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MODELING AND ANALYZING THE FACTORS AFFECTING THE MORTALITY OF PEDESTRIANS IN URBAN ACCIDENTS

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Abstract: The nature of urban and rural accidents has been different from each other in some of the factors and even the severity of damage rate, mayhem, and death. In this research, using statistical methods and binary logistic regression model, we have addressed to analyze important parameters such as age, gender, education level, the color of the pedestrian dress, season of accident, time of accident, the speed of the vehicle colliding with pedestrians and road surface conditions at the time of accident on the way of death (at the scene of the incident or in the hospital) pedestrians who have been traumatized. After the creation of the binary logistic regression model, it was determined that only the parameters of speed and the accident time have been significant in the level less than 5%. And other parameters such as age, gender, the season of accident occurrence, the color of the pedestrian dress, road surface conditions and education level had no significant effect in terms of statistical on the incidence of mortality arising from a pedestrian accident with the motor vehicle. The results revealed that by adopting decisions related to the traffic calming, attention to passages lighting and brightness the mortality rate of a pedestrian due to the urban accidents can be reduced.

Keywords: accident, pedestrian, speed, urbanization.

1. Introduction

There is no doubt that in today's world, the accidents are considered as one of the biggest public health problems and are known to be the leading cause of mortality so that every year the lives of approximately 1.35 million people are cut short as a result of a road traffic crash. Between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury. It is estimated that traffic accidents impose more than 518 billion $ cost all around the world, which is on average 1-5% of the gross domestic product of the countries. The average rate of mortality due to the accidents in the world is about 20 deaths per 100000 persons, whereas in Europe this amount is equivalent to 11 deaths per 100000 people and in Oriental Mediterranean and Africa, this number is 26.8 and 28.3 per 100000 people [2]. The World Health Organization and World Bank estimate that in the next two decades, the traffic accident rate in developed European countries will decrease by 28%, however, in less developed countries and/or undeveloped the rate of accidents leading to death will increase by about 92-147%. Thus, studying and reduction of traffic accidents around the world especially in developing countries require prioritizing [3]. Previous studies have indicated that pedestrian age, crossing or non-crossing the intersections by pedestrians, the time of accident occurrence (hour, day and day of the week), type of road and violation or non-violation of traffic rules are considered as the parameters affecting traffic accidents of pedestrians. So it seems that the key factors affecting the way of pedestrian death which are classified in the following two categories:

- in incident place
- in the hospital

have to be identified in order to reduce the number of losses. The situation has to be improved by providing solutions, so while reducing the costs of these accidents, has to maintain the existence of effective human resources which is the main source of the progress of any country. Therefore, the safety of human resources in the form of the pedestrian is considered to be very important in different types of built environment [4]. This is most obvious in urban spaces. Among all street users in urban areas, pedestrians are the most vulnerable one as they are the least unprotected users, and in a collision between a car and a pedestrian, the severity is usually high for the pedestrian [5].

Unfortunately, traffic accidents are the second leading cause of death in Iran, and East Azerbaijan province has been ranked first in the country for rural accidents and the forth for urban accidents [6]. The aim of this study was to evaluate the influence of the parameters on deaths caused by urban traffic accidents and to provide a regression model for these parameters and finally to present some solutions in order to prevent the problems and their complication, these parameters are as follows:

1. Gender in two categories of women and men,
2. Pedestrian age in the range of 5 to 90 years,
3. The level of education in classes of illiterate, under the diploma, diploma, Associate Degree, Bachelor's Degree, Master's Degree, and higher and uncertain,
4. The season of accidents occurring in classes of spring, summer, autumn, and winter,
5. Occurrence time of accident: in the morning or noon or evening and/or the night and uncertain
6. Vehicle speed in the range of 30 to 120 km/h
7. Road surface conditions as dry, wet and unclear
8. The bright or dark color of clothing.

This research was conducted by a descriptive-analytical study on pedestrians who died in traffic accidents in 2015 and 2016. The related information was collected from the data registered in the case files of Iran – Tabriz Forensic Medicine Organization, and has been modeled by the logistic regression method and was analyzed by SPSS software.

