Development of Statistical Prediction Models to Reduce Fatal and Injury Traffic Accidents

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Abstract
Recent studies have shown that Jordan suffers massive human and economical losses as well as social and emotional effects from traffic accidents every year. Despite the efforts of the public and private sectors, traffic accidents are still increasing and exhaust Jordan's resources at the price of other areas of development and construction.
The main objectives of this study are: to analyze traffic accidents in Jordan and their main causes; to reduce the number of traffic accidents and their severity. Also, to study the effect of driver behavior mistakes on traffic accidents and their severity. In addition, to determine and build prediction statistical regression models, which relates the number of accidents (dependent variable), with drivers behavior mistakes (independent variable) by using the Statistical Package for Social Sciences (SPSS) computer software.
The study was conducted based on accident data provided by the Jordan Traffic Institute from the year 2000 to year 2010. The study investigates 394188 total accidents during the period of the study with five independent variables (close following, lane violation, speeding or violation of speed limit, wrong passing and red light violation).
Regression techniques were used to analyze the collected data and to create four models .The models were developed by SPSS statistical package computer program. The first developed predicted model was for the total accident, the result indicated that the close following and lane violation are the most causes of accidents .The second developed model was for the fatal accidents, and the results indicated that the violation of speed limit and the lane violation are the most causes of the fatalities. The third and fourth models were developed for the slight and sever injuries; the result showed that the same independent variables causes of fatalities are applicable for injuries.
The accident prediction model can be used to develop warrants and standards for law enforcement, geometric design, and traffic operation and to improve the required countermeasures in order to reduce the traffic accidents especially fatal and injury accidents.
Keywords: World Health Organization, Healthcare, Fatality, Injury, Severity, Human losses, Social and Emotional Effects, Traffic Accidents, Traffic Safety, Speed Limit, Speeding, Driver Behavior, Countermeasures, Regression Models.

1. Introduction

A traffic accident is defined as a random event or an occurrence involving one or more motor vehicles in a traffic accident that results in property damage, injury, or death (Garber 2010). 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 humans are killed or seriously injured in motor vehicle accidents as reported by the Federal Highway Research Institute (FHWA 2010).
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 predict accident frequency or accident severity by using the statistical technique. The causes of traffic accidents are usually complex and involve several factors. The main factors can be divided into four separate categories: the driver, the vehicle, the roadway, and the environment. Human factors account wholly or partly to 93% of all traffic accidents. The human factor, the driver, is the primary cause of those accidents. The main cause of traffic accidents is disobeying the traffic safety laws, which include speeding, driver distraction, driving under the influence of drugs or alcohol, close following between the running vehicles, yielding for pedestrians and other vehicle etc. (NHTSA 2010)
Traffic accidents could be prevented, and its effects can be minimized by modifying driver behavior, vehicle design, roadway geometry, and by modifying 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 likely to result with the reduction or elimination of traffic accidents causing factors. (Garber 2010, FHWA 2010, NHTSA 2010, and WHO 2007)

In the past few years traffic accidents have become an epidemic. They cause the death of over one million people per year including those walking and riding bikes. Currently, road traffic injuries account for 2% of all deaths around the world. However in the next 20-25 years it will rise to 3.5% of all deaths making it the fifth leading cause of death around the world. Road accidents are one of the most serious issues facing developed and developing countries. The World Health Organization (WHO) anticipates road accidents to be the third cause of death among the fifteen causes of death in 2020. It causes human suffering to individuals, and huge financial losses to the state and the public as a result of accidents and deaths, injuries and disabilities. (WHO 2007)

Therefore, the concerted efforts of the society and the governmental and private organizations are necessary to improve road safety system, reduce the number of, and minimize fatalities and injuries. Road safety concept is not limited to the reduction of road accidents issue. It aims to adopt practically the road safety behavior by setting all necessary educational, engineering and medical programs and plans, traffic regulations and preventive measures. This would reduce or prevent accidents, ensure human and properties safety and preserve the human and economic wealth of Jordan. (FHWA 2010, NHTSA 2010, and WHO 2007)

In Jordan, traffic accidents constitute a major health problem. They are considered the second leading cause of death. Results of Analysis revealed that Jordan has experienced huge human and economic losses as well as social and emotional negative impacts. Despite the efforts of concerned public and private sectors, the accidents still constitute a source to exhaust the resources and efforts of the country and at the price of other areas of developments and construction. Therefore, the traffic accidents, death, and injures resulting from them are considered a stressful phenomena for the government and for the people at the same time. (Jordan Traffic Institute 2000-2012)

2. Review of Related Literature

The following studies are a review of a number of selected recent studies that have developed many models to identify the factors most important in determining accidents experienced by drivers' faults during traffic accidents. The studies are more related to the driver's mistakes or faults that cause traffic accidents. Therefore, it is important to present the most recorded driver faults in Jordan first.

