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Effect of geometric elements on Accidents' Rates

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Abstract:- This paper presents a categorization of accidents in Al-Sail Road in Taif city in KSA. The paper develops a number of statistical models that can be used in the prediction of the expected number of all of these categories of accidents.

Keywords:- Road Geometry – Highway Safety- Accidents Models- KSA.

I. INTRODUCTION

Traffic accidents have been recognized 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, [4]. In KSA, the problem of traffic accidents is very huge to the extent that more than 500000 accident was recorded during the year 2012. 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, [7]. 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 more safer, [9]. Much existing literature addresses the problem of accident rate estimation, and the identification of the various factors affecting this rate. Researchers have attempted three approaches to relate accidents to geometric characteristics and traffic related explanatory variables: Multiple Linear regression, Poisson regression and Negative Binomial regression, [6]. Various models have been intensively tested and validated ([3]; [10]; [8]). The adjustment of the models is based on historical accident data and on the characteristics of experimental sections selected from the road network. For example, Multiple linear and Poisson regression were used by [5] in order to estimate accident rates using traffic and geometric independent variables. Moreover, [10] developed a model to identify the most significant traffic and geometric elements in predicting accident frequency. They used both the Poisson and negative binomial regression models.

For this concern, the present study was to targeted to formulate practicable accident prediction models which would describe the expected number of accidents in the Saudi environment as accurately as possible. Furthermore, the models were to be used to identify factors affecting safety, e.g. geometry, land use, etc. Unlike the used models, which were based only on traffic flows, this study was to include additional explanatory variables in the modelling.

II. DATA COLLECTION

In order to study effect of the physical and operational geometric elements of roadways on accidents' rates, data collected for a specific roadway as a case study. This is to develop some predictive models representing the relationships between the operational and physical elements of roadways on accidents' rates. Detailed information on accident data, traffic flow and geometric elements of roadways were collected.

A. Roads data

A four lane rural road, two ways, divided was selected to be investigated as a case study. This road is running from Taif city to Mecca city in KSA. This road is named as Al-Sail road. A section of length of 30 Km of this road was taken into consideration. This section was divided into 30 subsections for further studies.

B. Accidents data

Accidents data of the specified 30 subsection of the investigated road was collected from the official database of accidents' statistics from Safety Management Administration of Taif city. The collected data represents all possible data on the accident, including a small text description of the nature and location of each accident . A 5 years accident period was used starting from year 2009 to year 2013. Traffic flow counts belong to the years 2009 to 2012 were collected from the road sector of Taif city governorate. However, the traffic flows of the year 2013 were collected by the research team during the study preparation.

C. Trends of Accidents

Collected accidents data was categorized based on accidents casualties. Fig. 1 shows the total number of accidents, the number of injuries and the number of deaths reported for the considered section of the investigated road.

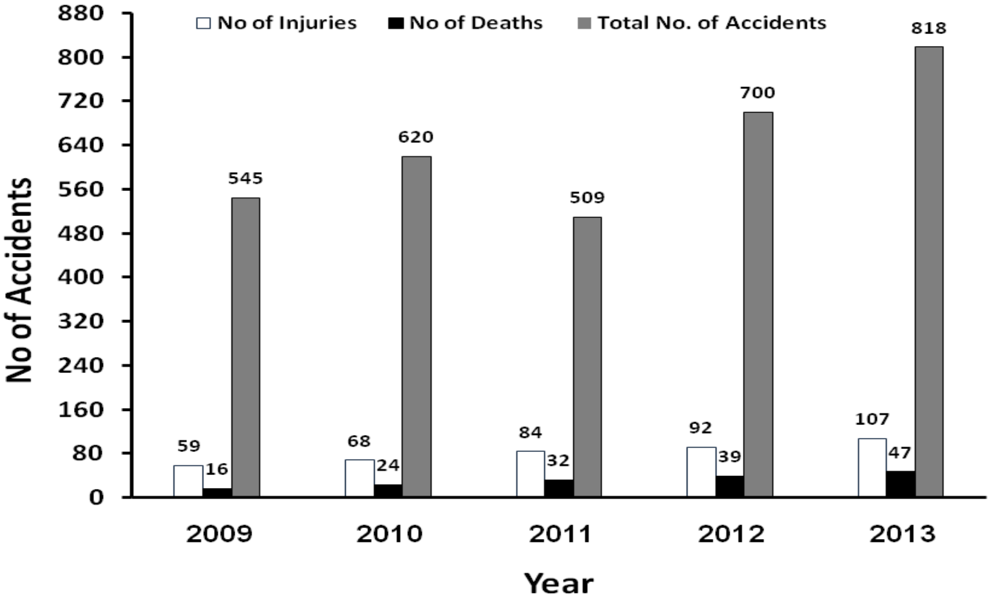

Fig. 1: Accidents Casualties and Total Number of Accidents for the Investigated Road

