Traffic Accidents At Hazardous Locations of Urban Roads

Conference Paper · June 2012

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ABSTRACT

The study aims at highlighting the most contributing and influential factors to accidents occurrence at hazardous locations of local urban roads, and correlating accidents characteristics to different factors including geometric elements, traffic speed, pavement type, lighting conditions, type of collisions, pedestrian facilities existence, and traffic conditions.

The study was conducted using twenty-eight hazardous locations at Amman-Jordan roads. Each of the hazardous locations had at least twenty accidents and two fatality records per year. Data were collected through different sources that included Great Amman Municipality, Traffic Institute, Police Traffic Department, and field studies. Different stepwise statistical regression models were developed to correlate accident characteristics with the studied variables. It was found that the logarithmic and linear models were the most significant and realistic models that can be used to predict the relationship between the accident characteristics as dependent variable and the other studied variables as independent variables. The developed models were strong and predictable because the coefficient of multiple determinations was very close to the adjusted coefficient of multiple determinations. The following variables were found to be the most significant contributors to traffic accidents at hazardous locations: average running speed, posted speed, maximum and average degree of horizontal curves, number of vertical curves, median width, type of road surface, lighting (day or night), number of vehicles per hour, number of pedestrian crossing facilities, and percentage of trucks.

The study could open the door for planners and traffic engineers to overcome the problems associated with traffic accident occurrence at hazardous locations and enhance their safety. The developed models showed that accident characteristics such as numbers of accidents, numbers of fatalities, numbers of injuries, type of accidents, and number of vehicles involved in accidents, and statistics of hazardous locations could be predicted if the traffic conditions, geometric elements, and environmental variables are known. The study could also be enhanced if incorporated with drivers' characteristics including socio-economic data.

KEY WORDS: Hazardous Locations, Traffic Accidents, Geometric Elements of Roads, Statistical Models, and Urban Roads.

1 INTRODUCTION

Highway safety at a roadway and roadside features is mainly affected by human factors (including driver ability, driver performance, driver knowledge, and awareness), environmental factors, and vehicle characteristics. However, there are other factors such as highway design and its associated geometry that also have a tangible impact on safety (AASHTO, 2004).

However, the three major factors those associated with fatal vehicle accidents are driver behavior, vehicle characteristics and roadway design. It is estimated that roadway design is an important factor in one-third of all fatal and serious traffic accidents (TRIP, 2009). Therefore, improving safety on roadways can be achieved through further improvements in vehicle safety; improvements in driver, pedestrian, and bicyclist behavior; and a variety of geometric design improvements in roadway safety features.

The primary indicator uses in ranking the severity of the road safety situation is fatalities per 10,000 registered vehicles (Traffic Safety Bureau, 2005). Average fatalities per 10,000 registered vehicles in Jordan were 13 for the last three year. This rate is about 6 to 8 times of the industrialized countries like USA or Sweden (Obaidat *et al*., 2008; Al-Khateeb *et al*., 2008; and Khedaywi *et al*., 2008).

In developing countries, accident number and type are mainly registered for the drivers to be the cause of accident regardless of the real cause of the accident. Neither the roadway geometry nor the environment is considered as a cause for accident, simply because there is an ambiguity of the accident's cause for the police officer who will register the accident.

One of the major topics of roadway safety in urban areas is to predict the numbers, types, and severities of different types of accidents as functions of geometrical, behavioral and environmental factors. Prediction models related to accidents at hazardous locations could give clear indications for traffic safety issues at urban roads. Further, it would identify the significance of each variable and its contribution to accidents, and distinguish the overlap between the geometric and behavioral factors.

This study attempts at predicting the numbers of accidents, and their types and severities based on geometrical road elements, environmental factors, and driver's behavioral issues like speed. Moreover, it will tackle the most influencing and contributing factors to traffic accidents at hazardous locations at urban areas.

