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Development of Driver Behavior's Accident Prediction Models

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Abstract

Amman, the capital city of Jordan, has been expanding in terms of size, investment, and growth of vehicles. Such a growth has lead to traffic jams and delays experienced at all levels of services, and higher accident frequency level at several locations, which resulted in loss of people's lives, and causing major economical and social concerns in the country. Statistical models were employed to analyze accident frequency for Amman. The objectives were to identify hazardous locations by developing accident prediction models. Accident data was collected and linked to independent variables. Several models were developed to identify the relationship between accident frequency and key behavioral characteristics of drivers. Different types of high-accident locations were identified, classified, and ranked according to their hazardous degrees by using statistical techniques. Findings indicated that the short distance between vehicles, lane changing, and non-yielding right-of-way variables were the most critical causes of accidents. A priority ranking for countermeasures was recommended to reduce accidents and improve the overall driving safety at hazardous locations based on the developed models. Recommendations were made for the way in which accidents on these locations would be treated. Suggestions were made for the practical and theoretical development for further research.

Keywords: Traffic accidents, regression, hazardous locations, safety, countermeasures.

INTRODUCTION

Accident analysis is an important component of traffic and transportation planning studies as accident frequency and patterns can shed light on locations that require special attention and safety improvement measures. Rapidly growing population and urbanization result in a significant increase in the number of vehicles and traffic accidents. A traffic accident is defined as a random event or an occurrence involving one or more motor vehicles in a collision that results in property damage, injury, or death. With each passing day, in every country in the world, traffic accidents inflict a staggering amount of destruction. The toll, country loss of life and limb plus the socio-economic costs to society, is high and getting higher. Traffic accident is not simply a loss of a life but it is an unrecoverable setback to all those concerned. Each year millions of persons are killed or seriously injured in motor vehicle accidents as reported by the Federal Highway Research Institute [1].

Causes of accidents and related injury severity are of special concern to researchers in traffic safety since such research would be aimed not only at prevention of accidents but also at reduction of their severity. One way to accomplish this is to identify the most probable causes that affect accident frequency. The causes of traffic accidents are usually complex and involve several factors. The main factors can be divided into four separate categories:

a) Driver: this includes the demographic characteristics such as age, gender, experience, education of the driver and the behavioral characteristics such as seatbelt usage, use of drugs or alcohol while driving, and driving types.

b) Vehicle: this includes the technical characteristics of the vehicle itself such as age, mileage, and body type.

c) Roadway: this includes the conditions at the time of the accident occurrence such as surface, the direction of impact, vehicle role, or occurrence of a rollover.

d) Environment: this includes weather, visibility, rain, and lighting conditions.

Traffic accidents could be prevented, and its effects could be minimized by modifying driver behavior, vehicle design, roadway geometry, and the traveling environment. If the factors that have contributed to any traffic accident are identified, it is then possible to modify and improve the highway system. A safer highway system is more likely to result with the reduction or elimination of accident causing factors. The focus of this research was to study the influence of driver behavioral characteristics to traffic accidents.

There is an extensive literature devoted to the influence of driver's behavior on traffic accidents and modeling. The majority of this literature references the studies that deal primarily with analysis of accident involvement and prediction of accidents. Research has attempted to develop accident predication models with focus on traffic accident records, geographic areas, accident types, and environmental road conditions. A review of selected recent studies that developed models to identify the factors most important in determining accidents experienced by drivers or passengers during traffic accidents is presented.