2. Research Background

A large number of traffic accidents prediction model are based on the statistical regression techniques. Smeed (1949) studied the calculated number of severely injured people in accidents thus accident rate in different countries calculated. Then, the first study was focusing on the mortalities number caused by accidents conducted by Smeed and the study was the beginning of a large number of practical models. He followed the process of accidents rates in the U.S and the economic cost of road accidents and analyzed the success level of various methods used to prevent accidents.

A large number of practical models have been created based on his work. Leemimg (1976) proposed the factors of Smeed for different countries and if different years. Pitsiava- Latinapoulou and Tsohos (1982) analyzed data related to 14 years with a focus on the relation between deadly road accidents and the number of vehicles produced in Greece using statistical methods and presented a relation with a higher degree of accuracy using the equation of Smeed. Adams (1985) evaluated the correction of incident-prone points and Belt Safety Act as a part of automobile safety regulations utilizing the explanations of the Smeed Act. Broughton validated the empirical relationships between Smeed equation and other developed models based on the Smeed equation in order to provide common methods for predicting mortalities and the total number of accidents. Gharaybeh (1994) evaluated traffic safety development in Jordan using Smeed equation for more than two decades. In Iran, Navin et al. have developed a road safety model which includes special items from Smeed model.

Dissanayake and Lu (2002) have used logistic regression method to determine factors which affect the severity of injuries arising from accidents and also mortalities of old drivers who work on the private vehicles. In the study conducted by Abdelwahab, H. T. & Abdel-Aty, M. A(2006), which has done in Saudi Arabia one logistic regression approach has been used for evaluating individual variables contributing to the severity of injuries and mortalities. The results indicate that the place (location) and the reason for the accident are important factors to increase the severity of injuries and mortality caused by accidents. Another logistic regression model was used for determining the relationship of drivers' age with the severity of injuries and losses due to traffic accidents. Data used were related to Wisconsin accidents during the years 2002 and 2004 to study 602.964 drivers who were involved in a car accident, and it was found that the oldest drivers – especially those who are over 85 years old – are most at risk of the severity of injuries and death[7].

3. Method

SPSS software is one of the oldest applications in the field of statistical analysis. Statistical software has the ability to perform a beautiful and illustrative description of information, including drawing of various charts and calculations related to the mean, standard deviation of variance, median and performing calculations regarding different regressions. Given these abilities, descriptive and inferential analysis have been done in this research, using this software. Descriptive statistics have been used to describe the research variables in the form of tables and charts and in the inferential statistics part for analyzing data to judge assumptions of the research after it is specified whether data are normal or abnormal. Using the Kolmogorov-Smirnov test by Tolerance parameter values, it has been evaluated the lack of multicollinearity between independent variables and finally the modeling of binary logistic regression has been performed. Using Omnibus test this hypothesis is testing whether the independent models that have been added to the model are statistically effective or not. Using logarithm statistical values, the likelihood of model power for predicting is determined. By coefficient of Cox & Snell and Nagelkerke, it is determined how independent variables have been able to explain the variance of the independent variables. In the next step, with the assistance of statistic of Hosmer – Lemeshow goodness of fit and the ROC curve, it will be investigated whether the membership or grouping which was predicted for each triable equals to what it has been observed.

Then, using classification table, the model power is determined in separating people or differentiating individuals independent variable classes helping to show the function of model and the power of differentiating individuals independent variable classes or categories to expected response on the same class through drawing responses in an agreed manner. This table is useful for investigating the amount of predictability function of the model.

Finally, using the related table it has determined the role of each independent variable, and by the β factor, Wald statistic, and values related to the meaningful level of each variable it was interpreted the meaningful and impact rate of each independent variable on dependent variable and it will be presented in the corresponding regression equation.