2 LITERATURE REVIEW

Highway geometry should be designed for vehicle traffic safety and efficiency, particularly on the trunk roads or Expressways on which traffic function must be most important. For example, minimum radius of horizontal curve is defined with design speed, superelevation and side slip friction factor. The value of the side slip friction factor used in any design standards, such as AASHTO Green Book (AASHTO, 2004) is not clearly determined with changes according to the road surface condition, such as dry, wet, or snowy surface. The authors insist that all of the design values should have a unique safety factor to keep consistent traffic safety.

Studies showed that horizontal curves typically have crash rates from 1.5 to 4 times higher than tangent sections. In fact, crash rates tend to increase with the reduced sight distance associated with either a reduced curve radius or an increased deflection angle or curvature. Therefore, it is usually beneficial to design horizontal alignments with combinations of maximum curve radii and minimum deflection angles. On the other hand, the use of composite curves; i.e. spiral curves and simple circular curves, could help to mitigate some of the safety problems associated with horizontal curves by providing a smooth and safer path for driver from tangent to curve position and a location for the required length of transition from normal crown to full superelevation pavement (NCHRP, 2003 and AASHTO 2004).

Vertical alignments can also lead to higher crash rates due to the reduced sight distance imposed by the crest of a vertical curve. Therefore, the severity of vertical curvatures is minimized. Avoidance of intersections on or near vertical curves represents one of the practical examples in this domain.

Conflicts in roadways are mainly contributed by intersections. Medians, auxiliary lanes, and protected left-turn phasing signals are some of the safety measures that can reduce conflicts. Enlarging the corner radius can increase the roadway crossing width that makes it difficult for pedestrian crossing and allows for increased vehicle speed around intersection corner. However, decreasing radius can cause maneuverability problems for large vehicles (MUTCD, 2003).

Loo (2009) analyzed the spatial characteristics of road crashes in Hong Kong by the hot zone methodology and compared with the blacksite methodology. His study was important both theoretically in enriching conceptualizing and identifying hazardous road locations and practically in providing useful information for addressing road safety problems.

McCarthy (2001) made an empirical review on literature to study the effect of motor vehicle speed limits on highway speeds and highway safety. Among the findings of his research, small speed limit changes on non-limited-access roads will contribute little effect on speed distribution and highway safety unless complemented with speed-reducing actions. Implications for further research relate to the importance of controlling for confounding factors, aggregation, and the importance of enforcement in affecting speed distributions and highway safety.

Hong and Oguchie (2005) evaluated the values of operating speed with highway design elements such as curvature of horizontal radius and vertical grade.

Mungnimit, S. (2001) and Bener (2005) explored the pattern of road traffic accidents and their causes in developing countries. They took Thailand and State of Qatar as representative examples for developing countries. Results of their research showed that the major cause of traffic accidents was careless driving (71%). The majority of accidents victims (53%) were in the most productive class in society; i.e. age group 10 to 40 years. Deaths due to road traffic accidents were the third leading cause of death after the diseases of the circulatory system and cancer. Therefore, they suggested controlling the epidemic of road traffic injuries through strict policy interventions, mass media, road safety program, and a national traffic campaign to increase the use of seat belt (Obaidat *et al*., 2008; Al-Khateeb *et al*., 2008; and Khedaywi *et al*., 2008).

Khorshid and Alfares (2004) found the optimum speed control hump geometric design by using the sequential quadratic programming method. The speed hump design can be improved in terms of not only the hump dimensions but also the hump profiles in the rise and return stages. Therefore, the polynomial hump has the best design because of its profile flexibility.

The severity of serious traffic crashes at hazardous locations could be reduced through roadway improvements, where appropriate, such as adding turn lanes, removing or shielding obstacles, adding or improving medians, widening lanes, widening and paving shoulders, improving intersection layout, and providing better road markings and upgrading or installing traffic signals. Literature showed that geometric design improvement can reduce fatal accident rate. For examples, fatal reduction rate of installation of new traffic signal reaches 53%, turning lanes and traffic signalization 47%, widen or modify bridge 49%, construction median for traffic separation 73%, realign roadway 66%, remove roadside obstacles 66%, and widen or improve shoulder 22%. Roads with poor geometry, with insufficient clear distances, without turn lanes, inadequate shoulders for the posted speed limits, or poorly laid out intersections or interchanges, pose greater risks to motorists, pedestrians and bicyclists (TRIP, 2009).