Bonsall et al. [2] explored the questions associated with the choice of values for safety-related parameters in simulation models. They identified the key parameters of traffic simulation models and noted that several of them have been derived from theory or informed guesswork rather than observation of real behavior. Tests with the micro-simulation model demonstrated the sensitivity of model prediction to the value of some of the key parameters and was concluded that, in general, it was better to use values that were realistic –but-unsafe than values that were safe- but- unrealistic, and the adoption of unsafe designs could be overcome by paying attention to the safety aspect of designs. Chang and Chen [3] collected the 2001-2002 accident data of major national freeway 1 of Taiwan. Classification and regression tree model (CART) and a negative binomial regression model were developed to establish the empirical relationship between traffic accidents and highway geometric variables, traffic characteristics, and environmental factors. The CART model findings indicated that the average daily traffic volume and precipitation variable were the key determinants for freeway accident frequency. By comparing the prediction performance between the CART model and the negative binomial regression models, the study demonstrated that CART model was a good alternative method for analyzing freeway accident frequency. Delen et al. [4] used a series of artificial neural networks to model the potentially non-linear relationships between the injury severity levels and accident-related factors to identify the circumstances under which drivers and passengers were more likely to be killed or more severely injured in an automobile accident. Variables that affect the risk of increased injury of occupants in the event of an automotive accident included demographic and behavioral characteristics of drivers, environmental factors and roadway conditions at the time of the accident occurrence. These variables were the use of a seat belt, use of alcohol or drugs, drivers' age and gender, vehicle role in the accident, weather conditions, and the time of accident. Their findings indicated that no single factor by itself appeared to be a key determinant of accident severity, but could act as a catalyst or a barrier in combination with other factors in affecting the injury severity levels. They stated that the problems should be analyzed and attacked from a multidimensional perspective like vehicle characteristics, road characteristics, and collision avoidance systems. Hadayeghi et al. [5] examined the temporal transferability of the zonal accident prediction models by using appropriate evaluation measures of predicting performance to assess whether the relationship between the dependent and independent variable would hold reasonably well across time. The two temporal contents were the years 1996 and 2001 with updated 1996 models being sensitivity of the performance of the updated models to the 2001 sample used to predict 2001 accident in each traffic zone of the city of Toronto. The size was explored and the updating procedures examined included the Bayesian updating approach and the application of calibration factors to the 1996 models. The results showed that the models were not transferable in a strict statistical sense and the relative measures of transferability indicated that the transferred models yield useful information in the application context. In addition, it was concluded that the updated accident models using the calibration factors produce provided better results for predicting the number of accidents in the year 2001 than using the Bayesian approach. Svensson and Hyden [6] used several accident models to identify the critical variables that influence the different parts forming the traffic safety processes. Their findings indicated that using accident and conflict data in traffic safety analysis was not sufficient due to the low occurrence rates and the focus on rather exceptional and unsuccessful events. They proposed a new framework that considers the importance of feedback to the road users, the inclusion of more frequent events, and the prediction of safety and unsafety based on the more frequent events. Akgungor and Yildiy [7] investigated the sensitivity of the accident prediction model to its parameters by the fractional factorial analysis method. They incorporated both traffic and road geometry parameters besides terrain characteristics. The evaluation of sensitivity analysis indicated that average daily traffic, lane width, width of paved shoulder, median and their interactions have significant effects on number of accidents. They found that the fractional factorial method was an efficient tool to examine the relative importance of the selected accident prediction model parameters. Jrew et al. [8] analyzed 1780 traffic accident data on Arbil street network between 1997 and 1999. Different prediction statistical models were developed related to different types of locations (streets and intersections) in Arbil urban area at the northern part of Iraq. Hazardous locations were ranked and identified, and countermeasures were proposed to reduce traffic accidents. In another study, Jrew and Aloush [9] analyze 1428 traffic accidents on 28 streets at Marka area of Amman by using statistical techniques. Traffic models were developed and related to different types of locations and variables. They have studied and identified the driver behavioral factors that affect accident frequency. The developed prediction models indicated that missing attention of the drivers is the most significant variable causing accidents. The second significant independent variable was the short space-way between vehicles.

High level of traffic accidents is one of the major problems in Jordan. The economical and industrial rise that spread rapidly all over the country in the past recent years directly contributed to this problem. The rapidly increasing number of vehicles led to a direct increase

Table 1. Statistical data of traffic accidents in Jordan between 1993 and 2005

Year	Population (1000)	Vehicles	Accidents	Fatalities	Fatality Rate (10000 vehicles)	Accidents Cost ($1000000)
1993	4152	291347	24799	440	15.1	105
1994	4200	304893	26837	443	14.5	116
1995	4290	321373	28970	469	14.6	128
1996	4444	342337	33784	552	16.1	142
1997	4600	362811	39005	577	15.9	156
1998	4756	389196	43343	612	15.7	175
1999	4900	418433	50330	676	16.2	194
2000	5039	473339	52796	686	14.5	214
2001	5153	509832	52662	783	15.4	211
2002	5307	535112	52913	758	14.2	239
2003	5325	568096	62115	832	14.6	268
2004	5350	614614	70266	818	13.3	285
2005	5473	679731	83129	790	11.6	310

of accident frequency and their severity. In Jordan, it is recognized that vehicles are sometimes, perhaps often, driven unsafely. Some drivers are ignorant of the fundamentals of safe driving while others willfully ignore them usually in order to get to their destination more quickly. Therefore, it is necessary that an effective plan be coordinated to protect the country from excessive social, economic, and health losses, through the development of a safety model system.

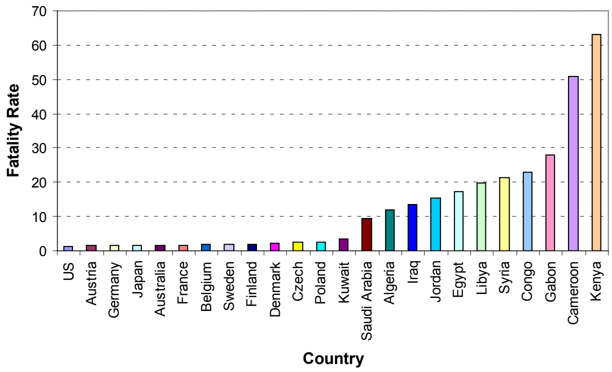

Figure 1. Fatality rate per 10000 vehicles for some selected industrial and non-industrial countries