The Jordan Traffic Institute published every year accident statistics data based on police reports and based on the summary reports determined from the Traffic Department Studies. The accident data include the following driver faults that cause the accidents. Some of these faults were used as independent variables to determine the prediction models. (Jordan Traffic Institute 2000-2012)

Svensson and Hyden in 2006 used several accidents models to identify the critical variables that influence the different parts forming the traffic safety processes. Their findings indicated that using accident data and conflict data in traffic safety analysis is 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. (Svensson 2006)

Jrew et al. in 2007 analyzed 1780 traffic accidents data on Arbil street network by using SPSS software. Different prediction statistical models were developed and related to different types of locations (streets and intersections) in Arbil urban area at the northern part of Iraq. Potential Accident Reduction (PAR) criteria were recommended to identify accident prone locations. In their approach, they defined a term named (di) as the difference between actual and expected accidents provided by the statistical model. Larger and positive values of (di) indicate that the accidents frequency at a certain location is high. Comparing the (di) values of all sections determines the High Accident Locations (HAL). (Jrew 2007, 20012)

Ismeik and Jrew in 2010 studied the accidents caused by drivers at the west area of Amman. The research contains data on all property damage accidents as well as injury-causing and fatal accidents. The study concentrates on accidents with greatest influence on roadway safety. (Ismeik 2010)

The study used 1578 available police-reported accident records that describe motor vehicle accidents during 2004 and 2005 at different intersections in Amman. The accident files contained information about the causes of accidents, their location, and the circumstances of the accident; the data contains different types of high-accident locations at intersections on the Amman street network. A total of 43 intersections were chosen in 11 areas, namely: Abdaly, Wadi Sir, Sweileh, Marka, Tela Ali, Jebbeha, Tareq, Zahran, Madina, Naser, and Basman. The results indicated that close following (tailgating), lane change, and not yielding right of way to the others are the most independent variables affecting the causes of accidents. (Ismeik 2010)

Abo-Alush and Jrew in 2008 developed many prediction models for Marka district in east Amman. The study included 2119 accident reports on 22 streets and eight signalized intersection for the year of 2005. The results of the models showed that the following too closely and not yielding right of way is the most causes of the total accident. The following too closely, lane change and not yielding the right of way are the most causes for the accident injuries. The violation of traffic signs are the most causes of the fatalities. (Aloush 2008)

Abojaradeh and Jrew in their study in 2009 focus on major streets and intersections in five main areas in the Greater Amman Municipality. The study area includes the following areas: Marj Al-Hamam in Western Amman and Abu Nusair, and Suweileh in North Amman, Jubeeha in Middle Amman, and Marka in Eastern Amman. A total number of accidents of 6901 were analyzed in the study area. The results of the prediction models indicates that the close following, lane violation, and not taking enough precaution are the most causes of total accidents. The lane violation and wrong u- turn, and sudden turning are the most causes of accident injuries, and the last tow factors are the most causes of fatalities on street and not taking enough precaution and close following are the most causes of fatalities at signalized intersections. (Abojaradeh 2009, 2012, and 2013)

3. Study Objective

From the above studies and other studies it is decided to select the most independent variables that can be controlled by different countermeasures to develop prediction models in order to recommend a national safety program to reduce the total accidents, fatalities, sever and slight injuries in Jordan.

The selected independent variables as shown in Table 1 are:

1. Close following.
2. Lane violation.
3. Wrong passing.
4. Speeding (violation of speed limit).
5. Red light violation.

4. Definitions

4.1 Close Following

Is the practice of driving on a road too close to the vehicle in front, at a distance which does not guarantee that stopping to avoid traffic accident is possible. Approximately one third of rear-end traffic accidents involve close following (Wikipedia 2013).

4.2 Red Light Violation

The driver may legally enter the intersection during the yellow signal indication and be within the intersection during a red indication. At the onset of the green indication, all drivers receiving the green are required to yield to any vehicles that are legally in the intersection. These drivers cannot legally proceed into the intersection until it is clear. It follows from these legal points that a red-light violation occurs when any vehicle enters (and proceeds through) the intersection after the signal has turned red. A vehicle is said to "enter" the intersection when it crosses the stop line or its equivalent location on the intersection approach (Wikipedia 2013).

4.3 Speeding (Violation of Speed Limit)

Speeding is a major cause of serious and fatal vehicle accidents in Jordan. Every kilometer per hour over the speed limit not only affects whether an accident happens, but also how severe it is (Wikipedia 2013).