Therefore, this paper will focus on hazardous locations in urban areas and the correlation of accidents characteristics with geometrical elements of the roads, and other factors such as driver's behavioral issues like speed, traffic safety factors, and environmental factors.

3 TRAFFIC ACCIDENTS IN JORDAN

Jordan, of a population about six millions, has about one million vehicles. Jordan accidents statistics showed that traffic crashes were the first cause of death. Official data shows that the human factor's share; that is represented by the drivers and their behavioral mistakes, reached up to 90% of the accident's responsibility. Further, statistics showed that more than 85% of the drivers' mistakes were due to speeding; i.e. about 77% of crashes causes were due to speeding. However, vehicles, road geometry, and environmental factors share of accidents' percentages didn't exceed a 10% (Jordan Traffic Institute Report 2008; and Obaidat *et al*., 2008). Of course, these statistics are misleading because many accidents occur due to geometrical problems; however, officials consider them due to drivers' fatal mistakes. Therefore, this study will focus on the contribution of geometrical factors on traffic accidents using a statistical modeling approach.

The accidents' percentages for 12 Jordanian governorates for the year 2008 were 94.5% for vehicles' crashing, 3.7% for pedestrians' accidents, and 1.8% for flipping over accidents. Most of these accidents fatalities were due to changing lanes while driving; that shares about 42% of the accidents' percentages. Of course, lane numbers, road furniture, and geometrical elements do have relationships with number and type of accidents (Obaidat *et al*., 2008; Al-Khateeb *et al*., 2008; and Khedaywi *et al*., 2008).

Since Amman, the capital of Jordan, has more than 50% of the Jordanian population and vehicles, it has about 66% of Jordan accidents. The percentages of different categories of Amman's accidents with respect to the other eleven governorates were 20% of flipping over because it is an urban area, 68% of vehicles' crashes, and 39% of pedestrians' accidents. Therefore, this study was conducted for hazardous locations in Amman roads (Jordan Traffic Institute Report 2008).

The most important accident causes are crashes and flipping over accidents because they are correlated with geometric design elements of the roads.

4 HAZARDOUS LOCATIONS

Geographic Information Systems (GIS) concepts and methodologies were used to identify the hazardous locations in Amman-Jordan. The threshold values for number of accidents and fatalities used to define the hazardous locations were twenty and two, respectively. Table 1 shows the names and locations, number of accidents, injuries and fatalities of the studied hazardous locations that represent the yearly average of the years 2005-2008. However, Figure 1 shows the streets' network contains the studied hazardous locations. Two examples of these locations are shown in Figure 2 for Al-Madina Al-Monawarah Street. The hazardous locations form black spots areas for traffic accidents where frequent repetitions of accidents happen mainly on them. The locations represent a length or area rather than spot locations because there is a lack of this piece of information. However, a recent service has been launched at the police traffic department that shows the exact three-dimension (3-D) accident's location using portable Global Positioning Systems (GPS) units. Great Amman Municipality regularly makes some geometric enhancement on them to control traffic movement, while the locations are always under traffic control and police patrol by the traffic department.

It is worthwhile mentioning here that the definition of hazardous locations is different from a country to another and depends on number of fatalities or injuries threshold values as well as other geometrical and traffic conditions factors.

Table 1: Hazardous Locations in Amman-Jordan.