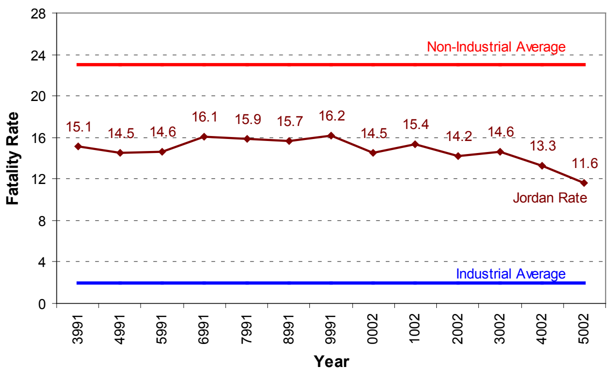

Figure 2. Fatality rate per 10000 vehicles of Jordan among industrial and non-industrial countries

Motorization has increased very rapidly in the country. Some statistical data of population, number of vehicles, accident frequency, and severity growth between the years 1993 and 2005 is presented in Table 1 as reported by the Jordan Traffic Institute [10]. At the beginning of 1993, there were approximately 291347 vehicles in the country. By 2005, the number of vehicles raised to about 679731. Fatality rate per 10000 vehicles has an average of about 15 ± 1.26. In 1993, about 440 people died in traffic accidents and the figure rose to about 790 by 2005. During 2005, the annual accident cost in Jordan was $310 millions, which represented more than 2.4 % of the Gross National Product (GNP) of the country. Among selected industrial and non-industrial countries, Jordan has a relatively high accidents fatality rate as shown in Figure 1. Figure 2 shows the variation of country fatality rate between 1993 and 2005 compared with selected industrial and non-industrial countries average fatality rates. The industrial and non-industrial countries average fatality rates were about 2 and 23, respectively while the fatality rate of Jordan was about 15 during the same period of time.

The primary interest of this research was to identify driver key behavioral characteristics that influence accident frequency and to identify hazardous locations at Amman. Accidents examined represent multi-vehicle collision accidents, single vehicle fixed-object collisions, and single vehicle non-collision (rollover) accidents. It was believed that this investigation would reveal relationships and trends that were valuable in understanding the broader dimensions of accidents in Jordan. This understanding is critical to developing policies and countermeasures that are intended to decrease the potential for accidents. Linear regression models where the functional relationships between the accident frequency and the accident-related factors were used as suggested by Abdelaty and Mussone [11, 12]. In this research, different types of high-accident locations in Amman were identified, classified, and ranked according