It is clear that there is no definite trend for the total number of accidents while, the number of injuries and deaths are increasing from year 2009 to 2013 for both roads. This means there is an urgent need to study the accidents causes in the investigated road and subsequently, decreasing such increased rates of injuries and deaths. On the other hand, accidents rates were further categorized based on the severity of damage caused by the accident. This categorization is starting from fatal accidents cases, moving through serious injuries, slight injuries and only damage. Unfortunately, it was observed that the rates fatal, serious and minor accidents are increasing from year to year as shown in Fig. 2. This is another motivation for the present study to search for the causes of these increasing rates of accidents under different categories.

Regression analysis is used to correlate dependent and independent variables. These variables were specified base upon the number of accidents happened in the past 5-years. Accidents' rates were categorized into 4 groups, namely total, fatal, injury and damage accidents' rates. Each rate was designated hereafter with the following symbols

- Total Accident Rate (TAR)
- Fatal Accident Rate (FAR)
- Injury Accident Rate (IAR)
- Damage Accident Rate (DAR)

These rates were considered as dependent variables while, a group of independent variables were specified that mainly related to the physical features of geometric design elements of highways over a section of the highway of length (L). These variables include [1] and [2].

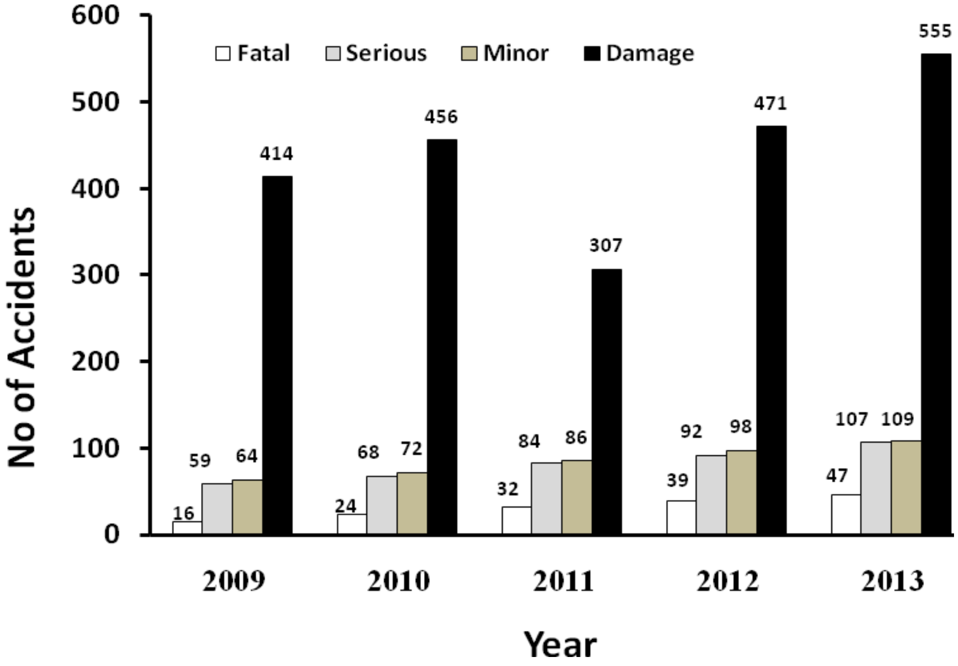

Fig. 2 Classification Accidents as per Caused Severity Level for the Investigated Road Analysis Methodology

- Average Curvature (AC)
- Average Gradient (AG)
- Number of Horizontal Curves in the considered section. (HC)
- Number of Vertical Curves in the considered section. (VC)

Moreover, the operational parameters of this road were referred to the average annual daily traffic (AADT) passes through different subsections of the investigated road.

A set of statistical models were developed to predict the expected numbers of accidents, injuries, fatalities and casualties. Initially, individual models were developed between each category of accidents and different specified independent variables. The data used for the calibration of these models spanned over a period of 5 years (2009–2013). To establish the goodness of fit and statistical significance of the calibrated models two statistical measured were computed, namely, the R2 and the F statistics.
On the other hand, the "Multiple Linear Regression" method was used in order to develop a general model which relates both the physical and operational parameters with different categories of accident rates. The theoretical model of accident rate is represented by Eq. 1.

$$\text{Accident Rate} = a_0 + a_1x_1 + a_2x_2 + \ldots\ldots + a_nx_n \quad (1)$$

Where:
the dependent variable (accident rate) may be TAR or FAR or IAR or DAR while, all the independent variable are X_1, X_2 and X_n that represent the physical and operational parameters of the roadway.
The coefficients a_0, a_1 to a_n are the regression coefficients to be estimated in terms of the error representing the residual difference between observed and predicted model value.