Location Number	Street Name	Number of Accidents	Number of Injuries	Number of Fatalities
1	Abu Alanda Street	52	72	2
2	Airport Street (Naoor to Yadodah)	45	63	6
3	Madaba Street (Kraibt Al-Sog to Yadodah)	36	60	3
4	Kraibt Al-Sog Street	24	28	2
5	Al-Steen Street	48	75	8
6	Sahab Main Road	43	51	3
7	Airport Street (Seventh to Eight Roundabouts)	104	153	7
8	Al-Shaheed Street (Workshops to Tabarbor)	26	45	3
9	King Abdullah the First Street (AlMahatah to Airport)	22	42	5
10	Military Street (Pepsi to Marka)	24	60	6
11	Military Street (Marka to Ain Gazal)	41	70	3
12	Military Street (Ain Gazal Bridge to Ain Gazal Signal)	24	46	3
13	Military Street (Al-Mahata to Ragadan)	60	96	2
14	Ring Road (Pepsi to Coca Cola)	30	49	5
15	Ring Road (Coca Cola to Salheiat Al-abed)	27	30	2
16	Ring Road (Salheiat Al-abed to Al-Shaaer)	27	37	5
17	Almanarah Street	29	31	2
18	Al-Madina Al-Monawarah St. (University -Al-Youbel)	26	34	2
19	Wasfi Al-Tal Street (Kalda to Al-Youbel Roundabout)	28	31	2
20	Queen Rania Street (Traffic Dept. to University)	26	33	8
21	Queen Rania Street (University Signal to Bridge)	49	62	3
22	Arar Street	35	54	4
23	Zahran Street (Seventh to Sixth Roundabout)	20	20	2
24	Independent Street (Interior Roundabout to Bridge)	26	29	3
25	Prince Al-Hasan Street	21	26	2
26	Al-Madina Al-Monawarah (Al-Youbel - Al-Haramain)	28	31	2
27	Wasfi Al-Tal Street (Al-Youbel to Safeway)	62	64	3
28	Queen Alia Street	24	35	2

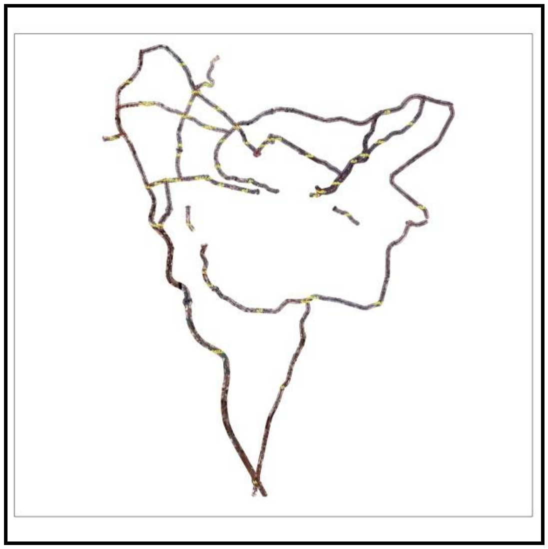

Figure 1: Streets' Network having the Studied Hazardous Locations in Amman.

Figure 2: Examples of Hazardous Locations at Al-Madina Al-Monawarah Street.

5 DATA COLLECTION

To achieve the objectives of this paper, data was collected and integrated from different sources and from the field, too. The followings are the main approached agencies and their associated data:

1. Jordan Traffic Institute and Traffic Department: The followings data were obtained for roads that contain hazardous locations: Number of vehicles involved in accidents (NVA), Numbers of accidents (NA); injuries (NI); and fatalities (NF) for hazardous locations; type of accidents (collision/crash, pedestrian (FP for fatalities, IP for injuries, and SP number of slight injuries caused by pedestrian accidents), or turnover/flipping over) and their associated numbers of fatalities (FC fatalities for collision, IC injuries for collision, FT fatalities for turnover, and IT injuries for turnover), severe injuries collision (SEIC), slight injuries collisions (SLIC), severe

injuries pedestrian accidents (SEIP), slight injuries pedestrian accidents (SLIP), severe injuries turnover (SEIT), slight injuries turnover (SLIT), and number of accidents (NAC); type of road surface (dry, wet, or unpaved); lighting conditions and time of accident (night and day); and type of collisions for each type of accident (tail gating, incorrect lane usage, sudden swerve, failing to take measures, disallowing priority to vehicle, exceeding speed limit, driving opposite to traffic, incorrect bending, failing to comply with obligatory signs, or brake failure).

2. Greater Amman Municipality: Degree of curvature based on arc definition (D_a) for horizontal curves, maximum and average degree of curvature (D_{max}; and D_{ava} respectively), median width (MW), roadway sketches and dimensions, and aerial photographs for hazardous locations.

