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Evaluation of Safety Criteria for Road Equipment in Suburban Axes Using the Quantitative Evaluation Process of Two-Lane Roads

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Abstract- Since the amount of accidents on suburban roads is higher compared to urban roads due to vehicle speeds and topography, local and long communication paths, it is essential to examine and study the roads safety at the design stage of a new route and also the development and maintenance of the current roads through improvement and elimination of accident black spots. The study is conducted based on descriptive analytic method. Descriptive and inferential statistics were used for statistical analysis of collected data. Inferential statistics such as Friedman test and mean analysis were used for data collected from field surveys and questionnaires and t-test was used to test the hypothesis significance and the reliability of questions was tested using Cronbach's alpha. Following, human factors were in second place among them, speed and unauthorized overtaking, deviation to the left and undue haste acceleration were among the human reason for the accidents at the axis, explaining that that two factors of speed and unauthorized overtaking were among the affective factors for accidents at the axis regardless of the categories. Technical factors and quality of the car s were at the third place and finally natural environment were at the fourth place. Furthermore, hypotheses relating to the factors with accidents axis mentioned above were proven except the environment factors, the significance of which were not approved.

Keywords- *Accident, Descriptive and Inferential Statistics, Friedman Test, Cronbach's Alpha, Environment Factors*

I. INTRODUCTION

Transport growth, or simplification of load and human transportation has been major contributions to the progress of human societies both at individual and social aspect. Today, the number of accidents in our cities is on the rise and as a result, the financial losses caused by them imposed on family and the state are very high and given that financial, physical, psychological and social losses are irreversible issues in some cases, it is essential to consider effective ways to prevent losses due to car accidents. Regarding the existed need for effective coordination and implementation of criteria to increase road safety regarding engineering aspects, there is more need for designers and road constructors, specifically consultant engineers and monitoring personnel to consider and provide the criterion, better implementation of them in various improving procedures for road safety and correction of accident dark points, seven basic criteria, the provision of which in case of allocating more funds, would improve road safety, are regarded in this study. It should also be mentioned that the road safety and provision of its requirements in accordance with the road type (freeway, highway, main road, side roads and rural roads) and the speed of designing are determined and considered as the basis of action. The present study aims to analyze and evaluate the accident rates and road construction and safety to reduce road accidents.

II. RESEARCH PROBLEM

Arched road sections and the connection path associated with them can be an important factor to reduce the number and severity of the accident. This inconsistency should be controlled by the engineers. The two-lane suburban roads have higher accident rate and higher rate of accidents costs compared to the multi-lane roads. So there should be more emphasis and special attention to this part of the road network during the design process, redesigns, restoration projects, modernization and reconstruction of the pavement. As regards the impact on road safety is significantly related to the causes of road accidents and associated factors, the present study is conducted regarding the safety causes of road accidents and ways to prevent them, many of the parameters affecting road safety can be classified in one of the groups linked to human, vehicle, road and environment. According to the most variable parameters associated with the human, vehicle and the environment, the possibility of invoking these parameters and establishing the basis for research model as the subject of this research to predict the road safety index is almost impossible. However, the parameters related to road conditions, the use of physical and geometric conditions, urban population in its coverage and other characteristics of a road can be a good basis to be considered for the design of the study. In this research, safety issue is coordinated and considered with economic considerations, environmental and aesthetic issues.