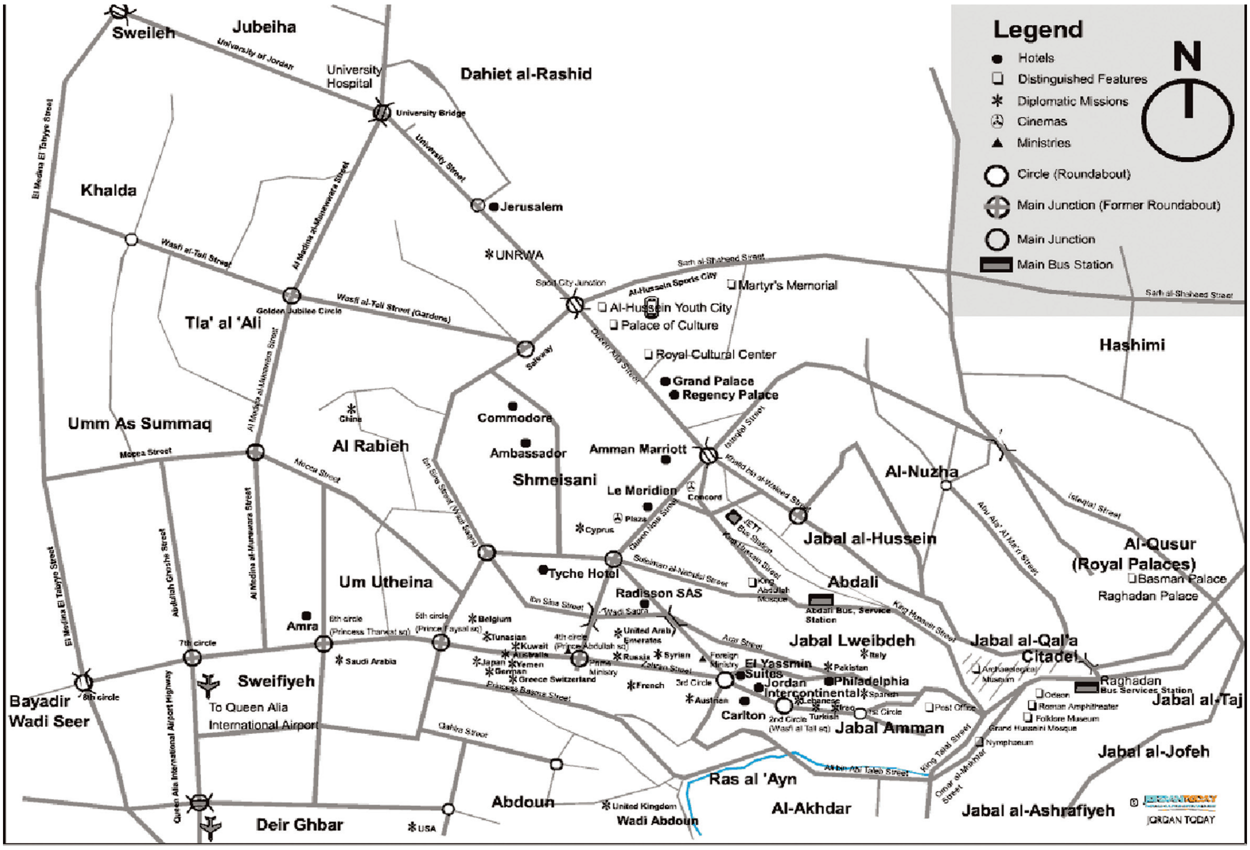

Figure 3. Layout of the study area at Amman, Jordan

to their hazardous degrees by using statistical techniques. Recommendations were made for the way in which accidents may be reduced. It is hoped that the outcome of this research would assist policy makers, transportation system designers, safety officials, and researchers, to understand the circumstances under which drivers and passengers were more likely to be involved in an automobile accident, and to establish countermeasures to reduce accident frequency and their potential.

MATERIALS AND METHODS

Data organization and study area

This research investigated the accidents caused by drivers in Amman. Data was acquired from the Jordan Traffic Institute [10], which documented all accidents reported by the police. Relevant information was recorded by the police on an accident report form. Each item of information on the accident report form was coded and stored in a computer system forming a database. Accident data was summarized according to type, severity, contributing circumstances, environmental conditions, and time periods. The reports contained information on all property damage accidents as well as injury-causing and fatal accidents. Although it was believed that some motor vehicle accidents were not reported to the police, majority of these unreported cases involved only negligible property damage and no significant injury to people involved. Thus, restricting data collection to police-reported accidents, the research concentrated on accidents with greatest influence on roadway safety. The accident files used in this research contained information about the causes of accidents, their locations, and the circumstances of the accident. 1578 available police-reported accident records were used in this research. The data represented 43 major intersections at 11 areas in Amman as shown in Table 2. These areas were Abdaly, Wadi Sir, Sweileh, Marka, Tela Ali, Jebbeha, Tareq, Zahran, Madina, Naser, and Basman. Figure 3 shows the layout of study area and Figure 4 shows the accidents distribution of the data at the 43 intersections.

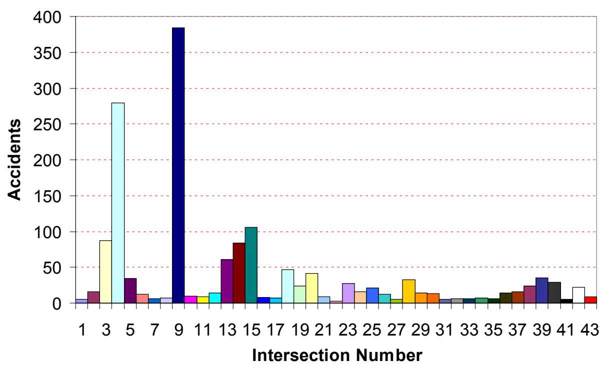

Figure 4. Observed number of accidents at the intersections

Table 2. Intersections accident data

Area	#	Intersection name	Accidents
Abdaly	1	Ajlouni St - Abu-Madi St	5
	2	Ibn-Hayan St - Abu-Sofyan St	16
	3	Wadi Saqra circle	87
	4	Madina Riadia circle	279
	5	Middle East Hotel signal	34
	6	King Abdullah Gardens signal	12
	7	Rayan signal	6
	8	Aradi St - Mohd Ali St	7
	9	Dakhlia circle	384
	10	Ma'mounia circle	10
	11	Mukhabarat signal	9
Wadi Sir	12	8th circle	14
	13	7th circle	61
	14	6th circle	84
	15	Yobil circle	106
	16	Hamra - Omari	8
	17	Gattan - Sarrara	7
	18	Macca St. - King Abdullah St	47
Sweileh	19	Albahawes signal	24
	20	Sweileh circle	41
	21	Ma'rouf Market signal	9
	22	Dabok signal	3
	23	Fahmawi signal	27
	24	Dawriat signal	16
Marka	25	Ein Ghazal signal	21
	26	Iskan Bank signal	12
	27	Masani signal	5
	28	Tatweer Hadhari signal	33
	29	Tarkhees signal	14
Tela Ali	30	Khalda traffic signal	13
	31	Assaf traffic signal	5
	32	Rabia circle	6
	33	Jabri signal	6
Jebbeha	34	Jordan University signal	7
	35	Ein Yajouz signal	6
	36	Jordan St - Yajouz St	14
Tareq	37	Queen Alea hospital circle	16
	38	Tareq signal	24
	39	Mashaghel signal	35
Zahran	40	3rd circle	29
Madina	41	Qahira signal	5
Naser	42	Mahata signal	22
Basman	43	Efaan signal	9