3. Field Data Collection: Field surveys using different surveying instruments and inventories were conducted to find the followings: Road name, Road zone or location, Traffic count (Average Daily Traffic (ADT)), Numbers and percentages of vehicles (passenger cars (PC), buses (B), and trucks (T)), minimum and maximum posted speed limit (V_{min} and V_{max} respectively), number of lanes (NL), width of each direction of the road (W), divided or undivided road (DR and UR respectively), median width and type (MW), number of pedestrian crossing facilities (Overpass (PO), underpass (PU), or marked pedestrian crossing (PM)), numbers and types of horizontal and vertical curves (NHC and NVC respectively), and minimum and maximum grade of vertical curves (G_{min} and G_{max} respectively).

6 ANALYSIS OF RESULTS AND FINDINGS

SPSS software statistical package was used to perform the statistical analysis of this research work (George and Mallery, 2009). Stepwise regression analysis procedure was used to predict statistical models that have the capability of determining the values of dependent variable (numbers, types, and severities of accidents) using different observations of independent variables (geometrical, behavioral and environmental factors). Multiple regression analysis was applied to find the relationship between several independent variables or predictor variables and a dependent or criterion variable. The selection of best models used the general goodness of fit represented by coefficient of simple and multiple regression determination (R^2), general linearity by applying F-test, significance of individual variables through t- or F-test, normality of residual distribution and consistency of variance, and standard error of estimate.

The statistical characteristic of the developed linear models are shown in Table 2, whereas the models associated with the logarithmic function are shown in Table 3. As shown in these tables, the developed models were statistically significant at α-level less than 0.05 with R^2 around 99% to 100% which can be considered relatively high. Moreover, the differences between R^2 and adj. R^2 were relatively very small, which is an indication that the models are strong and predictable. The models had small standard errors of estimates. This means that the accidents characteristics can be predicted and explained by the included independent variables.

Based on these findings, the models shown in Tables 2 and 3 could be used to predict the accidents characteristics at urban roads. These models could be applicable and employed by the highway and traffic engineers to estimate or predict the occurrence of accidents' numbers and types while they are at early design stages of the roads.

Table 2: Developed Linear Models and their Associated Statistical Characteristics.

Dependent Variable	Independent Variables	Developed Equations	R^2	Adjusted R^2	Signi-ficance
Number of Accidents (NA)	DRY (Type of surface) WET (Type of surface) Unpaved (Type of surface)	NA = 0.0590+ 0.995*Dry+ 0.988* Wet + 1.025*Unpaved	1	1	0.000
Number of fatalities in all accidents (NF)	DRY (type of surface) WET (type of surface) UNPAVED (type of surface) NIGHT (Lighting) DAY (Lighting) VPH (vehicle per hour) PC (% of cars) B (% of buses) T (% of Trucks) V (posted speed in km/hr) V_{Avg} (average speed on road) NL (number of lanes) W (width of one way) MW (width of median) PO and PU (# of pedestrian bridges) PM (# of markers for pedestrian walk) NHC (# of horizontal curves) NVC (# of vertical curves) D_{max} (maximum of Da) D_{ava} (average of Da)	NF=+67.423+0.292*Dry+0.0902*Wet+0.715*Unpaved+0.05376*Night-0.413*Day-0.00065*Vph-0.377*PC-0.663*B-0.287*T-0.0714*V-1.142*VAvg-1.617*NL+0.353*W-0.214*MW+0.803*PO+0.138*PM-0.538*NHC+0.428*NVC+1.392*D_{max}-1.547*D_{ava}	0.884	0.880	0.026
SEIC (Number of severe injuries caused by collision accidents)		SEIC=362.108+1.86*DRY+1.75*Wet+7.09*Unpaved-1.56*Night-1.71*Day-0.0026*VPH-3.10*PC-2.00*B-2.97*T-1.38*V -0.35*VAvg+0.56 *NL -0.08*W-1.20*MW+1.41*PO-0.34*PM-4.04*NHC+3.38NVC+3.92*D_{max}-4.163D_{ava}	0.971	0.950	0.015
NAC (number of accidents caused by Incorrect Lane usage by pedestrian)		NAC=-9.369+0.05468*Dry+0.04532*Wet-0.256*Unpaved-0.0269*Night-0.00002765*Day+0.02765*Vph+0.08721*PC+0.05329*B+0.08171*T-0.00985*V+0.01030*VAvg+0.04138*NL+0.03174*W+0.103*MW+0.006026*PO-0.128*PM-0.0303*NHC-0.00388*NVC+0.07062*D_{max}-0.115*D_{ava}	0.814	0.804	0.005
NAC (Number of accident caused by collisions)	Dry (type of surface) Wet (type of surface) D_{ava} (average of Degree of curvature)	NAC= -7.487+0.596*Dry+ 1.573*Wet+1.028*D_{ava}	0.919	0.909	0.000