4.4 Lane Violation

Drivers should always drive in the right lane. There are three basics for driving in the three lanes (Wikipedia 2013):

- **Right Lane:** You may take this lane when you are driving at below the speed limit or to continuing driving or turning to the right before reaching the crossroad.
- **Middle Lane:** It is for overtaking the slow vehicles on the right lane.
- **Left Lane:** It is for overtaking by speed not exceeding the speed limit or to turn to the left side.

4.5 Wrong Passing

When you change lanes, you have to do more than just signal and check your mirrors. You must also turn your head and look into the lane that you want to enter. Remember that you have blind spots which limit your ability to see vehicles to the sides of you. A number of side swipe accidents are caused by drivers not checking their blind spots before merging into another lane (Wikipedia 2013).

5. Methodology

5.1 Statistical Data

Traffic Accident Data were collected from the General Security Department and from Jordan Traffic Institute for the years 2000 to 2010. Data were organized in statistical tables, charts, and figures and prepared in order to represent data in an easy and illustrative way (Jordan Traffic Institute 2000-2012, Public Security Department 2000-2012).

The following tables and figures show the statistical data of the four dependent variables (total number of driver faults, total number of fatalities, total number of injuries, and total number of sever injuries) that are related to the five selected independent variables (close following, lane violation, speeding, red light violation and wrong passing) for each year from year 2000 to year 2010.

Table 1: Drivers' behavior faults which contributed to traffic accidents

Variables	Drivers faults (Independent Variables)
1	Close following (not enough safe gap)
2	Lanes violation
3	Wrong passing
4	Wrong turning
5	Sudden turning
6	Wrong u-turning
7	Wrong backing
8	Distraction and not taking enough precautions
9	Yield violation (Not respecting priorities of vehicles)
10	Pedestrian yield violation (Not respecting the rights of way for pedestrians)
11	Wrong way driving
12	Speeding (violation of speed limit)
13	Violation of traffic signs
14	Brake system failure
15	Not securing the vehicle when stopping
16	Running on the red light
17	Not securing the vehicle loads

Table 2: Total number of accident for the selected five driver faults in Jordan

Sever Injuries	Slight Injuries	Fatalities	No. of faults	Year
191	5765	287	23251	**2000**
849	3777	280	23931	**2001**
683	3615	380	28458	**2002**
359	2255	143	26247	**2003**
1208	7606	436	34346	**2004**
745	5076	238	28607	**2005**
941	5089	283	30031	**2006**
1009	6367	435	43120	**2007**
861	4484	277	39302	**2008**
717	5769	312	57167	**2009**
1311	6858	356	59728	**2010**
Σ 8874	**Σ 56661**	**Σ 3427**	**Σ 394188**	

Table 3: Total number of accidents for the five selected drivers' faults (2000-2010).

Total Faults	Wrong Passing	Red Light Violation	Speeding	Lane Violation	Close following	Year
23251	686	557	2475	9889	9644	**2000**
23931	672	566	2261	10219	10213	**2001**
28458	683	655	1967	12775	12378	**2002**
26247	686	699	1970	9991	12901	**2003**
34346	708	620	1771	18022	13225	**2004**
28607	728	681	1531	11076	14591	**2005**
30031	708	706	1114	13403	14100	**2006**
43120	856	726	1525	17817	22196	**2007**
39302	811	382	1332	15527	21250	**2008**
57167	822	667	2620	25847	27211	**2009**
59728	830	636	2125	25417	30720	**2010**
Σ 394188	**Σ 8190**	**Σ 6895**	**Σ 20691**	**Σ 169983**	**Σ 188429**	