III. THEORETICAL FRAMEWORK HADDON MATRIX

In 1960w, an American epidemiologist called William Haddon provided a systematic framework for road safety based on disease model which included infrastructure, vehicles and users at three phases of pre-crash, crash and post-crash. Attempts by Haddon were made to use systems theory for explaining the ways to reduce frequency and severity of accidents. The main proposition of systems theory is that crashes are the results of mismatch in the relationship between the components of complex systems. According to this theory, none of the components of transportation system are more important than others for successful performance. For example, people make mistake, but what the reason is? It could be said that human mistakes happens due to lack of proper mismatch between system and human capabilities. Systems theory is trying to find a solution for accidents using correction of transportation system components. Road engineering and vehicle safety are quite important in applying the system theory for road safety. Systems theory, as a theory to prevent accidents, has been acted more successful than other theories. Improvement in roads systems, traffic control and vehicle design significantly decreased the accidents rates in Western countries. This matrix is provided by an engineer and physicist called William Haddon including two axes: the vertical axis which is composed of various factors of safety system (human, vehicle and equipment, and environment) and horizontal axis of pre-crash, crash and post-crash. The intersection of these two axes forms a matrix with 9 cells, every one of which explains a list of factors causing the crash (table 1).

IV. GANARSON INJURY EQUATION

This equation was proposed by Ganarson in 1999 which indicates the relationship among road injuries (I) with exposure (Q), crash risks (A/Q) and injuries rate (I/A). The general formula is:

$$I=Q.(A/Q).(I/A) \quad (2)$$

The equation clearly shows that reduction in traffic casualties is the result of three reducing actions of exposure, crash risks and resulted injuries rate and a list of these actions can be provided and listed as safety measures:

TABLE I. LIST OF GANARSON FACTORS

strategies	General measures	Partial measures
Controlling exposure	1-demand transport and traffic 2. promote safety and comfort of walking and cycling 3- improving public transport 4. Support the transition to safer model	- urban transport policy, modernization - pricing regulations, efficient service - telecommunications, demand management - information from the automotive, logistics - Development Area sidewalks and cycling network -integration and use public transport
Reducing accident rates	1. increase the homogeneity of the flow of traffic 2. Separation of traffic flows 3. improve traffic control and road management	- geometric design standards - functional classification of roads Traffic Manager, quiet pace of - Non Level intercept of the level crossings - Channeling - distribution of travel time - traffic control -maintenance and inspection
Reducing injuries rate	1. reduce the consequences of accidents -Preventive measures - efficient rescue service 2. reinstall the physical equipment	- Emergency unobstructed areas - installation of central PA and lateral protection - Create Relief and rescue services - Emergency Operations - Inspection and maintenance of way

V. THE PROBABILITY DISTRIBUTION OF THE DEPENDENT VARIABLE

A probability distribution function is a theoretical model which relates random variables to each of the probable values and obtains the given chance with reasonable proposition about the mechanism. These functions are often defined as normal, Poisson, negative binomial and selected in stochastic modeling process according to the type and nature of the dependent variable. It is proven that the accidents have random, discrete and non-negative nature. So, in the majority of predictive models to quantify accidents, two types of Poisson and negative binomial distribution are used. The Poisson and negative binomial distribution functions are as follows, respectively:

$$P(y_i) = \frac{\Gamma(y_i+\frac{1}{k})}{y_i!\Gamma(\frac{1}{k})}\left\{\frac{K\lambda_i}{1+k\lambda_i}\right\}^{y_i}\left\{\frac{1}{1+k\lambda_i}\right\}^{\frac{1}{k}} \quad (2)$$

Where, P(yi) is the probability of observed accidents and λi is the mean of accidents and k is the distribution parameter.

VI. REVIEW OF RELATED LITERATURE

Rouicher (2007) stated that issues surrounding the promotion and improvement of skid resistance or tangential

and side friction are often neglected and not considered. Many journals and articles have suggested that the adequacy of friction represents one of the most important aspects of safety. Studies show that the possibility of arch to become one of the black spots is increased by reducing the sliding resistance.

Sohrabi (2006) in a study stated that if the national scale shows good design level for an element, that element does not need any correction or adjustment. If a national safety shows medium rating scale design safety deficiencies can be somewhat reduced with the installation of traffic control devices and equipment and applying appropriate guidelines on speed. Also, in some cases Safety can be increased with some modification such as reconstruction of the pavement to increase and improve skid resistance.