Table 3: Developed Logarithmic Models and their Associated Statistical Characteristics.

Dependent Variable	Independent Variables	Developed Equations	R^2	Adjusted R^2	Signi-ficance
NF (Number of fatalities)	Night (Lighting) VPH (vehicle per hour) V_{avg} (average speed in km/hr) D_{ava} (average of Da)	NF=-9.67+ night *log1.05- Vph *log.12+V_{avg}*log5.97+D_{ava}*log1.15	1	1	0
NI (Number of injuries)		NI= -56.128+night*log20.67- Vph*log6.10+V_{avg}*log47.15+ D_{avg}*log22.22	1	1	0
SEIT (Number of severe injuries caused by turnover)		SEIT= 31.520-night*log6.38- Vph*log1.58- V_{avg}*log10.813+D_{avg}*log0.606	1	1	0
NAC (Number of accidents causeD by turnover)		NAC = 32.520-night*log6.38- Vph*log1.58-avg*log110.81+ D_{avg} *log0.696	1	1	0
NVA (Number of vehicles involved in accidents)		NVA= -158.53+night*log69.80+ Vph*log12.77+V_{avg}*log48.89+ D_{avg}*log13.08	1	1	0
FC (Number of fatalities by collisions)	VPH (vehicle per hour) B (% of buses) V_{avg} (Average speed - km/hr) NVC (# of vertical curves) D_{ava} (average Degree of curvature (D_a))	FC = -64.27-Vph*log4.97 +B*log0.065+ V_{avg}*log29.21 -NVC*log11.70- D_{avg}*log6.32	1	1	0
SLIC (Number of slight Injuries by collisions)		SLIC = 11.67-Vph*log0.108 - B*log9.773- V_{avg} *log0.881 + NVC *log27.186+ D_{avg} *log20.367	1	1	0
NAC (Number of accidents caused by collisions)		NAC = 97.21-Vph*log3.217 - B *log7.950- V_{avg} *log38.410 + NVC *log13.04+ D_{avg} *log5.11	1	1	0
SLIP (Number of slight Injuries by ped. accidents)	DRY(type of surface) W (width of one way) D_{avg} (average of Da)	SLIP=-60.58+dry*log53.90-W*log6.05- D_{avg} *log1.723	1	1	0.003
SLIT (Number of slight injuries caused by turnover)	Night (Lighting) D_{avg} (average of Da) PM (# of markers for pedestrian walk)	SLIT= 19.59- night*log19.36+ D_{avg} *log4.095-PM*log1.470	1	1	0.002
TGC (Number of accidents caused by tail gating collision)	Vph (vehicle per hour) B (% of buses) V_{avg} (Average speed- km/hr) NVC (# of vertical curves) D_{ava} (average of Da)	TGC = 117.36+Vph*log4.13 + B*log2.61- V_{avg}*log80.81 +NVC*log30.118+D_{ava}*log21.43	1	1	0
NAS (Number of collisions caused by Speed Limit exceeding)		NAS= 20.70-Vph*log2.07 +B*log4.93- V_{avg} *log8.80 -NVC*log3.167+ D_{ava} *log1.557	1	1	0
NAR (Number of accidents caused by reversing incorrect by pedestrian)	Night (lighting) VPH (vehicle per hour) V_{avg} (average speed in km/hr) D_{ava} (average of Da)	NAR= 2.415+night*log1.875- Vph*log0.947- V_{avg}*log0.519+D_{ava}*log0.809	1	1	0
NAL (Number of accidents caused by incorrect lane Usage by pedestrian)		NAL= 15.76- night*log3.195- Vph*log0.790- V_{avg} *log5.49+ D_{ava} *log0.348	1	1	0

