A TECHNICAL STUDY ON THE RELATIONSHIP OF ACCIDENT RATES AND ROAD GEOMETRIC DESIGN

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ABSTRACT

Besides geometric design elements, this study focuses on the effect of access management strategies such as the provision of service lane and the presence of median openings on crash types. To capture the effect of mixed traffic on crash occurrence, vehicle composition is considered in addition to average daily traffic (ADT). Results suggest that the effects of segment length and ADT are generally fixed and consistent across crash types. Still, there exists variation in safety performance of horizontal alignment, access management strategies, and type of vehicles. Although the coefficient for the proportion of motorised two-wheelers is found to be random for rear-end crashes, higher proportions of truck traffic are found to be always associated with higher head-on collisions. Although segments with service lanes are associated with fewer rear-end and head-on crashes, median opening presence is found to increase both of these crash types, even though the effect on total crashes is random. The relationship between safety and road geometric design are examined through results of studies mad in different countries and it compares the results of studies in different countries and summarises current international knowledge of the relationship between safety and the principal non-intersection geometric design parameters. In general, there is broad international agreement on these relationships.

I. INTRODUCTION

Traffic accidents have been recognised as one of the major causes for human and economic losses both in developed and developing countries; therefore, they are considered as the main criterion for road safety. The three basic aspects of transport, humans, roads and vehicles, are the primary factors in accidents. Human factor seems to be the dominant cause of accidents compared to the others. However, the number of accidents can be seriously reduced if the road factor is evaluated better and highway design is made correctly, the problem of traffic accidents is huge to the extent that more than 500000 accidents was recorded during the year 2019

These accidents caused about 7200 deaths (an average of 19 deaths from accidents every single day), 39000 injuries and social costs more than 20 billion SR. In addition, the very high cost of highway accidents paid by societies around the world makes highway safety improvement an important objective of transportation engineering. Highway safety specialists can influence traffic safety either through means such as road rules, law enforcement, and education, or by applying local traffic control and geometry improvements. Therefore, highway safety must be based on both historic accident data and the risk (probability) of accidents at a location. On the other hand, numerical modelling is a common tool for estimating the frequency of road accidents. For this concern, road safety modelling has attracted considerable research interest in the past three decades because of its wide variety of applications and important practical implications. Numerous road-accident-prediction models have been developed to investigate the effects that various variables may have on the value of a pre-selected crash indicator. Transportation engineers may be interested in identifying those factors (traffic, geometric, etc.) that influence accident rates. This is to improve the design of roadways and to make driving safer.

The safety of the road does not depend only on the characteristics of the roadway but also depends on the condition of the roadside. The term “clear zone” is used to designate the unobstructed, traversable area provided beyond the edge of the travel way for the recovery of the errant vehicle. The clear zone includes shoulders, bicycle lanes and any additional space, if available.

The greater the width of the clear zone, the more room is available for an errant driver to recover before hitting an object; thus, a greater clear zone means a safer road. In locations where right of way or the width available for providing clear areas is not sufficient, it is not practical or feasible to consider the concept of clear zones as expected in general. This type of environment is more common in densely populated urban areas. Considering safety aspects, a lateral offset to vertical obstructions (signs, utility poles, etc.) is needed to avoid crashes.

Road traffic crashes are the major economic, social and health problems, especially in developing countries. For example, in Ethiopia, it’s found with one of the world's worst accident records when estimated with a fatality rate of 25.3 per 100,000 population, as well as road traffic crashes cost about 0.8 to 0.9 % of its gross domestic product (WHO, 2015).

Geometric design elements play an important role in defining the traffic operational efficiency of any roadway. Key geometric design elements that influence traffic operations include the number and width of lanes, the presence and widths of shoulders and highway medians, and the horizontal and vertical alignment of the highway. Generally speaking, any evaluation of road safety, such as in the driving dynamic field, has been conducted more or less qualitatively. It is safe to say, from a traffic safety point of view, that no one can say with great certainty, or prove by measure or number, where traffic accidents could occur or where accident black spots could develop.

OBJECTIVES OF THE STUDY

General Objective

The main objective of this study is to investigate the road geometric design elements that cause road traffic crash occurrences at road segments and to model road geometric variables with road traffic crashes in Bole Sub-city.

