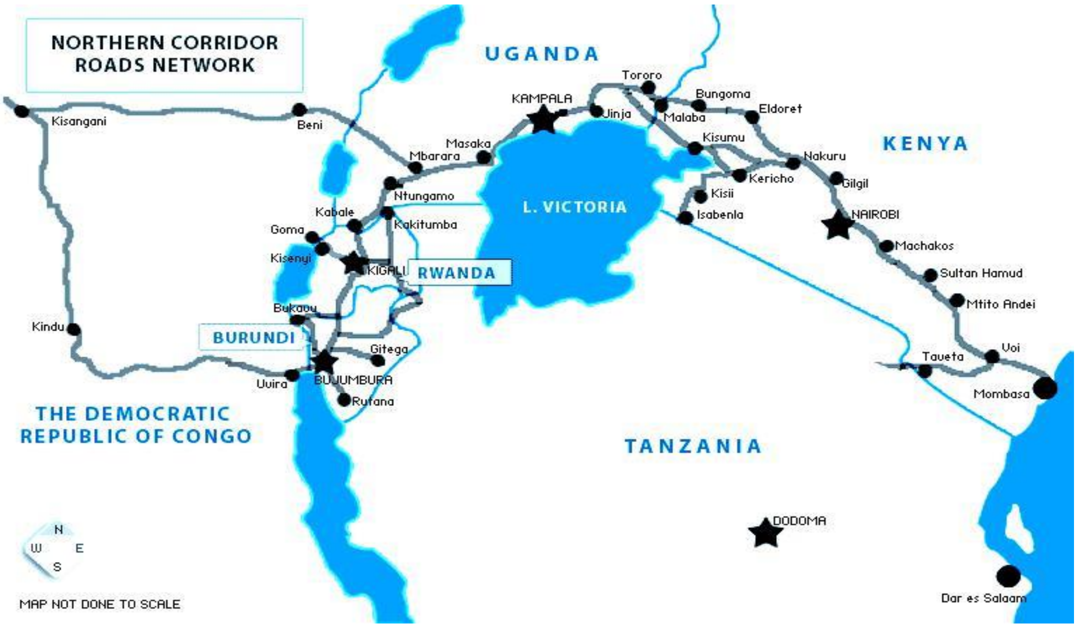

Figure 1: Study Location and Area

Source: Kenya Roads Board (2016)

The study population consisted of 80black spots (according to data by road safety department) in areas along Mombasa-Malaba road. Road users whose responses to the structured questionnaire in relation to road design variables and accident variables were sought and compared with actual measures and observations of the research team. Random sampling of sections of Mombasa/Malabaroad, which are accident-prone (black spots), and which aremostly used for public transport was carried out.The sampling of the study population and road sections was done to measure the state of affairs of existing variables in the field without an experimenter bias or manipulation of data or responses.

A sampling frame was drawn from the list of 80 black spots on Mombasa/Malaba Highway, from the police reports or listing and compared with drivers' knowledge of the black spots from the drivers plying aforesaid roads. A random sample of the black spots was drawn from the sampling frames prepared using Geographical Information System (GIS) and mobile vehicle.

Sampling design is that part of statistical practice concerned with the selection of a subset of individual observations within a population of individuals intended to yield some knowledge about the population of concern, especially for the purposes of making predictions based on statistical inference (Cooper & Schindler, 2003). According to Mugenda and Mugenda (2003) from normal distribution, the population proportion can be estimated by:

$$n = \frac{Z^2PQ}{\alpha^2}$$

Where:

Z = standard normal deviation set at 95% confidence level (1.96)

P = percentage picking a choice or response (0.9)

Q = 1-P

α = level of significance = 5%

(1) $n=\frac{1.96^2 \times 0.9 \times (1-0.9)}{0.05^2}$

(2) $n=\frac{1.96^2 \times 0.9 \times 0.1}{0.05^2}$

(3) $n= 0.345744/0.0025$

(4) n=138

From 80 black spots along Mombasa-Malaba road, the researchers used random sampling techniques to select 10 black spot along the road. From the 10 black spots, the study employed simple random sampling techniques to select a sample size of 130 respondents, this included, 1police officer, 5 pedestrians, 2 neighbours and 5 drivers (PSV), private service vehicle, long distance drivers, motorists and cyclist) in each black spot.