Models development

Linear regression analysis was used to develop realistic equations that could predict the accident frequency. The method of least squares that leads to the best fitting line of a postulated form to a set of data is used to form regression models between the dependent variable and independent variables. Statistical Product and Service Solutions (SPSS) software was used to analyze the observed accident data. Accident prediction models were developed and analyzed based on the available records. Step wise calibration procedure was then used to form the multiple linear regression models and to determine the most critical influencing variables. The model used consists of a dependent variable Y as a function of several independent variables X_i as shown in Equation 1.

$$Y = B_o + B_1X_1 + B_2X_2 + \ldots\ldots\ldots + B_nX_n \quad (0 \leq R^2 \leq 1) \quad (1)$$

where
Y = dependent variable
B_o = sample intercept
B_n = regression coefficient of the n^{th} independent variable
X_n = value of the n^{th} independent variable

The overall accuracy of any predictive model is reflected by the correlation coefficient R^2. It is used in linear regression analysis as the proportion of the variation in the dependent variable explained by its association with the independent variables. The value of R^2 ranges from zero when none of the variation is explained by the regression line to unity when all of the variation is explained by the line.

In this research, the dependent variable Y and the identified 17 independent driver's characteristics variables were defined as:

Y = accident frequency
X_1 = short distances between vehicles (tailgating)
X_2 = lane changing
X_3 = improper passing
X_4 = improper turns
X_5 = sudden deviation
X_6 = improper turning
X_7 = improper reversing
X_8 = missing attention
X_9 = non-yielding right-of-way
X_{10} = non-compliancy to pedestrians priority
X_{11} = movement in opposite direction (wrong side)
X_{12} = high speed (over the speed limit)
X_{13} = non-compliancy with traffic signals and regulations
X_1 = break failure
X_{15} = inappropriate parking
X_{16} = passing the red signal
X_{17} = overloading of vehicle

RESULTS AND DISCUSSION

Application of the prediction models

Accidents were analyzed and used in the predicted regression models. Several prediction models were formed and the best ones were chosen. The intersections in this study were arranged according to the accident's severity. Multivariate linear regression models, where the functional relationships between accident frequency and the 17 driver's characteristics independent variables, were used in this study as suggested by Abdelaty and Mussone [11, 12]. The results of the analysis with all independent variables provided 14 models as shown in Table 3. It was noticed that dependent variable Y (accident frequency) had a strong relation with the independent variables X_1 to X_{17} since all models provided a coefficient of correlation R^2 of more than 0.90. Stepwise variables reduction technique was used to eliminate variables that exhibit a weak relationship with the dependent variables. The resulting models included variables that were shown to significantly affect accident frequency. Models 2 and 3, along with their coefficients of correlation, were selected below as:

$$Y = 1.965 + 2.067\ X_1 + 2.393\ X_2 \qquad (R^2 = 0.980) \quad (2)$$

$$Y = 1.437 + 1.743\ X_1 + 1.959\ X_2 + 0.807\ X_9 \qquad (R^2 = 0.992) \quad (3)$$

Model 2 provided a correlation coefficient of R^2 = 0.980, and showed that the variables X_1 (short distance between vehicles), and X_2 (lane changing) were the most significant independent variables. Such a high value of R^2 means that 98.0% of the total number of accidents is explained by X_1 and X_2. Model 3 provided a correlation coefficient of R^2 = 0.992, and showed that the variables X_1 (distances between vehicles), X_2 (lane changing), and X_9 (non-yielding right-of-way), were the most significant independent variables. Again, such a high value of R^2 means that 99.2% of the total number of accidents is explained by X_1, X_2. and X_9. According to Models 2 and 3, the other 14 independent variables (X_3, X_4, X_5, X_6, X_7, X_8, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, and X_{17}) were not as strongly significant because there was no significance increase in R^2 when additional variables were added. This is shown clearly through Models 4 to 14 in Table 3.

Examining Table 3 carefully, accident causing factors can be ranked based on their influence on the accident frequency as shown in Table 4. A major practical benefit