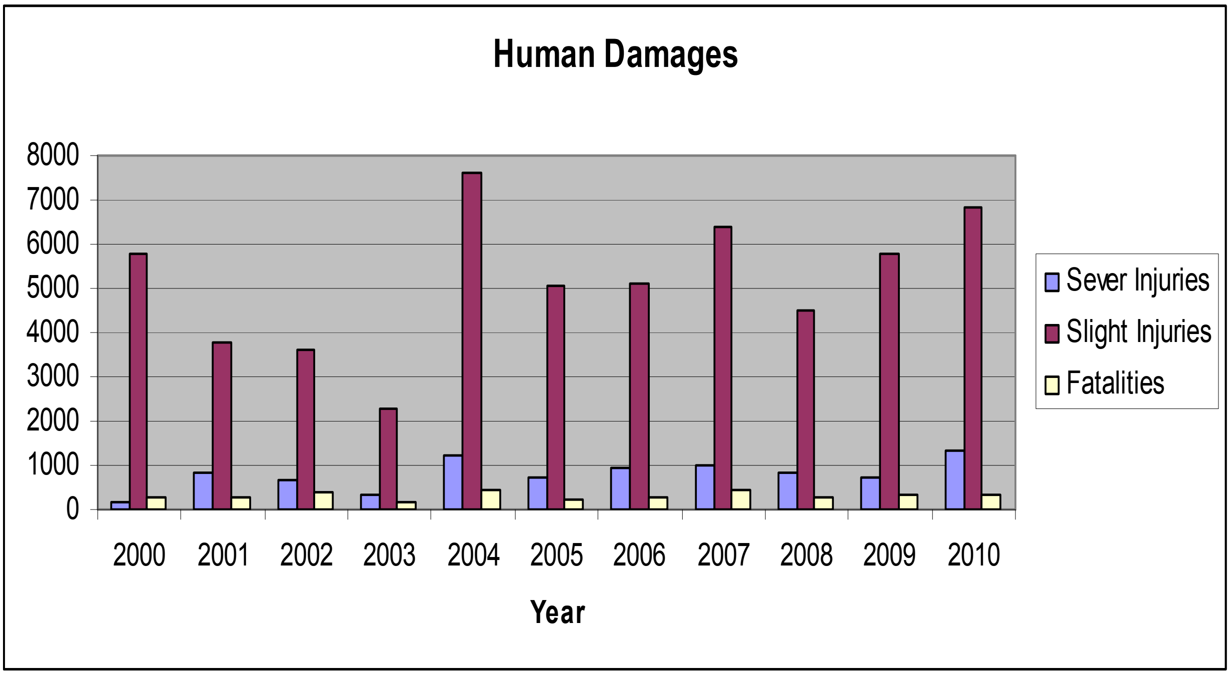
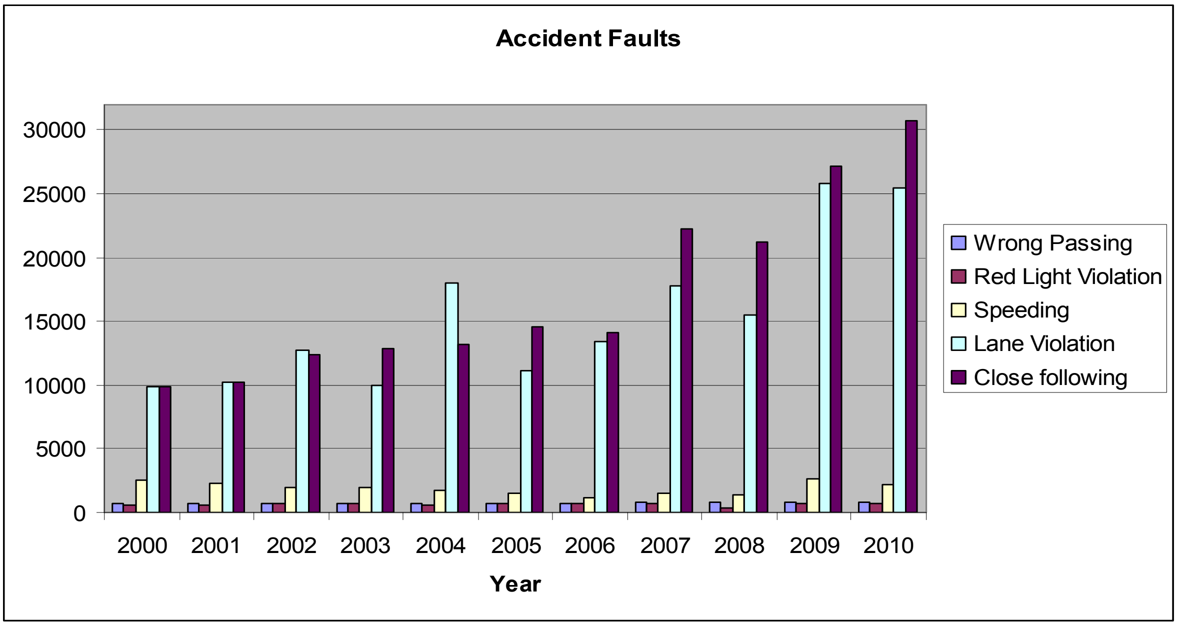


Figure 1: Human damages due to accidents for the five selected driver faults (2000-2010).

Figure 2: The selected five Drivers' Faults (2000-2010).