It's worthwhile mentioning here that other models such as the power, polynomial, and exponential functions have been checked, however, they were statistically insignificant and the linear models and the logarithmic models were statistically better than them.

Linear models could predict number of accidents as function of pavement surface whether it is dry, wet or unpaved. However, number of accidents fatalities and number of accidents caused by incorrect lane usage could be predicted knowing the type of surface, lighting condition, traffic volume, percentages of each vehicle's type, posted and average running speed, number of lanes, width of each direction of road, median width, number and types of pedestrian crossings, number of horizontal and vertical curves, and maximum and average of degrees of curvatures on the road. Numbers of accidents caused by collisions are predicted as functions of the types of surfaces and the average degrees of curvature. Of course, these factors form the contributions of different categories causing traffic accidents such as:

1. Geometric factors: Number of lanes, width of one way of the road, median width, number and types of pedestrian crossings, number of horizontal and vertical curves, and maximum and average degrees of curvature.
2. Drivers' behavioral factors: Posted and average running speeds.
3. Environmental factors: Surface type, lighting condition, and day/night.
4. Traffic conditions: Traffic volume (ADT) and percentages of different vehicles.

Obviously, the majority of the factors are belonging to geometrical factors. This is an indicator that accidents caused by geometrical errors are wrongly interpreted when recording accidents by the police department. Therefore, at the time of accident and when recording the causes of accidents at the police report, police department should correctly define new indicators to distinguish between accidents caused by geometrical elements, and drivers' behavioral factors and other factors.

The logarithmic models predicted the same dependent variables found by the linear model, besides number of accidents caused by specific types of accidents whether they are collisions, turnover or pedestrians. The predicted dependent variables were numbers of accidents, fatalities, injuries, and severities for each type of accidents. In the logarithmic models, the most contributing independent variables were:

1. Geometric factors: Average degree of curvature, number of vertical curves, width of one way of the road, and number and types of pedestrian crossings.
2. Drivers' behavioral factors: Average running speed.
3. Environmental factors: Surface type, lighting condition, and day/night.
4. Traffic conditions: Traffic volume (ADT) and percentages of different vehicles.

The logarithmic models show less number of independent variables; i.e. an indication of practicality and easy-to-use of the models. However, the models didn't use the width of the road neither its number of lanes nor the median width. The models used the average degree of curvature as indicator for number of horizontal curves and the maximum degree of curvature. They also used the average running speed as indicator for the posted speed. The models are also more realistic and practical by predicting the types of accidents and their associated influencing independent variables.

The prediction of the dependent variables could open the door for roadway designers to enhance their roadway geometric design by minimizing the predicted numbers of accidents, injuries and fatalities. This could be considered as a new methodology to connect roadway design procedures with traffic safety factors or indicators without including the sight distance directly in geometric design. The new methodology could overcome safety problems associated with hazardous locations and eliminating their effects.

7 CONCLUSIONS

Road accident in Jordan is a major social and economic problem that causes a lot of losses in lives and injuries. A new approach was used to tackle the traffic safety issues in urban roads. The approach used stepwise regression statistical analysis concepts besides traffic accidents contributing factors in order to check urban roadway design efficiency as far as safety is concerned during early design stages. Logarithmic and linear statistical models could efficiently and practically predict the expected numbers of accidents, injuries, fatalities and their associated types as functions of numerous independent variables. It was found that the most important contributing factors to traffic safety issues at urban roads were geometrical, behavioral, traffic condition, and environmental factors. The most contributing factors to accidents at hazardous locations at urban roads were speed, degree of curvature, road surface type, traffic properties, number of horizontal and vertical curves, lighting conditions, and roadway geometry and dimensions.