The study research assistants helped to collect accident primary data from the respondents along the Mombasa-Malaba road and using a checklist observed the road design variables on the sample sections.The questionnaire as a data collection instrument was employed to give relevant information from respondents because of ease of administration, time saving, upholding of confidentiality between the respondents and the researcher as well as being the best source of primary data (Orodho, 2007).Both closed and open-ended questions were prepared for data collection. Closed questions were expected to offer uniformity to respondents in answering the questions while open-ended questions accorded objectivity and freedom to respond to question without personal indulgence or biasness (Copper & Schindler 2011).

The data obtained was subjected to rigorous analysis to ensure research objectives were successfully tested, firm and accurate, correct and meaningful data. The questionnaire and interview checklist was pretested through a pilot study (Sushil&Verma 2010). The research instruments are accepted as reliable when Crobach's alpha coefficient (α) for determining reliability is 0.8 or higher (Smith 2003).The also researcher ensured that validity was achieved by inclusion of objective questions and content in the questionnaire and other instruments and the supervisors' or principal investigators' involvement and guidance. The research assistants and key informants evaluated the pilot study responses to questionnaire, discussed and reviewed the instruments of study to ensure the questions and content addressed the research objectives and hypotheses through clear responses from the intended respondents to remove ambiguity (Copper & Schindler 2011).

Conceptual and Operational Definitions

This study summarised the variables into a table of conceptual and operational definitions. A conceptual definition accords a variable a constitutive meaning from one concept to another while an operational definition defines or assigned clear and quantifiable meaning of what the variable is and how to measure it. A Likert scale, of 1 to 5, was used to quantify the variables in the questionnaire or interview checklist where a continuous scale of the measurements are not objectively attainable.

Table 1: Variables in the Study

Code	Variables	Conceptual definition	Operational definition	Scale
Y_1	Incidence rate	The number of road accidents occurring on sections of road way per time period	Number of accidents per day, week, month or year	Continuous
Y_2	Fatality rate	The number of fatalities due to road accidents, measured in deaths per vehicle kilometre (distance travelled)	Number of deaths per 1000 vehicle kilometre per annum or per day	Continuous
Y_3	Morbidity rate	Are the number of injuries and disabilities due to road crashes or accidents per vehicle kilometre per day or month or year	Number of injuries suffered per 1000 kilometre (distance travelled) per day per month or year	Continuous
Y_4	Economic cost	Is the cost, in Kenya Shillings, incidental of expenses incurredinhealthcentres, as compensation of life and damage of property per time period: day or month or year	Amount of Kenya Shilling per day or month or year lost in damages	Continuous
Y_5	Risks	The accumulative expose to number of traffic events, accidents, mishaps through driving along sections of road networks that road users experience, measured in number of traffic events or mishaps per passenger or distance travelled	Number of traffic events or mishaps per 100,000 passengers per annum or number of traffic events per 1000 vehicle-kilometre	Continuous absolute numbers per Km or 100,000 passengers
Y_6	Safety	The scarcity of number of accidents, fatalities or injuries occurring on roadway through ensuring of safe roads and traffic conditions by all and sundry.	Number of accidents per 100,000 population per day or year or vehicle kilometre per day or year	Continuous: Near orAbsolute 0 (zero) accidents value
X_1	Human factor	These are drivers and/or other road users'non-compliant behaviours with road traffic safety regulation, laws and rules, measured in number of noncompliance per total registered drivers.	Number of non-compliant driver or road user per registered driver per time period	Continuous: Absolute number per time

X_2	Vehicular factor	The number of non-compliance of vehicles to RTA regulations and rules together with traffic flow and vehicle conditions that engender accidents or crashes per time period. Traffic volume measured in number of vehicle per the period	Number of non-compliant vehicle and inclement traffic volume and flow beyond road capacity or function Number of vehicles per day or year or hour	Continuous
X_3	Environmental factors	The conditions of bad weather, inclement topography land use and encroachment on the right of that impure or compromise safe drive on road sections per time period	Number of days of inclement weather and environmental conditions per year or number of encroachments of right of way	Continuous
X_4	Road Surface condition	Road surface aspects which when aggravated by environmental-vehicle and vehicular factor cause accidents or road crashes measured skid resistance or sliding ratio	Degree of roughness or slipperiness, between tyre and wet road or ratio in N/N between tyre and road forces	Continuous/ Ordinate ratio or ordinate scale
X_5	Road design geometry	The presence of road geometrical elements, whose dimensions determine traffic conditions and road safety along the roadways measured in metre of length, radius or degree of slope or elevation of curve or absolute number per black spot of kilometre road length	Width in metre of elements or radius of curvature or degree of elevation of curves Distance in metre of straight stretch of road Number of element per black spot	Continuous in metre Orordinate scale
X_6	Road safety measures	The transport/traffic performance indicators through enforcement of traffic and road safety regulations rules and law, measured in number of arrest, penalties or prosecution of violations of non-compliance by drivers or other road users	Number of arrests, penalties and prosecutions per vehicle kilometre or per number of road safety audits done	Continuous