5.2 Statistical Model Formation

SPSS (Statistical Package for Social Sciences) software was used in forming the Regression Models in this study. SPSS is considered one of the most frequently used program for researchers in many fields such as engineering, science, art, education, and psychology. (SPSS 2007)

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 Yi, and independent variables Xi. In this study, the dependent variable Yi includes accident frequency, injuries, and fatalities. On the other hand, the independent variable Xi includes the drivers' behavior mistakes which caused traffic accidents. The detailed the total accidents for the selected drivers' mistakes (Faults) are shown in Table 2 as dependent variables. The total numbers of accidents in the study area caused by selected drivers' behavior mistakes (Faults) are shown in Table 3 as independent variables.

A relationship between the dependent and the independent variables of the form

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n$$

Where: Y_i : dependent variable. X_n : value of the nth independent variable.
B_0 : sample intercept. B_n : regression coefficient of the nth independent variable.
Stepwise calibration procedure was used to form the Multiple Linear Regression Model. The selections of explanatory variables follow the following four guidelines to decide which explanatory (independent) variables to include in the linear regression model. The selected independent variable has to follow the following four rules (Papacostas 2008, Montgomery 2010, Abojaradeh 2009, 2012, Jrew 2012, and 2013):

1. Must be linearly related to the dependent variable.
2. Must be highly correlated with the dependent variable.
3. Must not be highly correlated between themselves.
4. Must be relatively easy projected.

The selected regression model has to have maximum 3 to 4 variables in order to have an easy projection and application, and in order to have a lower cost. Also, the selected regression model should have strong coefficient of determination R^2 value. The coefficient of determination R^2, quantifies the fact that the goodness of fit of a regression line increases with the proportion of the total variation that is explained by the regression line. R^2 ranges from zero when none of the total variation is explained by the regression line to unity when all of the variation is explained by the line. It is denoted as a squared quantity to capture the fact that it is always non negative. The square root of R^2 the Coefficient of determination is called the coefficient of correlation (r or R). Its value can range from -1 to 1. In the case of linear regression the sign of R is the same as the sign of the slope of the regression line. When R is near 1, there is a high positive correlation between x and y. when R is near -1, there is a high negative correlation. If R is around zero, then there is no correlation between x and y. (Papacostas 2008, Montgomery 2010)

5.3 Prediction Regression Models:

The dependent variables Yi include the following variables that are shown in Table 4, and the independent variables Xi include the following variables that are shown in Table 5.

Table 4: The dependent variables for each model

Dependent variables	Definitions
Y_1	Number of faults.
Y_2	Number of fatalities.
Y_3	Number of slight injuries.
Y_4	Number of sever injuries.

Table 5: The independent variables for the four models (Driver Faults or Mistake)

Independent variables	Drivers Mistakes
X_1	Close following
X_2	Lane Violation
X3	Speeding (violation of speed limit)
X4	Red Light Violation
X5	Wrong Passing

6. Analysis of Results

6.1 Development of Driver Faults Model (Y_1)

The statistical input data shown in Table 3 and the output of SPSS computer program are explained in Table 6 and Table 7 as follows:
The selected model is as follow:

$$Y_1 = 2809.282 + 0.961X_1 + 1.072X_2$$

Table 6: Model Summary of the Drivers' Faults.
Model Summary[f]

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	0.977[a]	0.955	0.950	2841.578	0.955	192.321	1	9	0.000
2	0.999[b]	0.999	0.999	489.439	0.044	295.364	1	8	0.000
3	1.000[c]	1.000	1.000	114.468	0.001	139.259	1	7	0.000
4	1.000[d]	1.000	1.000	31.997	0.000	83.584	1	6	0.000
5	1.000[e]	1.000	1.000	0.000	0.000	.	1	5	.

a. Predictors: (Constant), X_1
b. Predictors: (Constant), X_1, X_2
c. Predictors: (Constant), X_1, X_2, X_3
d. Predictors: (Constant), X_1, X_2, X_3, X_4
e. Predictors: (Constant), X_1, X_2, X_3, X_4, X_5
f. Dependent Variable: Y_1

6.2 Development of number of fatalities Model (Y_2)

The statistical input data shown in Table 8 and the output of SPSS computer program is explained in Table 9 as follows: The selected model is as follow:

$$\mathbf{Y_2 = 14.104 + 1.108X_2 + 1.039X_3}$$

6.3 Development of number of slight injuries Model "Y_3"

The statistical input data shown in Table 10 and the output of SPSS computer program are explained in Table 11 as follows:

The selected model is as follow:

$$\mathbf{Y_3 = 477.992 + 0.868\ X_2 + 5.501\ X_4}$$

Table 7: Coefficients of the Drivers' Faults Model.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T-Test	Sig.
		B	Std. Error	Beta		
1	(Constant)	5772.090	2330.977		2.476	0.035
	X_1	1.755	0.127	0.977	13.868	0.000
2	(Constant)	2809.282	436.940		6.429	0.000
	X_1	0.961	0.051	0.535	18.823	0.000
	X_2	1.072	0.062	0.489	17.186	0.000
3	(Constant)	1261.794	166.249		7.590	0.000
	X_1	1.005	0.013	0.560	80.354	0.000
	X_2	1.006	0.016	0.459	64.454	0.000
	X_3	0.962	0.082	0.036	11.801	0.000
4	(Constant)	654.867	81.035		8.081	0.000
	X_1	1.010	0.004	0.563	285.194	0.000
	X_2	0.998	0.004	0.455	224.807	0.000
	X_3	0.978	0.023	0.037	42.794	0.000
	X_4	0.965	0.106	0.007	9.142	0.000

a. Dependent Variable: Total Faults (Y_1)

Table 8: Fatalities Accidents (2000-2010).

Total Fatalities	Wrong Passing	Red Light Violation	Speeding	Lane Violation	Close Following	Year
287	30	3	127	124	3	**2000**
280	17	4	123	133	3	**2001**
380	34	4	85	239	18	**2002**
143	13	0	28	97	5	**2003**
436	31	4	40	341	20	**2004**
238	20	12	38	144	24	**2005**
283	12	12	55	186	18	**2006**
435	45	11	109	261	9	**2007**
277	10	7	85	168	7	**2008**
312	11	7	63	222	9	**2009**
356	12	5	66	269	4	**2010**
Σ 3427	**Σ 235**	**Σ 69**	**Σ 819**	**Σ 2184**	**Σ 120**	

Table 9: Model Summary of the Fatalities Accidents.

Model Summary[f]

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	0.896[a]	0.803	0.781	40.447	0.803	36.731	1	9	0.000
2	0.985[b]	0.970	0.962	16.755	0.167	44.446	1	8	0.000
3	0.996[c]	0.991	0.988	9.552	0.021	17.617	1	7	0.004
4	0.999[d]	0.999	0.998	3.970	0.007	34.514	1	6	0.001
5	1.000[e]	1.000	1.000	0.000	0.001	.	1	5	.
a. Predictors: (Constant), X_2									
b. Predictors: (Constant), X_2, X_3									
c. Predictors: (Constant), X_2, X_3, X_1									
d. Predictors: (Constant), X_2, X_3, X_1, X_5									
e. Predictors: (Constant), X_2, X_3, X_1, X_5, X_4									
f. Dependent Variable: Y_2									

Table 10: Slight Injuries Accidents.

Total Slight Injuries	Wrong Passing	Red Light Violation	Speeding	Lane Violation	Close Following	Year
5765	275	474	1632	2593	791	**2000**
3777	189	283	977	1874	454	**2001**
3615	212	215	767	2011	410	**2002**
2255	93	172	480	1306	204	**2003**
7606	335	512	883	4986	890	**2004**
5076	255	475	511	2779	1056	**2005**
5089	198	395	567	2958	971	**2006**
6367	274	507	969	3495	1122	**2007**
4484	128	282	681	2642	751	**2008**
5769	132	434	735	3484	984	**2009**
6858	142	463	777	4406	1070	**2010**
Σ 56661	**Σ 2233**	**Σ 4212**	**Σ 8979**	**Σ 32534**	**Σ 8703**	

Table 11: Model Summary of the Slight Injuries Accidents.

Model Summary[f]

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	0.953[a]	0.909	0.898	496.701	0.909	89.361	1	9	0.000
2	0.988[b]	0.976	0.970	268.567	0.068	22.784	1	8	0.001
3	0.998[c]	0.996	0.995	113.294	0.020	37.956	1	7	0.000
4	1.000[d]	0.999	0.998	61.278	0.003	17.928	1	6	0.005
5	1.000[e]	1.000	1.000	0.000	0.001	.	1	5	.

a. Predictors: (Constant), X_2
b. Predictors: (Constant), X_2, X_3
c. Predictors: (Constant), X_2, X_3, X_4
d. Predictors: (Constant), X_2, X_3 ,X_4, X_1
e. Predictors: (Constant), X_2, X_3 ,X_4, X_1, X_5
f. Dependent Variable: Y_3

Table 12: Sever Injuries Accidents.

Total Sever Injuries	Wrong Passing	Red Light Violation	Speeding	Lane Violation	Close Following	Year
191	13	2	81	88	7	**2000**
849	53	23	265	441	67	**2001**
683	62	42	114	393	72	**2002**
359	25	13	86	223	12	**2003**
1208	56	55	125	880	92	**2004**
745	50	23	72	497	103	**2005**
941	51	59	101	611	119	**2006**
1009	57	52	173	644	83	**2007**
861	36	48	148	562	67	**2008**
717	38	36	80	512	51	**2009**
1311	40	34	131	1016	90	**2010**
Σ 8874	**Σ 481**	**Σ 387**	**Σ 1376**	**Σ 5867**	**Σ 763**	

Table 13: Model Summary of the Sever Injuries Accidents.