City planners, traffic engineers as well as roadway designers could use the findings of this research work to assure safe planning and geometrical design of new roads at early planning and design stages. Therefore, problem arise due to traffic safety issues at expected hazardous locations could be controlled.

Of course, road safety works is a complex issue and involve several sectors, which require a multi-disciplinary approach to tackle the problems in order to achieve more practical results. The findings of this study could be enhanced if database incorporated with drivers' characteristics including socio-economic data, and accurate locations of traffic accidents and hazardous locations.

REFERENCES

AASHTO. (2004); A *Policy of Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

Al-Khateeb, Ghazi; Obaidat, Mohammed Taleb; and Taiser Khedaywi; (2008), Pedestrian and Driving Behaviors and Traffic Systems Issues in Jordan; Fifth Traffic Safety Conference in Jordan, organized by Jordanian Traffic Institute, Public Security Directorate, Amman-Jordan, April 22-24, pp. 1-2 to 15-2.

Bener, A. (2005), "The Neglected Epidemic: Road Traffic Accidents in A Developing Country, State of Qatar", International Journal of Injury Control and Safety Promotion, Volume 12, Issue 1, March 2005, pp. 45-47.

CDOT. (2006); *Standard Plans-M & S Standards*, Colorado Department of Transportation.

George, D.; and Mallery, P. (2009). SPSS for Windows Step-by-Step: A Simple Guide and Reference 16.0 Update, Ninth Edition, *Publisher: Allyn and Bacon*, 386 pages.

Hong S., and Oguchie, T. (2005), "Evaluation of Highway Geometric Design And Analysis of Actual Operating Speed", Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 1048 – 1061

Jordan Traffic Institute Report (2008), *Public Security Directory*, Ministry of Interior, Amman, Jordan.

Khedaywi, Taiser; Obaidat, Mohammed Taleb; Al-Khateeb, Ghazi; and Ramadan, Thanaa (2008), Pedestrian Accidents: Causes and Solutions, Fifth Traffic Safety Conference in Jordan,, organized by Jordanian Traffic Institute, Public Security Directorate, Amman-Jordan, April 22-24, pp. 1-10 to 15-10.

Khorshid, E. and Alfares, M. (2004), "A Numerical Study on the Optimal Geometric Design of Speed Control Humps", *Engineering Optimization*, Vol. 36, No. 1, February 2004, pp. 77-100.

Loo, B. P. Y. (2009), "The identification of Hazardous Road Locations: A Comparison of the Blacksites and Hot Zone Methodologies in Hong Kong", *International Journal of Sustainable Transportation,* Volume 3, Issue 3, May 2009, pp. 187-202.

McCarthy, P. (2001), "Effect of Speed Limits on Speed Distribution and Highway Safety: A Survey of Recent Literature", *Transport Reviews*, Volume 21, Issue 1, January 2001, pp. 31-50.

Mungnimit, S. (2001), Transport and Communications Policy and Planning Bureau, Ministry of Transport and Communications, *Road Traffic Accident Losses.*

NCHRP (2003) Geometric Design Consistency on High-Speed Rural Two-Lane Roadways, NCHRP Report 502, Transportation Research Board.

Obaidat, Mohammed Taleb; Al-Khateeb, Ghazi; Khedaywi, Taiser; and Bannoura, Balkees; (2008), Evaluation of Drivers` Behavioral Mistakes In Jordan**;** Fifth Traffic Safety Conference in Jordan, organized by Jordanian Traffic Institute, Public Security Directorate, Amman-Jordan, April 22-24, pp. 1-6 to 14-6.

Traffic Safety Bureau, (2005); Department of Highways, Traffic Accident on National Highways.

TRIP, (2009), Future Mobility in West Virginia: Meeting the State's Need for Safe and Efficient Mobility, *U.S. Department of Transportation*, Washington, D.C.; www.tripnet.org.

U. S. Department of Transportation, (2003); *Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD),* Washington, D.C.