4. Descriptive Analysis of Data

In this section, following the collection of data and information in Tables 1- 4, a summary of casualty statistics related to the traffic accidents in 2014 and 2015 will be provided. Using descriptive statistics, which includes central indicators and dispersion such as frequency, frequency percentage, charts and tables, the qualitative and quantitative variables in the data will be described.

Table 1

Death rates due to driving accidents in East Azerbaijan during 2014-2015

Accident location				**Season of Accident**
Total (N)	**Suburban**	**Rural**	**Urban**	
336	31	210	95	Spring
438	45	299	94	Summer
360	22	244	94	Autumn
277	14	171	92	Winter
1411	112	924	375	Total

Table 2

Death rates due to the urban driving accidents for pedestrians during 2014-2015

Pedestrian	Tabriz	East Azerbaijan Province	Gender
44	46	73	Female
114	168	302	Male
158	214	375	Total

Qualitative Variables

The total number of pedestrians injured in traffic accidents in Tabriz during 2014 and 2015 (referred to the Forensic Medicine Organization) was 158 cases according to the results of Table 3.

Table 3

The number of recorded items for urban accidents of pedestrians in Tabriz during 2014-2015

Total statistics								
		Gender	Marital status	Level of graduation	Season of accident	Time of accident	Dress color	Road surface conditions
Number	Valid items	158	158	158	158	158	158	158
	Missing value	0	0	0	0	0	0	0

Table 4 provides a summary of the statistics concerning each considered independent qualitative variable and shows that:

- the frequency of fatal injuries in men was higher than women.
- the frequency of fatal injuries in married people was higher than single people.
- the frequency of fatal injuries in illiterate people was higher than others.
- the frequency of fatal injuries in the winter was higher than in other seasons.

- the frequency of fatal injuries in the morning was higher than other tımes.
- the frequency of fatal injuries in the dry conditions was higher than wet conditions.
- the frequency of fatal injuries in the dark dress is higher than the bright dress.

Table 4

Statistical indicators considered in the research

		frequency	Frequency percentage	Valid items percentage	Cumulative percentage
Gender	Male	114	72.2	72.2	72.2
	Female	44	27.8	27.8	100
Marital status	Unmarried	36	22.8	22.8	22.8
	Married	122	77.2	77.2	100
Level of Education	Illiterate	64	40.5	40.5	40.5
	Under diploma	55	34.8	34.8	75.3
	Diploma	16	10.1	10.1	85.4
	Associate Degree	10	6.3	6.3	91.8
	Bachelor Degree	9	5.7	5.7	97.5
	Masters' Degree and higher	4	2.5	2.5	100
Season of accident	Spring	38	24.1	24.1	24.1
	Summer	42	26.6	26.6	50.6
	Autumn	28	17.7	17.7	68.4
	Winter	50	31.6	31.6	100
Time of accident	Morning	61	68.6	38.6	38.6
	The Noon	37	23.4	23.4	62
	Evening	31	19.6	19.6	81.6
	The Night	29	18.4	18.4	100
Road surface conditions	Dry	81	51.3	51.3	51.3
	Wet	77	48.7	48.7	100
Dress color	Dark	115	72.8	72.8	72.8
	Bright	43	27.2	27.2	100

Quantitative Variables

Among considered variables for analyzing and evaluating the variables affecting the mortality due to the traffic accidents of pedestrians just the variables of age and speed are quantitative and therefore they are dealt with in this section.

Table 5

Statistical indicators regarding the age of studied people and the speed of the vehicle collisions

Descriptive statistics											
	No.	Variations domain	Min	Max	Mean	Standard deviation	Variance	Coefficient of skewness		Coefficient of kurtosis	
					Amount or value	Amount or value	Amount or value	Amount or value	Standard error	Amount or value	Standard error
Age	158	93	1	94	52.9	23.9	573	-0.295	0.193	-0.874	0.384
Speed	158	65	40	105	68.99	14.3	204.62	0.200	0.193	-0.645	0.384
Number of valid items	78										

In the case of these variables, it should be noted that it can have a normal distribution in terms of descriptive statistics. Due to the amount of the coefficient of skewness and kurtosis each of the variables which have the amounts of -0.295 and -0.874 for age and 0.200 and -0.645 for speed respectively, and all of these amounts and values have been placed in the range of (-2, +2). Kolmogorov-Smirnov test has been used to prove this issue in terms of inferential, which is stated in Table 6.