Model Summary[f]

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	0.974[a]	0.950	0.944	77.967	0.950	169.611	1	9	0.000
2	0.992[b]	0.983	0.979	47.733	0.034	16.012	1	8	0.004
3	0.999[c]	0.997	0.996	19.742	0.014	39.767	1	7	0.000
4	1.000[d]	0.999	0.999	9.799	0.002	22.412	1	6	0.003
5	1.000[e]	1.000	1.000	0.000	0.001	.	1	5	.

a. Predictors: (Constant), X_2
b. Predictors: (Constant), X_2, X_3
c. Predictors: (Constant), X_2, X_3, X_1
d. Predictors: (Constant), X_2, X_3, X_1, X_4
e. Predictors: (Constant), X_2, X_3, X_1, X_4, X_5
f. Dependent Variable: Y_4

6.4 Development of number of sever injuries Model "Y_4"

The statistical input data shown in table 12 and the output of SPSS computer program are explained in table 13 as follows:

The selected model is as follows:

$$\mathbf{Y_4 = 45.793 + 1.169X_2 + 1.100X_3}$$

7. Discussion of Results

The multivariate linear regression analysis was used to explore the functional relationships between accident frequency and the five driver's characteristics independent variables. The results of the analysis with the selected independent variables provided 4 models. The summary of model results is shown in Table 14.

Table 14: Summary of the Developed Regression Models

Model No.	Regression Models	R^2
1	$Y_1 = 2809.282 + 0.961X_1 + 1.072X_2$	0.999
2	$Y_2 = 14.104 + 1.108X_2 + 1.039X_3$	0.970
3	$Y_3 = 477.992 + 0.868\ X_2 + 5.501\ X_3$	0.976
4	$Y_4 = 45.793 + 1.169X_2 + 1.100X_3$	0.983

7.1 Validation of Model "1" (Faults)

$$\mathbf{Y_1 = 2809.282 + 0.961X_1 + 1.072X_2}$$

The statistical output results presented in Tables 6 and 7 show a significant F-test of the model and significant t-test for each variable. Also, the results show a strong correlation coefficient between dependent variable and independent variables ($R^2 = 0.999$).

The application of the model on accident statistics of year 2001 shows that the predicted total accident faults are 1.7% less than observed total accidents faults which means that the developed model is valid for application to reduce total driver accident faults. The application of the model also shows that If 10% reduction of accidents on close following (X_1) and lane violation (X_2) each year respectively for the next ten years will reduce the total accidents from 63562 registered in year 2011 to 2809 total accident faults. The percentage of total accident reduction is about 96% with $X_1= 0$ and $X_2=0$.

The accident reductions required a countermeasures program for close following and for lane violation which should be implemented by the traffic management authorities and also a (before and after) studies that are required to determine the accurate percentage of reduction for each countermeasure.

7.2 Validation of Model "2" (Fatalities)

$$\mathbf{Y_2 = 14.104 + 1.108X_2 + 1.039X_3}$$

The statistical output results presented on tables 8 and 9 shows a significant F-test of the model and significant t-test for each variable. Also, the results show a strong correlation coefficient between dependent variable and independent variables ($R^2 = 0.97$).

The application of the model on accident statistics of year 2001 shows that the predicted accident fatalities are 2.2% more than the observed accidents fatalities, which means that the developed model is valid for application to reduce accident fatalities. The application of the model also shows that If 10% reduction of accidents on lane violation (X_2) and speeding (X_3) each year for the next ten years will reduce the accident fatalities from 327 registered in year 2011 to 14 fatalities. The percentage of accident reduction in fatalities is about 96% with $X_2= 0$ and $X_3=0$.

The accident reductions required a countermeasures program for lane violation and speeding that should be implemented by the traffic management authorities and also a (before and after) studies that are required to determine the accurate percentage of reduction for each countermeasure.

7.3 Validation of Model "3" (Slight Injuries):

$$\mathbf{Y_3 = 477.992 + 0.868\ X_2 + 5.501\ X_4}$$

The statistical output results presented in tables 10 and 11 shows a significant F-test of the model and significant t-test for each variable. Also the results show a strong correlation coefficient between dependent variables and independent variables ($R^2 = 0.976$).