Data analysis

On receipt of the completed questionnaires, the data collected was checked for errors or omissions, exaggerations and biases, responses and cleared before subjection to appropriate statistical tools of analysis. Data was coded into Statistical Package for Social Sciences (SPSS) for and analysed using descriptive statistics. Descriptive statistics involved use of absolute and relative (percentages) frequencies, measures of central tendency and dispersion (mean and standard deviation respectively). Initially the data was verified, coded and entered in SPSS, before being subjected to analysis. Inconsistencies, anomalies, missing data and outliers was cleaned using SPSS syntax test potential irrelevant summaries were produced. Results for each item were based on the number of cases which had valid data for the item in question.Quantitative data was presented in tables, charts and graphs to illustrate the relationship between variables. Descriptive statistics was used to complement inferential or parametric tests in demonstrating patterns, frequency and severity of accidents on Kenyan highways.

RESEARCH RESULTS

Incidence of Road Accidents

The study found that incidence of fatal road traffic accidents frequently occur mainly in the designated black spots in Kenya.This agrees with a study by Manyara, (2013) that vulnerability of accidents tends to be clustered along accident-prone sections (black spots) of highways, amongst specific or particular classes of road users on highways or urban centres and to specific times or hours of the day or days of the week.

It was also established that the nature of the incidence of accidents that occur within the black spot, morbidity affected the victims the most. This is in agreement with a study by WHO, (2012) which reported that morbidity (injuries and disabilities) due to Road Traffic Accidents (RTAs) is disproportionately higher, and constitutes 90 percent of the 50 million fatalities, which occur annually worldwide.

The study further established that drivers are the main cause of road accidents at the black spots. The findings agree with a study byOgendi et al. (2012) which established that 70 percent of all fatalities and serious injuries is attributed to drivers' errors among others. This is consistent with police departmentreport(85%) of incidences of road accidents mainly caused by poor drivers' discipline or judgement in Kenya as documented by Manyara (2013).

Additionally the study found that driving behaviours such as speeding, experience and drunkenness were the major reasons associated with incidence of road traffic accident. This agrees with a study by Ogendi et al. (2012) who argued that variables attributable to occurrence of road crash comprises driver's over speeding, inattention or distraction, fatigue, drink-driving, and general indiscipline, impairment of judgement and competence of the drivers and other road users.

The study further established that drivers' personal characteristics influences occurrence of traffic road accidents.This agrees with a study by Muchene (2012) which stated that drivers' impairment among other personal characteristics are a significant causes of incidence of road traffic accidents both in developed and in developing countries.

Factors that Influence Road Accidents

The study established that road surface conditions greatly influence incidence of road accidents in black spots.The findings by Ruyters*et al.* (1994) agree with the findings of this study. In his study, he found out that the condition of road surface has important influence or effect on speed, manoeuvres and traffic flow on sections of the road or highway. The road conditions as a variable is measured and expressed in units of surface friction coefficient, skid resistance and polished stone value (PSV) to quantify the roughness and friction on the road surface as well as its texture.

In addition, the study established that, to a moderate extent road conditions, vision, speeding, bad brakes or tyres, and trees along the roads correlated with the factors that influence incidence of traffic road accidents. This agrees with a study by Manyara, (2013) that vision speeding can act in correlation with the human, vehicle and environmental parameters into a complex matrix of predisposing circumstances or situations within unexpected spatial and temporal dimensions not cogent to the driver's behaviour, pedestrians or cyclists involved in the road thus causing accident.

Road Designs and Maintenance Standards

The study established that road design affects traffic speed, flow and road safety of motorway. This agrees with a study by Derry (2011) who argues that road geometry has a couple of variables that affect both the traffic speed, flow and road safety of motorway or highway which may lead to occurrence of accidents.

In addition, the study found that T- access junctions influence incidences of road traffic accidents to moderate extent.This agrees with a study by Ruyters et al (1995) that transitional curves are associated with high incidences of crashes, especially if a driver engages high speed, a centrifugal force is created by the curved sections. Vehicles experience difficulties when climbing vertical curves or steep slopes hence an additional climbing lane for heavy vehicles.