III. RESULTS AND DISCUSSIONS

As illustrated earlier, data which was taken during the study was analyzed to develop some models. Before the data was analyzed in both models, all the parameters were firstly analyzed in order to determine whether the parameters were significant or not. These models were calibrated using 30 data points. The analysis shows that there are obvious relationships between different categories of traffic accidents and the physical and operational elements of roadways.

Table 1: Models relating Different Categories of Accidents with physical and Operational Parameters of Al-Sail Road, KSA

Independent Variable	TAR	FAR	IAR	DAR
AADT	TAR = 0.0002AADT +36.95	FAR = 0.0002AADT -2.72	IAR = 0.0002AADT +5.63	DAR = 0.001AADT +41.88
	R^2= 0.58, F=30.39, Sign.	R^2= 0.81, F=91.86, sign.	R^2= 0.71, F=52.87, Sign.	R^2= 0.64, F=38.66, Sign.
AC	TAR = 12.13AC+64.82	FAR = 1.15AC+0.64	IAR = 1.26AC+10	DAR = 8.46AC+61.66
	R^2= 0.52, F=22.75, Sign.	R^2= 0.63, F=36.73, Sign.	R^2= 0.73, F= 44.4, Sign.	R^2= 0.6, F=32.71, Sign.
AG	TAR = 1650.5AG+38.76	FAR = 156AG-1.99	IAR = 170.5AG+7.33	DAR = 1112.8AG+40.92
	R^2= 0.51, F=23.17, Sign.	R^2= 0.66, F=41.61, Sign.	R^2= 0.47, F=19.13, Sign.	R^2= 0.55, F=27.13, Sign.
HC	TAR = 16.51HC+22.26	FAR = 1.56HC-3.56	IAR = 1.71HC+5.63	DAR = 11.46HC+32.26
	R^2= 0.51, F=23.17, Sign.	R^2= 0.63, F=37.58, Sign.	R^2= 0.57, F=27.19, Sign.	R^2= 0.65, F=38.19, Sign.
VC	TAR = 16.51VC+55.27	FAR = 1.72VC-0.44	IAR = 2.01VC+9.04	DAR = 13.01VC+55.17
	R^2= 0.55, F=26.47, Sign.	R^2= 0.68, F=41.36, Sign.	R^2= 0.53, F=25.31, Sign.	R^2= 0.58, F=31.26, Sign.

The above developed models proved to be significant. However, it should be pointed that, in using such models for future forecast one has to be careful as this entails extrapolating outside the range where the real observations were made. These models can be used for short-term forecast of 1–3 years. It is advisable that whenever data is available, these models should be updated through recalibration.

The developed general models revealed acceptable level of correlation and all models proved to be significant. However, the coefficient corresponding to the number of horizontal curves was vanished in all models. This may be acceptable since, the alignment of the investigated road include very little number of horizontal curves. Equations 2 to 5 represent the developed general models relating the physical and operational parameters of roadways.

TAR = 103.07+46.13AC-2470.37AG-37.08VC+0.002AADT (2)
R^2 = 0.62, F= 7.73 (Significant)

TAR = -0.54+2.02AC-61.93AG-2.4VC+0.0002AADT (3)
R^2 = 0.81, F= 20.82 (Significant)

IAR = 10.44+4.53AC-146.14AG-5.94VC+0.0003AADT (4)
R^2 = 0.76, F= 14.79 (Significant)

DAR = 47.1+8.36AC+82.71AG-10.46VC+0.001AADT (5)
R^2 = 0.64, F= 8.61 (Significant)

IV. CONCLUSIONS

Many factors are effective in traffic accidents that are the criteria for highway safety. Road geometric design elements are effective factors on highway safety. As the relationships between highway safety and road geometric design elements (physical elements) and operational parameters like, the daily traffic using such roadway are considered, some relationships can be developed. In the present study conducted on a rural road in KSA, it became evident that there is a lack of past sustainable and detailed accident data collection programs as well as a lack of accident prediction models. The research developed a number of statistical models that can be used in the prediction of the expected number of accidents, injuries, fatalities and casualties on the rural roads in

KSA. Such models are meant to establish the relationships between the number of accidents, casualties fatalities, injuries as the dependent variables and other independent variables representing physical elements of roadways like, average curvature, average gradient, number of horizontal and vertical curves and also, the traffic exposure, such as AADT

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