Table 3. Summary of the linear regression models

#	Regression Model	R²
1	$Y = 6.011 + 4.473X_2$	0.930
2	$Y = 1.965 + 2.067X_1 + 2.393X_2$	0.980
3	$Y = 1.437 + 1.743X_1 + 1.959\ X_2 + 0.807X_9$	0.992
4	$Y = 2.386 + 1.092X_1 + 1.441X_2 + 1.121X_8 + 0.956X_9$	0.998
5	$Y = 2.387 + 1.175X_1 + 1.188X_2 + 1.092X_7 + 0.965X_8 + 1.019X_9$	0.999
6	$Y = 1.960 + 1.185X_2 + 1.117X_7 + 0.966X_8 + 1.025X_9 + 1.150X_{12} + 0.803X_{13}$	0.999
7	$Y = 1.522 + 0.951X_1 + 1.069X_2 + 0.833X_5 + 1.540X_7 + 1.051X_8 + 0.996X_9 + 0.771X_{13}$	0.999
8	$Y = 1.736 + 0.958X_1 + 1.044X_2 + 1.944X_3 + 1.069X_5 + 1.157X_7 + 0.991X_8 + 0.971X_9 + 0.755X_{13}$	0.999
9	$Y = 0.958 + 0.939X_1 + 1.036X_2 + 1.584X_3 + 1.035X_5 + 1.249X_7 + 1.020X_8 + 0.992X_9 + 0.867X_{13} + 0.692X_{16}$	0.999
10	$Y = 0.772 + 0.941X_1 + 1.031X_2 + 1.354X_3 + 1.047X_5 + .788X_6 + 1.281X_7 + 1.018X_8 + 0.995X_9 + 0.889X_{13} + 0.752X_{16}$	0.999
11	$Y = 0\ .619 + 0.928X_1 + 1.026X_2 + 0.761X_3 + 0\ 798X_4 + 1.084X_5 + 0.837X_6 + 1.311X_7 + 1.029X_8 + 0\ .993X_9 + 0.896X_{13} + 0.808X_{16}$	0.999
12	$Y = 0.386 + 0.946X_1 + 0.976X_2 + 0.932X_3 + 0.918X_4 + 1.138X_5 + 0.938X_6 + 1.206X_7 + 1.045X_8 + 0.993X_9 + 0.658X_{10} + 0.917X_{13} + 0.870X_{16}$	0.999
13	$Y = 0.223 + 0.979X_1 + 0.992X_2 + 1.096X_3. + 0.936X_4 + 1.067X_5 + 0.929X_6 + 1.074X_7 + 1.023X_8 + 0.995X_9 + 0.841X_{10} + 0.949X_{13} + 0.757X_{14} + 0.929X_{16}$	0.999
14	$Y = 0.072 + 0.963X_1 + 0.979X_2 + 0.970X_3 + 1.047X_4 + 1.113X_5 + 0.985X_6 + 1.114X_7 + 1.036X_8 + 0.996X_9 + 0.887X_{10} + 1.064X_{12} + 0.953X_{13} + 0.740X_{14} + 0.948X_{16}$	1.000

Table 4. Ranking the most influencing factors that affect accident frequency in Amman

Variable	Definition
X_2	lane changing
X_1	short distances between vehicles (tailgating)
X_9	non-yielding right-of-way
X_8	missing attention
X_7	improper reversing
X_{12}	high speed (over the speed limit)
X_{13}	non-compliancy with traffic signals and regulations
X_5	sudden deviation
X_3	improper passing
X_{16}	passing the red signal
X_6	improper turning
X_4	improper turns
X_{10}	non-compliancy to pedestrians priority
X_{14}	break failure
X_{11}	movement in opposite direction (wrong side)
X_{15}	inappropriate parking
X_{17}	overloading of vehicle

obtained from the above modeling would be to focus on the major causes of accidents. Law enforcement agencies could focus their enforcement efforts towards these critical variables that influence most accidents. For example, starting with the most critical ones, X_2 (lane changing), X_1 (distances between vehicles), X_9 (non-yielding right-of-way), X_8, X_7, X_{12}, X_{13}, X_5, X_3, X_{16}, X_6, X_4, X_{10}, X_{14}, X_{11}, and ending with least influencing ones X_{15} (inappropriate parking), and X_{17} (overloading vehicle) as shown in Table 4. This critical ranking of factors affecting accidents would save time, resources, and efforts when the priority of these listed factors is considered.

Identification of hazardous locations

The effort involved in hazardous location identification varies among researchers and depends mostly on the procedure employed. Among many approaches, regression models were used as markers in order to compare aspects of the way in which hazardous locations were identified, analyzed, and treated. The identification of hazardous locations for investigation with a view to remedial treatment does not depend entirely upon the apparent level of hazard. It is necessary to consider all factors including the expected case and effect of treatment, resource constrains for both investigation and implementation, and potential political and/or public pressure factors as discussed by Silcock and Worsey [13]. Identifying hazardous locations is a very important process in traffic safety. Hazardous locations are sites where accident frequency, calculated on the basis of the same exposure data, is higher than the expected value for other similar locations. A detailed engineering study should be performed for the hazardous locations to identify the safety problem so that suitable safety related countermeasures could be developed.

In traffic safety, a common approach used in the identification of hazardous locations was proposed by McGuigan [14] and used by Turner and Nicholson [15]. The approach used the Potential Accident Reduction (PAR) method to identify High Accident Locations (HAL) and to determine the hazardous priority ranking for countermeasures. The method defines an index term called DI which is the difference between the actual and predicted number of accidents as provided by the statistical model for a particular location during some period of time. Larger and positive values of the index DI indicates higher hazardous ranking of the location and the greater is the scope for reducing accidents. Therefore, comparing the DI values of several intersections determines HAL. Further background of the procedure for ranking hazardous locations by PAR method was explained in details by McGuigan [16].