Specific Objectives

- To study the nature and characteristics of road traffic crashes in Bole Sub-city; and
- To model road geometric variables with road traffic crashes for use in Bole Sub-city.

Significance of the Study

The investigation has revealed the influence of road geometric characteristics on the occurrence of road crashes. Thus, the significances of the research findings are envisaged to be:

Road safety authorities, road designers and planners;

Developing countries like Ethiopia and others with similar road conditions and traffic characteristics, and Other researchers who are interested to study on related areas.

II LITERATURE REVIEW

Literature shows that skidding crashes are a major concern in road safety. When the surface friction is not adequate to help stop a vehicle, the vehicle goes out of control and crashes occur.

Vertical and horizontal alignment, pavement types and texture affect a roadway’s skid resistance. Different pavement distresses or faults like rutting, polishing, bleeding and also dirty pavements cause poor skid resistances of road surfaces.

The FPCE (2012) reports a total of 9,301 road crashes of 9,301 in the country during the year of 2007/08 period, about 29% of the total road crashes occurred in the city of Addis Ababa. Road traffic crash in the city of Addis Ababa resulted in significant losses of human and economic resources. In addition, between years of 2000 to 2009 in the city, a total of 25,110 road traffic crashes occurred with about 3,415 fatalities. This indicates that, death rate due to road crashes has significantly increased among pedestrians and passengers from time to time. The majority of fatalities were pedestrians (87%), followed by passengers (9%), and drivers (4%).

The research conducted in Addis Ababa by Tariku et al. (2017) showed that out of the road crash data between 2010 and 2014, 14,263 people sustained different levels of crash severity (fatal, severe injury, slight injury) and estimated property damage to be over 19 million US dollars, without the costs of injuries for road users. In addition, the findings explained the amount of severity occurred during the course of the five years; 1,911 were fatalities, 6,932 serious injuries and 5,420 minor injuries. Moreover, the researchers showed pedestrians were the most affected (79%) road users, followed by passengers (17%), and drivers (4%).

Another study conducted in the city of Addis Ababa by Alemu (2016) revealed that the frequency of crashes in the city had varied. The study analysed the percentages of road crash occurrence in three years for 10 sub-cities of Addis Ababa, and found that Bole and Kirkos Sub-cities were leading others, which accounted for 18.5 and 16.4% of total crashes, respectively. Accordingly, the highest number of road crashes occurred in Bole Sub-city. The researcher concluded that this was due to its largest area coverage, which contributes to the highest movement of vehicles in the Sub-city and it is the place where the high-income inhabitants are dominantly living. Consequently, more car ownership, a higher traffic and pedestrian volume are generated, which creates a higher opportunity for road traffic crashes.

III METHODS

Investigations of the effect of road geometric design elements on road traffic crash occurrences were conducted at road segments in this study. A road segment is a section of a road between two intersections and roundabouts, and between an intersection and a roundabout without its physical areas. The average radius of the physical area of the roundabout and intersections was estimated to be 55m from the centres of the intersections and roundabouts

ROAD CRASH DATA

Road traffic crash data were collected from the Bole Sub-city Police Station from July 2015 to June, 2018, which occurred at selected road segments. However, fatal crashes data and summarised crash data were collected from the Addis Ababa Police Commission between the same years. The crashes registered for three years were in hardcopy and it includes time of day, day of the week, education, age and gender of drivers, driving experience, driver's relationship with vehicle, vehicle service years, vehicle type, vehicle ownership, road type, median and junction types, terrain, pavement type, pavement conditions, illumination, weather conditions, casualty type, causes for the crash and crash locations. The data gathered was a prepared manually and transferred into an Excel file format for the crash frequency analysis.

CANDIDATE VARIABLES IDENTIFICATION IN THE MODEL

The main target of getting effective parameters was to select influencing variables with the available data to develop a more realistic model. The effective explanatory and exposure variables that influence the road traffic crashes was evaluated by statistical analysis method. Table 3.3 shows the independent candidate variables (major road alignment and cross-section) suggested for the crash prediction model. The main road characteristics used for the analysis are described in the following sections.