Inferential Statistics

To compute the correlation (strength) between dependent variable and the independent variables the study conducted inferential analysis which involved coefficient of determination, ANOVA and a multiple regression analysis. The coefficient of determination was carried out to measure how well the statistical model was likely to predict future outcomes. The coefficient of determination, r^2 is the square of the sample correlation coefficient between outcomes and predicted values. As such it explains the contribution of the five independent variables (human factors, environmental factors, vehicular factors, road surface condition and road safety measures) to the dependent variable (incidence road accidents). All the four independent variables that were studied, explain 54.5% incidence road accidents as represented by the adjusted R^2.This therefore means that other factors not studied in this research contribute 45.5% of incidence road accidents. Therefore, there is a dare need for further research that should be conducted to investigate the other factors

(45.5%) that that contribute to incidence road accidents. The finding of this study is shown in table 2.

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.738	0.545	0.214	0.160

As per the SPSS generated table 4....., the equation

$$(Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \varepsilon) \text{ becomes:}$$
$$Y = 1.180 + 0.501X_1 + 0.512X_2 + 0.545X_3 + 0.504X_4 + 0.529X_5$$

The regression equation above has established that taking all factors into account (human factors, environmental factors, vehicular factors, road surface condition and road safety measures) constant at zero, incidence road accidents will be 1.180. The findings presented also shows that taking all other independent variables at zero, a unit improvement on human factors will lead to a 0.501 reduce in incidence road accidents; a unit improvement in environmental factors will lead to a 0.512reduce in incidence road accidents; a unit improvement in vehicular factors will lead to a 0.545reduce in incidence road accidents, a unit improvement in road surface condition will lead to a 0.504reduce in incidence road accidents and a unit improvement in road safety measures will lead to a 0.531 reduce in incidence road accidents. This infers that vehicular factors contribute most to incidence road accidents followed by road safety measures then environmental factors, road surface condition while Human factors contributes little. This notwithstanding, all the variables were significant as their P-values were less than 0.05.The finding of this study is shown in table 3.

Table 3: Regression Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.180	0.330		0.245	3.88 -02
Human factors	0.501	0.231	0.700	1.180	2.71 -02
Environmental factors	0.512	0.291	0.145	1.557	1.60 -02
Vehicular factors	0.545	0.132	0.110	1.324	1.24 -02
Road surface condition	0.504	0.268	0.351	1.023	8.21 -02
Road safety measures	0.529	0.127	0.249	1.9302	1.73 -02

CONCLUSIONS

Primarily the study concluded that driving behaviours such as speeding were the major reasons associated with incidence of road traffic accident. Secondly, the study established that drivers' personal characteristics influence incidence of road accidents. Thirdly, the study determined that road surface conditions influence incidence of road traffic accidents in black spots along Mombasa-Malaba road. Finally the study established that road design affects traffic speed, flow and road safety of motorway/highway.

RECOMMENDATIONS

The following recommendations were made based on the study findings:

1. Stakeholders in the transport and communication sector should establish a well-coordinated and funded road safety research and development programme(s) in Kenya to provide the information needed for necessary decision-making process in road safety measures. This will assist in coming up with essential stop gap measures and road improvement/rehabilitation to eliminate or reduce incidence of road traffic accidents in designated black spots in Kenya as well as other major road network.

2. The government of Kenya should seek to reduce the number of taxes attributed to the public service vehicle business to avoid issues like overloading and speeding in an aim of meeting the high expenses.

3. There is need for amendment of existing legislation and policies and enacting of new bills in the transport sector and to ensure that proper implementation and enforcement is carried out. This is by having strict penalties on practices that are perceived to be causes of accidents. Some of these are drunken driving, breaking of traffic rules, carrying of excess passengers and mandatory use of seat belts.

4. Identification of unsafe areas on the roads and groups of persons at high risk, so that specific interventions can be implemented and evaluated, and appropriate advocacy efforts undertaken.

The current study focused on Mombasa-Malaba road. The reason for this was that it was most affected in terms of incidence of road traffic accidents compared to other road networks in Kenya and convenient for the researcher. Despite the fact that Mombasa-Malaba road contains a high number of vehicles, a research needs to be carried out on other road networks in Kenya. In this case, future research on this topic should in future concentrate on other section of Kenya road network.