Table 6

Results of Kolmogorov-Smirnov test for age and speed variables

Single-sample Kolmogorov-Smirnov test			
		Age	Speed
Number		158	158
Normal parameters a,b	Mean	52.88	68.99
	Standard deviation	23.94	14.30
Most Extreme Differences	Absolute	0.078	0.096
	Positive	0.054	0.096
	Negative	-0.078	-0.083
Kolmogorov-Smirnov test statistic		0.975	1.205
Significance level (2-tailed)		0.297	0.110

Based on the results in the above table and the amount of Asymp. Sig. (2-tailed) which has values or amounts greater than 0.05 for both variables of age and speed, we concluded that the null hypothesis is confirmed based on the fact that the distribution of data related to these variables is normal.

Evaluation of the lack of Multicollinearity between Independent Variables

It is clear from Table 7 and the values obtained from analyses for tolerance parameter of each variables that its value is closer to 1 for all variables, so that speed, dress color, the time of accident, gender, and road surface conditions with the values above 0.90 respectively have the highest values of tolerance parameter. The least value is dedicated to age which also has a value greater than 0.5.

Table 7

Results related to the evaluation of the lack of multicollinearity between independent variables

Model		Non-standard coefficients		standard coefficients	t statistic	Significance level	Range related to the confidence level of 95% for β		Statistics regarding multicollinearity between independent variables	
		β	Standard error	Beta			Lower bound	Upper bound	Tolerance parameter	Variance inflation factor (VIF)
	Constant number	2.3	0.26		8.75	0.00	1.78	2.82		
	Gender	0.068	0.063	0.077	1.079	0.282	-0.057	0.193	0.936	1.068
	Age	0.002 -	0.002	-0.149	-1.54	0.125	-0.006	0.001	0.506	1.978
	Speed	0.013 -	0.002	-0.454	-6.525	0.0	-0.016	-0.009	0.979	1.021
	Marital status	0.026	0.083	0.028	0.315	0.753	-0.137	0.190	0.619	1.614
1	Education level	0.030	0.025	0.098	1.195	0.234	-0.020	0.080	0.703	1.423
	Season of the accident	0.041	0.025	0.120	1.652	0.101	-0.008	0.090	0.891	1.123
	Time of the accident	0.077	0.025	0.219	3.119	0.002	0.028	0.125	0.958	1.044
	Road surface conditions	0.034	0.058	0.043	0.600	0.550	-0.079	0.148	0.903	1.107
	Dress color	0.014 -	0.063	-0.015	-0.220	0.827	-0.137	0.110	0.962	1.039

Therefore, the above table shows that none of the independent variables have multicollinearity with other variables.

Modeling by Binary Logistic Regression

Overall, the total outputs of logistic regression can be divided into 5 sections which are as follows:

1. General investigation of the model
2. Determination of the model power in predicting dependent variable based on the independent variables
3. Statistic of the goodness of fit
4. Statistical tests regarding the impact of each prediction variable (independent)
5. Evaluation of the predicted probabilities

General Investigation of the Model

Omnibus test related to the general investigation of the binary logistic regression model is used. Table 8 shows that the Significance level of this test is less than 0.05. Hence, we can conclude that the fitness of the model has been acceptable. From the statistical point of view adding the variables to model with/for an error level of less than 0.01 (0.00) is significant and meaningful.