VII. Effective parameter in safety of technical constructions

Road construction is accompanied by some operations such as excavation and embankment construction and in designing the road, it is always tried to pass the points with the lowest volume of earthworks as well as the shortest distance between two points and other specifications (minimum curve radius, maximum slope, etc.) of the road to be designed. However, when there are some natural barriers (valleys, rivers, neck, etc.) which should be passed by maintaining the proposed road specifications. The second technical construction examined in this study is discussed. In the field of construction, there are other technical constructions such as retaining walls, walls sponsor, galleries, Feb wells, siphon and others which given the importance of the issue and the key role of technical constructions in order to increase road safety and reduce accidents of the road. After a while, since the beginning of the operation to determine indicators individually are achieved with safety when comparing the designed situation. Bridges are important and complex parts of the road and are considered a large part of the national capital (Due to the cost of designing and construction).

VIII. Traffic-Related Death Rate in Iran 2011-2015

Traffic-related death rate of Iran is provided as a statistical dashboard for the first time by the engineering team of Transportation Safety website where one can selected the statistics based on the date and type of statistics to have immediate access to related data. The injured of road accidents, victims of accidents within the city, those killed in suburban accidents and general statistics of accidents are provided. The advantage of these statistical dashboards includes the interactive displays statistics, indicating statistics on maps and classification of the province based on the number of accidents per province. Statistical dashboards help the analysts to better understand statistics. Transportation Safety site tries to improve the quality of statistics related to the safety of Iran and to increase researchers' access to authoritative data of safety.

IX. Research Population and Methodology

Based on the research objective, the present study is conducted based on a descriptive-analytical method. Descriptive and inferential statistics were used for data analysis. Regarding descriptive statistics, first the nature of issue was investigated by collecting data for hypothesis analysis and answering the research question. The research is mostly considered as an applied study since the results of which will be used in decision-making, policy making and planning. Furthermore, it is a descriptive survey (Delavar, 2009). Population of the study included all the recorded data of road accidents which were recorded in various ways at tolling data software or as written reports. Population of the study included descriptive data of all the accidents and crashes in the related route which were recorded accordingly. However, for field and survey analysis, participants of the study included the drivers or users who frequently or professionally passed that road. Sample was selected using cluster sampling from among the users of the traffic road based on Cochran formula, as follows:

$$n=\frac{Z2pqn}{d2(N-1)+Z2pq} \quad (3)$$

Where:

N= number of population

N=sample

d= allowable error

Z= standard normal variable unit, which is 1.96 with 95% confidence level

P= the amount of characters available in the population. If not available, it can be considered 0.5. In this case, the amount of variance reaches its maximum value.

q= percent of people lacking the variable (q=1p)

The study period is considered as first three months of 2015. Due to higher traffic at holiday time, the statistics of first month was not included. Based on the estimations, nearly 13900 vehicles trafficked per day. Total traffic for May and June were calculated and the statistics based on the Cochran formula were 103 which were selected provided having features of permanent traffic so to be collected based on questionnaire and resulted data. Research sample included groups of users who passed the road (drivers), traffic police and experts, passengers and victims of the crashes who knew the condition and had related data.

X. T test, validity and reliability of questionnaire

The main assumption of the test is that the mean score is higher than the assumed test mean. However, it is not true to merely rely of the statistical mean. It should be examined if the observed mean is significant or not. Test hypothesis is done at 5% error level. However, if another error is used, the basis of analysis would not differentiate.

Significance is compared with error level. If the significance is lower than error, the null hypothesis is rejected. However, if it is greater, the null hypothesis is approved.

T statistics is compared with critical value of 0.05 which is 1.96. If the test statistics is greater than the critical value, null hypothesis is rejected, otherwise it is approved.