The current study was intended to provide traffic engineers and planners with the ability to determine HAL from regression Models 2 and 3. Adopting the PAR method to identify HAL, the index DI value of the difference between the actual and predicated number of accidents according to Models 2 and 3, respectively, is calculated as shown in Table 5. Figure 5 shows the relationships between the observed and predicted number of accidents for both models. Classifying the data based on the DI index is necessary to identify HAL. Table 6 shows a list of a priority ranking in descending order of DI for both Models 2 and 3, respectively. HAL were identified as intersections that have an index value DI greater than 1. Among the 43 intersections, Models 2 and 3 provided 14 and 19 intersections, respectively, that appeared to be critical. There were 12 HAL that appeared common in Models 2 and 3. Namely; intersections 14, 9, 2, 28, 20, 26, 5, 33, 41, 15, 1, and 7 as highlighted in Table 6. Among these common 12 intersections, 14, 9, 2, and 28 seemed to be extremely hazard since they had a relatively high value of DI that was greater than 10 as labeled boldly in Table 6.

By identifying the above intersections, law enforcement officers should focus their enforcement efforts at these locations, which may result in a reduction of accidents. It is believed that that the major causes of accidents in the country, and among these intersections in particular, is due mainly to the inattention, inadequate driving skills, and poor qualifications of drivers.

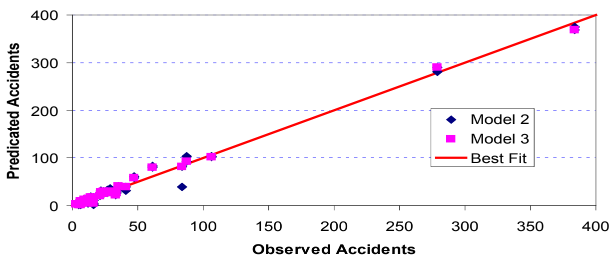

Figure 5. Compression between actual accidents and Models 2 and 3 predictions

Table 5. Predicted number of accidents according to Models 2 and 3

#	Actual Accidents	Predicted Accidents (Model 2)	DI	Predicted Accidents (Model 3)	DI
1	5	1.97	3.04	3.86	1.14
2	16	1.97	14.04	4.67	11.34
3	87	104.12	-17.11	91.89	-4.89
4	279	280.01	-1.01	290.82	-11.82
5	34	31.88	2.12	26.49	7.51
6	12	17.74	-5.74	14.5	-2.5
6	6	4.03	1.97	3.99	2.01
8	7	4.36	2.64	6.62	0.38
9	384	374.54	9.46	368.77	15.23
10	10	9.14	0.86	8.12	1.88
11	9	14.69	-5.69	12.11	-3.11
12	14	15.02	-1.02	17.17	-3.17
13	61	82.57	-21.57	80.39	-19.39
14	84	39.39	44.61	81.81	2.19
15	106	102.92	3.08	102.45	3.55
16	8	8.49	-0.49	9.3	-1.3
17	7	6.75	0.25	5.36	1.64
18	47	61.79	-14.79	57.68	-10.67
19	24	27.75	-3.75	24.62	-0.62
20	41	31.77	9.23	38.95	2.05
21	9	8.17	0.83	6.67	2.33
22	3	4.36	-1.36	3.4	-0.4
23	27	32.53	-5.53	26.92	0.08
24	16	17.09	-1.09	15.68	0.32
25	21	23.94	-2.94	20.54	0.46
26	12	4.03	7.97	4.79	7.21
27	5	4.03	0.97	3.18	1.82
28	33	25.68	7.32	22.07	10.93
29	14	16	-2	16.2	-2.2
30	13	14.37	-1.37	11.9	1.11
31	5	4.03	0.97	3.18	1.82
32	6	6.1	-0.1	5.73	0.27
33	6	1.97	4.04	2.24	3.76
34	7	6.75	0.25	5.36	1.64
35	6	10.89	-4.89	8.84	-2.84
36	14	19.48	-5.48	16.84	-2.84
37	16	10.56	5.44	16.7	-0.7
38	24	29.49	-5.49	29.37	-5.37
39	35	35.36	-0.36	40.03	-5.03
40	29	35.9	-6.9	29.53	-0.53
41	5	1.97	3.04	1.44	3.56
42	22	32.1	-10.1	28.68	-6.68
43	9	12.3	-3.3	10.15	-1.15

CONCLUSIONS and RECOMMENDATIONS

Traffic accidents are considered one of the most serious problems in Jordan. The toll, country loss of life and limb plus the socio-economic costs to society, is high and getting higher. This study made an effort towards the determination of most critical factors influencing traffic accidents in the country. The most hazardous intersections were located in the study areas. Proper treatments, improvements, and countermeasures are needed to reduce the number and severity of accidents in these areas. Statistical accident prediction models were developed and the appropriateness of the models to predict accidents was examined as an important tool for comparison. The statistical technique of regression was used to find relationships between a dependent variable (accident frequency) and independent variables (driver behaviors).

The research proposed for the analysis of intersections in Amman, and the determination of the hazardous locations was found effective the predication of those locations. The most critical influencing variables that affect the accident frequency were X_1 (the short distances between vehicles), X_2 (lane changing), and X_9 (non-yielding right-of-way). Further analysis of the most hazardous locations identified (intersections 14, 9, 2, and 28) is needed to identify the nature and type of countermeasures.

Further research is required to develop accident prediction models for the intersections based on environmental factors, roadway conditions at the time of the accident occurrence, and technical characteristics of the vehicle itself. Additional research is also required to develop prediction models for the street network and other cities of Jordan.