Road traffic crash frequency is defined as the number of crashes occurring within a specific jurisdiction, on a roadway segment, or at an intersection. A number of road traffic crashes is used as a response variable (or dependent) variable. Traffic volume is the number of vehicles that pass a given point on the roadway in a specified period of time. The average of the seven days counts is considered as average daily traffic (ADT) which is primarily computed from peak hour volume and k factor in this study. The K factor is defined as the proportion of average daily traffic occurring in an hour. This factor is used for designing and analyzing the flow of traffic on highways.

Peak hour volume is the maximum number of vehicles that pass a point on a highway during a period of 60 consecutive minutes. By counting the number of vehicles that pass a point on the roadway for a duration of an hour (15-minute interval); it is possible to arrive at the 15-minute maximum volume. Then, 15 minute (quarter volume) is converted to peak hour volume.

IV GEOMETRICAL DESIGN ELEMENTS ON TRAFFIC ACCIDENTS

CROSS-SECTION EFFECTS

The widths of the various cross-section elements affect the capability of the driver to perform evasive manoeuvres and determine the lateral clearances both between vehicles and between vehicles and other road users. In the existing literature are mentioned especially the following parameters:

LANE WIDTH

Wider lanes are traditionally associated with higher operating speeds and increased safety. The Highway Capacity Manual (HCM) documents that wider lanes for multilane highways result in higher free-flow speeds. On the other hand, very little has been found on the safety implications of wider lanes. It is reasonable to assume that wider lanes may provide additional space to the driver to correct potential mistakes and thus avoid crashes. However, a driver could be expected to adapt to the available space, and the positive safety effects from the wider lanes may be offset by the higher speeds. Generally, most studies agree that lower accident rates are attributed to wider lanes. But it seems that there is an optimal lane width around 3.5m. Studies have also noted that approaches should base on more parameters of the cross section, at least also on traffic volume. However, Hearne's results suggested that there was a marginal increase in accident occurrence with an increase in carriageway width. Hedman noted that some results indicated a rather steep decrease in accidents with increased width of 4m to 7m, but that little additional benefit is gained by widening the carriageway beyond 7m. Zeger, Zeger/Council, and Mclean have shown that width of 3.4□3.7m show the lowest accident rates. This is supported by the NCHRP Repot 197 conclusion that there is little difference between the accident rate for 3.35m and a 3.65m lane width. However, studies on low volume rural roads indicate that accidents continue to reduce for widths greater than 3.65m, although at a lower rate. TRB pointed out lanes wider than 3.70m do not contribute to a higher safety because they may result in unsafe maneuvers such as over taking despite of oncoming traffic. Another reason is the higher speed on wider lanes which leads to more accidents. Yagar and VanAerdo found that the passage of a vehicle requires a minimum lane width and that any additional width beyond this minimum allows one to drive faster and /or with a greater measure and perception of safety. For lane widths from 3.3m to 3.8m, they reported that the operating speed is decreased by approximately 5.7 km/hr for each 1m reduction in width of the road. Lamm et al. found a significant decline of accident rate up to 7.5m cross sections. Council/Stewart analysed data of four US states to develop a prediction model for non- intersection and non-intersection related accidents. The results were statistically for two states only and indicate huge differences regarding the benefits of widening cross sections. In North Carolina widening the surface by 1m reduces accidents by 14%, in California by 34%. Elvik et al. also figured out a decline of accident cost rates if the cross section is widened by a maximum 3m. Wider cross sections are not attributed by positive influence on road safety. All mentioned works have pointed out a decline of accident risk for wider cross sections. This positive trend is proven up to a certain lane width, wider cross sections are characterized by a lower safety benefit or even by increasing accident risk

The results showed that drivers were poor at evaluating actual road conditions. Less than 30 percent of the evaluations coincided with the measured values, and more than 27 percent differed by 2 to 3 the categories listed above. According to the study, as the friction value decreased, the relationship between the driver's estimate of friction and actual conditions increased. Consequently, the skid resistance of the pavement did not have a significant influence on driving speed. In 1984, the international Scientific Expert Group on Optimizing Road Surface Characteristics of the (OECD (Organization for Economic Co-operation and Development indicated that in the U.S. any reduction in friction was associated with a steady increase in accidents. Detailed analyses revealed a linear crash-skid resistance relationship as the proper function for interpreting the data. This behavioral function conflicts with other relationships obtained from Europe. A study of high-speed rural roads in Germany suggested a non-linear relation, with a higher slope for low friction values than for high friction values. Wallman and Astrom [69] also reported a similar regression analysis in Germany by Schulze [72]. Another study described by Wallman and Astrom with similar behaviour is the Norwegian Veg-greosprosjektet. In this study, comprehensive friction measurements and roadway observations were completed resulting in the assessment of crash rates for different friction intervals as summarized