If two limits of confidence interval are greater than zero (positive), the hull hypothesis is rejected. However, if one of the limits is positive and the other is negative, there is no reason to reject the null hypothesis. Alpha Cronbach can be used where the question values are determined as multi-valued and so we use this formula:

$$r\alpha = \frac{j}{i-1}\left(1-\frac{\sum Qj^2}{Q2}\right) \quad (4)$$

Where:

Reliability of test = rα

Number of test = j

Each of variance test scores = Qj2

Variance of test scores = Q2

It is clear, however, as Cronbach's alpha index is closer to 1, there will be more internal correlation among the research questions and so the questions will be more homogeneous. Cronbach has assumed alpha reliability coefficient of 0.45 as low, 0.75 as mean and acceptable, coefficient of 0.95 as high (Cronbach, 1951).

XI. Research Variables

In the present study, based on research domain, objectives, questions and hypotheses, various variables could be defined and as it is stated at review of literature and second part of the research, each study considered the issue from a different point of view and accordingly recognized various factors to be discussed. It is impossible to consider all the variables at a limited period of time and in one study and furthermore, it required a more comprehensive study at national level. However, considering the data limitation, location and also the capacity of research questions, following variables were analysed based on conclusions and abstracts of the previous studies to be considered as the bases for research question. Theoretical basis was inspired by Haddon matrice and descriptive statistics of accident prediction models (mentioned in section two).First and foremost, in order to analyse the descriptive answers of the interviewers, their idea about four main factors were extracted and so the mean and median of the answers were mostly used.

TABLE II. Main Factors

Main factors	Mean	Median
Road	3.91	4
Human factors	3.71	3.7
Vehicle and equipment factors	3.21	3.33
Environmental factors	3.06	3

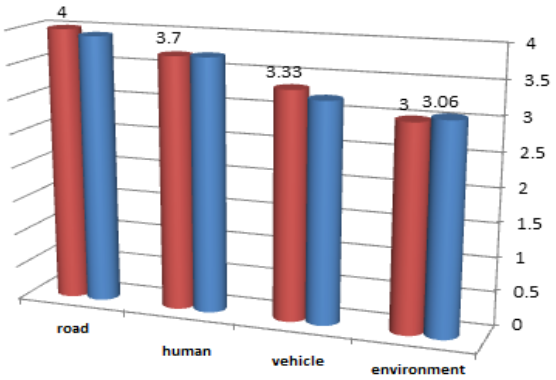

Figure 1. Main Factors

XII. Ranking Safety Variables Based on Fridman Model

In this section, safety variable ranking is done without considering the four groups and based on Fridman model. In order to examine which variables having higher or lower effect on accidents, the most effective factors based on interviewees were illegal overtaking, speeding, dangerous curves and deviation to the left and least important factors included sunshine and high temperatures, wind and not setting the tires (table 3).

TABLE III. Ranking Variables Based on Fridman Model

Raw	Factors	Rank
1	Illegal overtaking	20.78
2	Unauthorized speed	20.76
3	Dangerous curves	19.96
4	Deviation to the left	18.85
5	The low road	18.67
6	Undue hurry	17.80
7	Quality of	17.39
8	Driver fatigue and lack of adequate rest "	16.94
9	Culture and driving the wrong way	16.85
10	The absence or lack of adequate signs	16.84
11	Glacial	15.87
12	Type of road	15.76
13	Obsession and talking on a cell phone	15.46
14	Worn car tires	15.16
15	Agricultural and livestock movement	15.14
16	Snow rains	14.76
17	Non-observance of standards by the car maker	14.65
18	Fog	14.08
19	Worn-out vehicle	13.54
20	Lack of yield sign	13.47
21	Technical fault car	12.88
22	Type of vehicle	12.48
23	Tailgating	12.05
24	The reverse gear	8.86
25	dust	8.33
26	The lack of wind set tires	6.96
27	Wind	5.90
28	Sunshine and high temperatures	5.82

Findings of Fridman test are rated in following table as the main factors based on which the road factor was ranked first followed by human factor, vehicle and equipment factor, and environmental factor, respectively.