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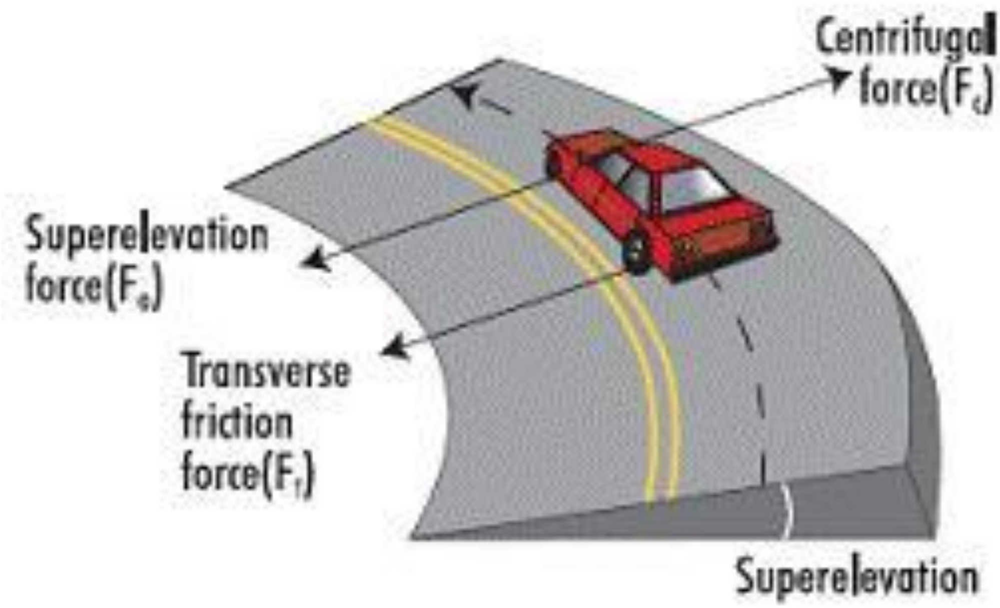
Annex I: List of Black Spots along Mombasa-Malaba Road

S/No	Black Spot Name
1.	Acre Tano
2.	Annex Stage (Nakuru)
3.	Bellevue
4.	Burnt Forest
5.	Chamowanga
6.	Chumvi Market
7.	Chyulu area
8.	Danger Corner
9.	DarajaMbili
10.	Delamare
11.	Delamare (Near Delamare shop)
12.	Doshi Corner
13.	Emali/Loitokitok Junction
14.	Equator-King'eero
15.	Free Area (Nakuru)
16.	General Motors (Nairobi)
17.	Gilgil Junction
18.	Gilgil Junction-St Mary's Hospital
19.	Gitaru
20.	GSU camp
21.	Hotel Kunste
22.	Hunter's Lodge
23.	Ikapalok-Malaba
24.	IkoyoMakindu stage
25.	Ikoyo township
26.	Kabete Police station
27.	KahoyaTimboroa
28.	Kangemi Market
29.	Kasarani-Voi
30.	Kenani area
31.	Kenya Meat Commission (Athi River)
32.	Kianda School
33.	Kibwezi Junction
34.	Kilimbini Market
35.	Kimende area
36.	Kimende Forest
37.	Kinale
38.	Kinungi Steeps
39.	Kirima area
40.	Konza Junction
41.	Lanet area
42.	Lukenya Junction
43.	MaaiMahiu
44.	MaaiMahiu Escarpment
45.	MaaiMahiu-Limuru road inter-change
46.	MailiMbiliNaivasha
47.	Manyani area
48.	Manyani Market
49.	Map Area
50.	Mariakani
51.	Mariakani
52.	Marula-Delamare
53.	Mau Summit
54.	Mazeras
55.	MbarukNakuru
56.	Mikindini
57.	Miritini
58.	Molem
59.	Molo Junction
60.	MtaayaNdege
61.	Mwandeti
62.	Naam-Nzoia
63.	Nation Centre -Mlolongo
64.	Ngata Bridge-Sobea
65.	Njoro road Junction
66.	Nzoia Bridge
67.	Pipeline area (Nakuru)
68.	Riverside Road Junction
69.	Salgaa (Past Nakuru)
70.	Salgaa-GSU camp
71.	Sameer Park
72.	Sigona
73.	Simba cement
74.	Taita Village
75.	Taleh Hotel-Mtito
76.	Timboroa
77.	Timboroa Danger
78.	Tsavo East
79.	Tsavo river area
80.	Webuye Market

Annex II: Illustration of super-elevation



Annex III: Illustration of horizontal curves

Annex IV: Vertical Stopping Sight Distance at a Crest Vertical Curve

Annex V: Headlight Sight Distance ata Sag Vertical Curve

Annex VI: Sight Distance at an Undercrossing on a Sag Vertical Curve