It is hoped that the accident prediction models developed in this research would aid in decision making with regard to Highway Safety Improvement Program (HSIP) and to Urban Transportation Planning Process (UTPP), and could be used as the basis for establishment of priority orders for alternative protection schemes. Study results should help the traffic safety community in understanding the major causes of accidents in Jordan. It is clear that the large number of accidents is a critical indication of the seriousness of driver noncompliance with traffic regulations. It is believed that the major causes of accidents and traffic safety problems found in this study can be explained by the inattention, inadequate driving skills, and poor qualifications of drivers.

To improve the traffic safety in Jordan in general, and of Amman in particular, full collaboration and coordination between all traffic and transportation agencies is required. In addition, immediate implementation of a comprehensive program through education, enforcement, and engineering is necessary among the driving and non-driving public. This is achieved through the following three initiatives:

Education initiative

Educational programs about the hazards of traffic accidents and violating traffic laws should be initiated at schools, universities, and other governmental and non-governmental offices.

Promoting safe driving practices and initiating public awareness campaign of traffic accidents among the driving population through training books, and educational campaigns adopted by the government.

Developing and implementing an improved competency-based training and improvement of driver skills, and assessment procedure for young and entry drivers.

Raising the importance of human, social, and financial losses, caused by traffic accidents through the media (TV, radio, newspapers, and public street ads).

Establishing and improving the training programs for teachers and facilitators in the driving licensing industry.

Mobilizing influence resources in the family, community, industry, and government to support “safe road” environment.

Enforcement initiative

Implementing periodic higher enforcement levels at hazardous intersections, and stiffer violation penalties should be considered.

Concentrating law enforcement personnel maximally at the most hazardous intersections.

Raising automobile insurance premiums for drivers with a track record of accidents, or lowering premiums for drivers who do not engage with accidents. Drivers would then have a monetary incentive to drive safely and follow the rules.

Increasing the effectiveness of license suspension/revocation and creating more effective ways to deal with repeat offenders.

Adopting and implementing a practical traffic safety strategy that has clear targets, objectives, action plans, time frame, and legislations.

Demanding an adequate judicial infrastructure and processes to deal with offenders promptly, competently, and appropriately.

Engineering initiative

Using established programs, safety research information, and available techniques to improve road safety.

Promoting the use of advanced technologies to support enforcement efforts and for monitoring traffic and driver noncompliance with traffic regulations.

Increase adoption of international standards and eliminate gaps in laws.

Structural changes in route reconfiguration according to research and scientific studies must be considered.

Using intelligent transportation systems (ITS) to improve traffic. For example, drivers could be encouraged to use alternative routs rather busy roads during peak hours, which in turn would reduce potential accidents.

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Table 6. HAL as ranked by Models 2 and 3

Model	#	Name	Actual Accidents	Predicted Accidents	DI
2	**14**	**6th circle**	**84**	**39.39**	**44.61**
	2	**Ibn-Hayan St - Abu-Sofyan St**	**16**	**1.97**	**14.04**
	9	Dakhlia circle	384	374.54	9.46
	20	Sweileh circle	41	31.77	9.23
	26	Iskan Bank signal	12	4.03	7.97
	28	Tatweer Hadhari signal	33	25.68	7.32
	37	Queen Alea hospital circle	16	10.56	5.44
	33	Jabri signal	6	1.97	4.04
	15	Yobil circle	106	102.92	3.08
	1	Ajlouni St - Abu-Madi St	5	1.97	3.04
	41	Qahira signal	5	1.97	3.04
	8	Aradi St - Mohd Ali St	7	4.36	2.64
	5	Middle East Hotel signal	34	31.88	2.12
	7	Rayan signal	6	4.03	1.97
3	**9**	**Dakhlia circle**	**384**	**368.77**	**15.23**
	2	**Ibn-Hayan St - Abu-Sofyan St**	**16**	**4.67**	**11.34**
	28	**Tatweer Hadhari signal**	**33**	**22.07**	**10.93**
	5	Middle East Hotel signal	34	26.49	7.51
	26	Iskan Bank signal	12	4.79	7.21
	33	Jabri signal	6	2.24	3.76
	41	Qahira signal	5	1.44	3.56
	15	Yobil circle	106	102.45	3.55
	21	Ma’rouf Market signal	9	6.67	2.33
	14	6th circle	84	81.81	2.19
	20	Sweileh circle	41	38.95	2.05
	7	Rayan signal	6	3.99	2.01
	10	Ma’mounia circle	10	8.12	1.88
	31	Assaf traffic signal	5	3.18	1.82
	27	Masani signal	5	3.18	1.82
	17	Gattan - Sarrara intrsection	7	5.36	1.64
	34	Jordan University signal	7	5.36	1.64
	1	Ajlouni St - Abu-Madi St	5	3.86	1.14
	30	Khalda traffic signal	13	11.9	1.11

Note: Shaded intersections represent common HAL while blooded ones represent extremely common HAL with a DI index greater than 10

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