Table 8

Tthe results of Omnibus test for general evaluation of the model

Factors related to Omnibus test				
		Chi-square	Degree of freedom	Significance level
Step 1	Step	57.69	17	0.000
	Block	57.69	17	0.000
	Model	57.69	17	0.000

Determination of Model Power in Predicting the Dependent Variable based on the Independent Variables

Table 9 indicates the results regarding two log-likelihood statistic and pseudo coefficient of determination (including Cox & Snell and Nagelkerke coefficient of determination). The log-likelihood statistic measures the rate of model prediction weakness in decision making among these coefficients and factors. Cox & Snell and Nagelkerke coefficients of determination are specifying that independent variables have been able to explain how much of dependent variable variate. The values of both statistics related to the pseudo coefficient of determination have been approximately suitable (0.58, 0.30) and this indicates that 9 independent variables of this research have appropriate power explanation regarding variance and the variations of the dependent variable. Actually, these 9 independent variables have been able to explain 30%-58% of dependent variable variations.

Table 9

Results related to two log-likelihood statistic and pseudo coefficient of determination

Summary of the model			
Step	Log-likelihood	Cox & Snell coefficient of determination	Nagelkerke coefficient of determination
1	98.76	0.30	0.58

The Goodness of Fit Statistics

In the logistic regression order with the aid of Hosmer-Lemeshow goodness of fit statistic and ROC curve it could be found the amount of fitness of the model with data. In other words, the Hosmer-Lemeshow test investigates this issue whether the membership or classification that we predicted for each triable is equal to what we have observed or not. Table 10 shows that the significance level is greater than 0.05 that means independent variables are able to predict the variations of the dependent variable.

Table 10

Results of Hosmer-Lemeshow test for determining the amount of Fitness of the model with data

Hosmer-Lemeshow test			
Step	Chi-square	df	Significance level
1	9.23	8	0.33

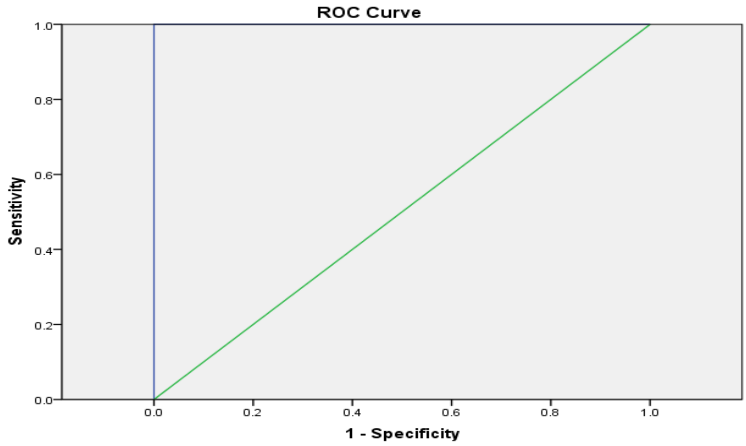

Fig. 1 - ROC Curve

Table 11

Predicted probability for the results of variables test

The area under the curve	Standard error	Significance level	Confidence level %95	
			Lower bound	Upper bound
0.94	0/03	0/0	0.87	1

Also, figure 1 and Table 11 which are related to ROC curve show that the area under curve is between 0.5 to 1 and its significance level is less than 0.05 as well, it is confirmed that research model has been suitable and has required fitness that means independent variables are able to predict the variations of dependent variable.

After performing logistic regression analysis, the power of model in differentiating individuals independent variable classes or categories can be determined using classification table. Based on the results of the table, the accuracy and precision of the model can be found, classifying the individuals. In table 12, the accuracy percentage of the model prediction and classification has been shown. It can be seen that the accuracy of the data classification independent variable classes or categories is 84.8%, which is obtained from equation 1:

Table 12

Classification Table

	Observed		Predicted		
			Place of death		Percentage of correct prediction
			At the scene of the incident	In the hospital	
Step 1	Place of death	At the scene of the incident	15	16	48.4
		In the hospital	8	119	93.7
	Total percentage				84.8

$$Percentage\ of\ correct\ prediction = \frac{SUM\ of\ primary\ diameter\ numbers\ of\ Matric}{Total\ Frequency\ of\ fatal\ injured\ people} * 100\ (1)$$

So:

$$Percentage\ of\ correct\ prediction = \frac{119 + 15}{158} * 100 = 84.8$$

Table 13 while presenting a summary of the role of each variable in the model indicates that which variables have been retained in the model after implementing the logistic model. This table has been the most important table for interpreting the results related to the significance and effect rate of each independent variable on the dependent variable. The final regression equation is also created based on the intercept values and β factor.