The application of the model on accident statistics of year 2001 shows that the predicted accident slight injuries are 3% more than the observed slight injuries accidents, which means that the developed model is valid for application to reduce slight injuries accident. The application of the model shows also that If 10% reduction of accidents on lane violation (X_2) and red light violation (X_4) each year for the next ten years will reduce the slight injuries accident from 7088 registered in year 2011 to 478 slight injuries. The percentage of accident reduction in slight injuries accidents is about 93% with $X_2= 0$ and $X_4=0$.

The accident reductions required a countermeasures program for lane violation and red light violation that should be implemented by the traffic management authorities and also a (before and after) studies that are required to determine the accurate percentage of reduction for each countermeasure.

7.4 Validation of Model "4" (Sever Injuries)

$$\mathbf{Y_4 = 45.793 + 1.169X_2 + 1.100X_3}$$

The statistical output results presented on tables 12 and 13 shows a significant F-test of the model and significant t-test for each variable. Also the results show a strong correlation coefficient between dependent variable and independent variables ($R^2 = 0.983$).

The application of the model on accident statistics of year 2001 shows that the predicted accident sever injuries are 4% more than the observed sever injuries accidents which means that the developed model is valid for application to reduce sever injuries accident . The application of the model shows also that if 10% reduction of

accidents on lane violation (X_2) and speeding (X_3) each year for the next ten years will reduce the sever injuries from 1100 registered in year 2011 to 46 sever injuries. The percentage of accident reduction in sever injuries is about 97% with X_2= 0 and X_3=0.
The same countermeasures and before and after studies for model 2 are required for model 4.

8. Reliability of the Developed Models

Because of the social relationship and the economic considerations, the traffic accidents are not 100% reported. This is obvious through a face to face interview with the experts in traffic safety in many occasions. Therefore it is estimated that traffic accidents in Jordan are not reported for about 20% to 25% of property damages, and about 10% to 15% of slight injuries and about 5% to 10% of sever injuries. According to previous estimations, the authors believe that the reliability of the developed model could be between 75% and 80%.
The percentage of reliability may be increased if the accident injuries divided in categories scale and included in the accident and medical reports as recommended by FHWA. The recommended scale is called AIS (Abbreviated Injury Scale) (2). The scale is divided to (Fatal, Critical, sever, serious, moderate, and minor) which explain exactly the type of injuries and help to estimate the cost of each type of accident.

9. Conclusions

1) The predicted models resulted from SPSS computer program indicate a very strong correlation coefficient between dependent variable and independent variables. The statistical results also show a high significant F-test and t-test for the models and variables respectively.
2) The validation of the developed predicted models indicate small error (less than 5%) with the observed statistical registered data for the year 2011 according to Jordan Traffic Institute.
3) It is possible to estimate the reliability of the models to be between 75% and 80% because the study is depending on the government yearly accident report provided by Jordan Traffic Institute.
4) The predicted models can be applied as a part of Highway Safety Improvement Program (HSIP) to reduce traffic accidents in Jordan.

10. Recommendations

According to the previous results and the conclusions for the developed predicted models, the following countermeasures can be recommended to apply the models and in order to reduce total accidents, slight injuries, sever injuries, and fatalities that are related to selected driver mistakes (Faults).
1) For close following, or tailgating (X_1), it is required to apply a high technology instrument to detect this driver faults and to increase the low enforcement in order to reduce accidents resulting from close following. Advanced warning and educational signs are important to be installed along the streets. A display of moving warning to pay more attention to the drivers to not drive closely.
2) For lane violation (X_2) on multilane highways and on principle arterials, it is recommended to detect this driver faults by the traffic police and apply the same recommendation for the close following driver faults.
3) For speeding or violation of the speed limit(X_3), a special attention should be taken to reduce the accident due to driving more than the speed limit. Speed reduction strategies are highly recommended to be applied. Countermeasures such as warning signs, hump, bump, pavement grooving or stripping are recommended to reduce speeding. High technology instruments to detect the violation of speed limit are also required.
4) For red light violations (X_4), which are the most fatal or injury on signalized intersections. Optimization of cycle length, increasing the ALL-Red clearance to 2 seconds interval, and redesign the yellow timing may reduce the violation on red interval.
5) For wrong passing (X_5) on two- lane highway may need a special design treatment to avoid the violation of wrong passing such as passing lane, climbing lane, turnout, paved shoulder, tow way left-turn lane.
6) All the above recommended countermeasures required a before- after studies to determine the accident reduction factor for each type of countermeasure.
7) More researches are recommended in this field with more driver violations (independent variables) are needed to reduce the total number of accident specially the accidents causing fatalities and injuries.

ACKNOWLEDGEMENT

The authors of this paper would like to acknowledge the following engineering students at Al-Isra University, Saif Hamdallah and Mohammed Al-Kahla, for their valuable contribution to this study during graduation project. Their work is highly appreciated.

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