TABLE IV. RESULTS OF FRIDMAN TEST

Ranks	
	Mean Rank
Human	2.83
Vehicle	2.01
Road	3.35
Environment	1.80

Since it was possible that each of the participants would have different understandings of variables based on their views and experiences, thus the research participants were divided into three groups of experts, drivers and passengers, the answers of whom are discussed following.

A. First Hypothesis Analysis

There was a significant relationship between human factor and road accidents. Since the 5-point Likert scale is used in this study, score 3 indicates neutral. The null hypothesis indicated lack of relationship between human factor and road accidents. Based on the following table, number of sample 103, standard deviation 0.557, mean 3.71 are obtained which are higher than the average. It seems that there is a significant relationship between human factor and road accidents. In order to examine the significance, results are used with 5% error as indicated in table 6; the significance is lower than 5%. Test statistics of 12.979 were obtained where the critical value is 0.5 which is 1.96 and the lower and upper limit was greater than zero. Therefore, it can be stated with 95% confidence level that there was a significant relationship between human factor and road accidents.

TABLE V. ONE-SAMPLE STATISTICS

	N	Mean	Std. Deviation	Std. Error Mean
ensani	103	3.7126	0.55725	0.05491

TABLE VI. ONE-SAMPLE TEST

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
ensani	12.979	102	0.000	0.71262	0.6037	0.8215

B. Second Hypothesis Analysis

There was a significant relationship between vehicle factor and road accidents. Since the 5-point Likert scale is used in this study, score 3 indicates neutral. The null hypothesis indicated lack of relationship between human factor and road accidents. Based on the following table, number of sample 103, standard deviation 0.741, mean 3.20 are obtained which are higher than the average. It seems that there is a significant relationship between vehicle factor and road accidents. In order to examine the significance, results are used with 5% error as indicated in table 6; the significance is lower than 5%. Test statistics of 2.807 were obtained where the critical value is 0.5 which is 1.96 and the lower and upper limit was greater than zero. Therefore, it can be stated with 95% confidence level that there was a significant relationship between vehicle factor and road accidents.

TABLE VII. ONE-SAMPLE STATISTICS

	N	Mean	Std. Deviation	Std. Error Mean
khodro	103	3.2050	0.74142	0.07305

TABLE VIII. ONE-SAMPLE TEST

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
khodro	2.807	102	0.006	0.20505	0.0601	0.3500

C. Third Hypothesis Analysis

There was a significant relationship between road factor and road accidents. Since the 5-point Likert scale is used in this study, score 3 indicates neutral. The null hypothesis indicated lack of relationship between human factor and road accidents. Based on the following table, number of sample 103, standard deviation 0.692, mean 3.91 are obtained which are higher than the average. It seems that there is a significant relationship between road factor and road accidents. In order to examine the significance, results are used with 5% error as indicated in table 6; the significance is lower than 5%. Test statistics of 13.431 were obtained where the critical value is 0.5 which is 1.96 and the lower and upper limit was greater than zero. Therefore, it can be stated with 95% confidence level that there was a significant relationship between road factor and road accidents.

TABLE IX. ONE-SAMPLE STATISTICS

	N	Mean	Std. Deviation	Std. Error Mean
rah	103	3.9165	0.69255	0.06824

TABLE X. ONE-SAMPLE TEST

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
rah	13.431	102	0.000	0.91650	0.7812	1.0519

D. Fourth Hypothesis Analysis

There was a significant relationship between environmental factor and road accidents. Since the 5-point Likert scale is used in this study, score 3 indicates neutral.