Table 13

Role of Independent Variables in the Model

		β	Standard error	Wald statistic	Degree of freedom	Significance level	Odds ratio
Step 1	Age	**-0.029**	**0.018**	**2.741**	**1**	**0.098**	**0.971**
	Speed	**-0.128**	**0.027**	**22.64**	**1**	**0.000**	**0.880**
	Gender(1)	**-0.779**	**0.662**	**1.387**	**1**	**0.239**	**0.459**
	Marital status (1)	**-0.642**	**0.869**	**0.546**	**1**	**0.460**	**0.526**
	Education level			**3.393**	**5**	**0.640**	
	Education level (1)	**-18.9**	**17951**	**0.000**	**1**	**0.999**	**0.000**
	Education level (2)	**-18.84**	**17951**	**0.000**	**1**	**0.999**	**0.000**
	Education level (3)	**-18.62**	**17951**	**0.000**	**1**	**0.999**	**0.000**
	Education level (4)	**-16.84**	**17951**	**0.000**	**1**	**0.999**	**0.000**
	Education level (5)	**-17.08**	**17951**	**0.000**	**1**	**0.999**	**0.000**
	Season of the accident			**3.111**	**3**	**0.375**	
	Season of the accident (1)	**-1.256**	**0.763**	**2.714**	**1**	**0.099**	**0.285**
	Season of the accident (2)	**-0.419**	**0.779**	**0.289**	**1**	**0.591**	**0.658**
	Season of the accident(3)	**-0.048**	**0.875**	**0.003**	**1**	**0.956**	**0.953**
	Time of accident			**5.836**	**3**	**0.120**	
	Time of accident (1)	**-2.095**	**0.949**	**4.869**	**1**	**0.027**	**0.123**
	Time of accident (2)	**-2.023**	**1.027**	**3.883**	**1**	**0.049**	**0.132**
	Time of accident(3)	**-1.103**	**1.104**	**0.998**	**1**	**0.318**	**0.332**
	Road surface conditions (1)	**-0.356**	**0.595**	**0.357**	**1**	**0.550**	**0.701**
	Dress color (1)	**0.639**	**0.661**	**0.935**	**1**	**0.334**	**1.894**
	Constant number (intercept)	**33.702**	**17951**	**0.000**	**1**	**0.999**	**43300451712**

Based on the results in Table 13, and usage of equation 2 which is related to the binary logistic regression model, the regression model was developed as equation 3.

$$\ln\left(\frac{\pi}{1-\pi}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k \qquad (2)$$

$$\begin{aligned}\ln\left(\frac{\pi}{1-\pi}\right) = {} & 33.70 - 0.029(age) - 0.128(speed) - 0.779(man) \\ & - 0.642(married) - 18.9(illiterate) - 18.84(under\ diploma) \\ & - 18.62(diploma) - 16.84(associate\ degree) \\ & - 17.08(bachelor\ degree) - 1.256(spring) - 0.419(summer) \\ & - 0.048(autumn) - 2.095(morning) - 2.033(the\ noon) \\ & - 1.103(evening) - 0.356(dry\ road) - 0.639(dark\ dress)\end{aligned} \qquad (3)$$

Conclusion

Based on the results from Table 13 and the values of significance level of each variables it became clear that only the parameters of speed and time of accident has been significant and meaningful at a level less than 5% and other parameters such as age, sex or gender, the season of accident, dress color of pedestrians, road surface conditions and level of education have not played a role in mortality of pedestrians due to the accidents with motor vehicles. Therefore, the mortality rate of pedestrians arising from urban accidents can be reduced by adopting decisions regarding the traffic calming, using intelligent traffic control cameras, also paying attention to the brightness of passages.

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