BEHAVIOURAL ASPECTS

The bad road behavior and attitude of the Kenyan road eg drunk driving, speeding, jay walking, disregard of the laws, impunity/careless and dangerous driving etc.

Fairly Low levels of Road Safety Awareness amongst road users in INDIA.

2. Insufficient funding for Road Safety-

With the increased lengths of the paved roads coupled with the increasing population and motorization, the exposure to crashes will increase as well.

The need to have commensurate increase in the levels of funding for sustainable road safety programmers.

Road safety is an expensive venture which requires sufficient funding to undertake road safety programmers.

3. Road engineering challenges-

Inadequate facilities for pedestrians, non-motorized & intermediate means of transport.

Inadequate treatment of black spots

4. Inadequate enforcement power-

To support and complement education and engineering measures.

NTSA currently relies on other agencies to support its enforcement operations.

(Greater collaboration and cooperation with the appropriate government agencies as a way forward)

5. Corruption-related challenges

6. Court outcomes on traffic offences that does not serve to deter traffic offenders.

7. Emerging and increasing Boda-related challenges.

8. Challenges in the county governments in supporting transport and safety

eg: Urban planning and land use

Allocation of bus stages and parking lots,

Boda boda enforcement,

Encroachment of small-scale traders along the highways, hawkers thereby increasing the human-vehicular conflict;

Vandalism of road signs.

V CONCLUSION

After reviewing on the many studies which are related the safety of cross-section and alignment elements can be concluded the following:

Lane and shoulder conditions directly affect run-off road (ROR) and opposite direction (OD) accidents. Other accident types, such as rear-end and angle accidents, are not directly affected by these conditions.

The presence of a median has the effect of reducing specific types of accidents, such as head-on collisions. Medians, particularly with barriers, reduce the severity of accidents

Rates of ROR and OD accidents decrease with increasing lane and shoulder width. However, the marginal effect of lane and shoulder width increments is diminished as either the base lane width or shoulder width increases.

On multilane roads, the more lanes that are provided in the travelled way, the lower the accident rates.

Shoulder wider than 2.5m give little additional safety. As the median shoulder width increase, accidents increase.

From the limited information available, it appears that climbing lanes can significantly reduce accident rates.

Lane width has a greater effect on accident rates than shoulder width.

Larger accident rates are exhibited on unstabilized shoulder, including loose gravel, crushed stone, raw earth or turf, than on stabilized (e.g. tar plus gravel) or paved (e.g. bituminous or concrete) shoulders.

The probability of an accident two-lane rural roads is highest at intersections, horizontal curves and bridges. The average accident rate for highway curves is about three times the average accident rate for highway tangents.

Horizontal curves are more dangerous when combined with gradients and surfaces with low coefficients of friction. Horizontal curves have higher crash rates than straight sections of similar length and traffic composition; this difference becomes apparent at radii less than 1000 m. the increase in crash rates becomes particularly significant at radii below 200 m. Small radius curves result in much shorter curve lengths and overall implications for crashes may not be as severe as would first appear.

There is only a minor decrease in the speed adopted by drivers approaching curves of radii which are significantly less than the minimum radii specified for the design speed. However, curve radii below 200 m have been found to limit the mean speed to 90 km/hr.

The average single vehicle accident rate for highway curves is about four times the average single vehicle accident rate for highway tangents.

Regarding general terrain descriptions it was found that accident rates in mountainous terrain can be 30 percent higher than in flat terrain.

Crashes increase with gradient and down-gradients have considerably higher crash rates than up-gradients. However, the overall crash implications a steep gradient may not be severe since steeper gradients are shorter. The geometry of vertical curves is not known to have a significant effect on crashes severity.

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