The null hypothesis indicated lack of relationship between human factor and road accidents. Based on the following table, number of sample 103, standard deviation 0.703, mean 3.06 are obtained which are higher than the average. It seems that there is a significant relationship between environmental factor and road accidents. In order to examine the significance, results are used with 5% error as indicated in table 6; the significance is lower than 5%. Test statistics of 0.872% were obtained where the critical value is 0.5 which is 1.96 and the lower and upper limit was greater than zero. Therefore, it can be stated with 95% confidence level that there was a significant relationship between environmental factor and road accidents

TABLE XI. ONE-SAMPLE STATISTICS

	N	Mean	Std. Deviation	Std. Error Mean
mohit	103	3.0628	0.73099	0.07203

TABLE XII. ONE-SAMPLE TEST

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
mohit	0.872	102	0.385	0.06282	-0.0800	0.2057

E. Main Hypothesis Analysis

There was a significant relationship between all factors and road accidents. Since the 5-point Likert scale is used in this study, score 3 indicates neutral. The null hypothesis indicated lack of relationship between human factor and road accidents. Based on the following table, number of sample 103, standard deviation 0.462, mean 3.47 are obtained which are higher than the average. It seems that there is a significant relationship between all factors and road accidents. In order to examine the significance, results are used with 5% error as indicated in table 6; the significance is lower than 5%. Test statistics of 10.475 were obtained where the critical value is 0.5 which is 1.96 and the lower and upper limit was greater than zero. Therefore, it can be stated with 95% confidence level that there was a significant relationship between all factors (road, human, vehicle and environmental factors) and road accidents.

TABLE XIII. ONE-SAMPLE STATISTICS

	N	Mean	Std. Deviation	Std. Error Mean
average	103	3.4778	0.46288	0.04561

TABLE XIV. ONE-SAMPLE TEST

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
average	10.475	102	0.000	0.47777	0.3873	0.5682

XIII. CONCLUSION

Along with development in communication networks and road communication, control and prevention of road accidents is one of the main issues in various transportation systems. Unfortunately, during last years, Iran has been first at the list of road casualties and accidents. It is clear that one can prevent the issue by prudence and improving transport systems and save millions of people. Unfortunately, Iran suffers from road casualties due to accidents so that the latest statistics showed that road accidents are the main cause of disabilities in Iran. This while, 10 percent is added to the number of casualties and injuries due to road accidents per year. Road safety has a high degree of importance on the development of transport networks. That is, before the expansion of communication networks, practical measures should be taken to reduce road accidents technically. This is eliminated or reduced with understanding the main cause of accidents or risks (human, natural, management).

So, it was accompanied by the curves, steep, dangerous curves and insufficient visibility. In addition, technical defects such as narrow lanes of the road, inadequate and non-standard signs would intensify the geometric characteristics of the road and pavement quality for road accidents. The second effective element are human factors which interviewees believed that overtaking and speeding, fatigue and drowsiness, deviation to the left, no proper sign, tailgating, hastily and without a case, moving the rear gear, culture and incorrect driving, distraction, obsession and talking on a cell phone have decisive role in the accidents. The following set of human variable are emphasized and the reports of experts and police officers and for accidents en route frequently have mentioned the clear impact of speed, unauthorized overtaking and deviation to the left in accidents, so that in this study, two factors of speed and unauthorized overtaking are mentioned in the list of prime factors regardless of groupings. These two elements are strongly oriented to the adventurous and risky road for user. Harnessing these two elements alone can be devastating and reduce accidents and road traffic. However, according to the findings of other factors such as poor driving culture, hurry and other elements also should not be ignored. Technical and qualitative factors of vehicles based on the findings are in third place. According to interviewees, the elements related to vehicle such as the type of vehicle, vehicle wear, worn tires, vehicle technical defects, lack of wind set of car tires and non-compliance with standards are caused by the automaker in the event of accidents. Some of these factors are related directly to the carelessness and negligence of the driver such as vehicle exhaustion, worn tires, vehicle technical defects, lack of setting car tires where undoubtedly driver can creates and is the underlying cause of the incident.

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