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Modeling Traffic Accidents in Turkey Using Regression Analysis

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ABSTRACT: Technological improvements have increased and diversified production based on people's needs. The most important needs include traffic safety and speed. An increasing number of motor vehicles and drivers have brought focus on the importance of traffic safety. In Turkey, one of the factors affecting traffic safety is highways. Lack of standards in Turkey's highway projects, no/poor control of road materials produced by companies in the road-making stage and problems after completion of the road, deformed roads, slope failure, failure gradient of roads, drainage problems, road settlement, road pits and other factors have affected traffic safety tremendously. In this study, structural properties of road components from main factors which affect traffic safety were investigated based on information and data from several sources. Eighteen-year each in four-period time series data that consist of main and road failures causing traffic accidents on highways were used to determine their effects on traffic safety of road component with linear regression analysis.

According to research results, driver, pedestrian, vehicle, passenger and road failures in main traffic accident failure list were ranked based on their effectiveness. It is found that road failures such as road pits, wheel trace, soft shoulders, loose material, permanent wave, deficiency of road signs and road settlements have an important effect on traffic accidents. To reduce road failures, road projects must be planned carefully to meet human needs. In addition to this, road infrastructure and superstructure must be built according to specific road projects and standards.

Keywords: Transportation, traffic safety, traffic accident, road component, regression analysis

Türkiye'de Trafik Kazalarının Lineer Regresyon İle Analizi

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ÖZET: Teknolojinin ilerlemesi, insan ihtiyaç ve istekleri ile paralel olarak üretimi artırmış ve çeşitlendirmiştir. Bu ihtiyaç ve isteklerin başında, hızlı ve güvenli ulaşım gelmektedir. Motorlu araçların insan hizmetine sunulması, sürücü ve araç sayısının artması; trafik güvenliği ihtiyacını da ortaya çıkarmıştır. Ülkemizde trafik güvenliğine etki eden unsurlardan birisi de karayollarıdır. Karayollarının gerekli standartlara uygun projelendirilmemesi ve/veya yapım aşamasında imalatların istenilen seviyede denetlenmemesinden doğan ve yolun tamamlanmasından sonra ortaya çıkan önemli olumsuzluklardan; deforme olmuş yollar, şev kaymaları, hatalı yol eğimleri, drenaj problemleri, çökmeler, çukurlar ve diğer etkenler trafik güvenliğini olumsuz yönde etkilemektedir.

Bu çalışmada, trafik güvenliğini etkileyen ana faktörlerden yol unsurunun yapısal özellikleri, çeşitli kaynaklardan alınan bilgilere göre incelenmiş ve karayolları üzerinde trafik kazalarını oluşturan genel kusurlar ile yol kusurları için 18 yıllık ve dört dönemlik zaman serisi verileri kullanılarak, lineer regresyon analiziyle yol faktörünün trafik güvenliğine etkileri belirlenmeye çalışılmıştır.

Araştırma sonuçlarına göre; trafik kazalarına sebep olan ana kusurlardan sürücü, yaya, araç, yolcu ve yol kusurları etkinlik derecesine göre sıralanmıştır. Ayrıca yol kusurlarından çukur, teker izi, düşük banket, gevşek malzeme, ondülasyon, yol işaretlerinin eksikliği ve yol çökmesi kazaların meydana gelmesinde önemli etkiye sahiptirler. Yol kusurlarını azaltmak için yol projesini tüm ihtiyaçlara cevap verecek şekilde hazırlamak gerekir. Bununla birlikte yol alt ve üst yapısı proje ve standartlara uygun bir şekilde yapılmalıdır.

Anahtar kelimeler: Ulaştırma, trafik güvenliği, trafik kazaları, yol bileşenleri, regresyon analizi

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INTRODUCTION

Today, the rapid development of technology and population growth further increase human needs. One of the most important needs is transportation. In Turkey, highways form the majority of the transportation network. The design of highways is one of the factors affecting transport safety.

Turkey has a significant problem with high levels of traffic, which exceeds normal figures due to various factors such as transportation policies, socio-cultural and economic characteristics. In terms of traffic-related deaths, the Traffic Research Committee of Turkish Grand National Assembly (January 2001) report states that deaths in traffic accidents exceeded the number of deaths from terrorism. The report further states that "Although we lost 30 thousand citizens due to terrorism in the last 15 years, approximately 100 thousand people died in traffic accidents in the last 10 years" (Tan, 2000; GDS, 2006).

The factors affecting traffic accidents can be listed as follows;

- Human
- Road
- Vehicle
- Environment

The factors affecting traffic safety include improper road project application or insufficient control during and after construction of the road. Important problems caused by project applications include deformed road slope, improper road slopes and drainage problems. The causes of deformation of roads can be listed as follows: insufficient ground improvement during subgrade works, insufficient road slope improper selection and use of materials and low-quality workmanship. Unfortunately, in Turkey, highway defects often arise only a few months after construction. The subsequent repair or re-construction works on the roads also have a negative effect on traffic safety.

The ground on which the highway is constructed may cause some problems. Problematic soil types include those with low bearing capacity, organic ground, flowing clays and grounds affected by frost flushing. After fully determining the characteristics of soils, road stabilization can be achieved through various methods. These methods include mechanical mixture, chemical stabilization and asphalt stabilization.

Slopes adjacent to the road should be kept stable throughout the service life of the road. The road can be deformed or become impassable as a result of slippage or subsidence in side slope on fill. In the case of an unstable side slope in cut, the slope can slide towards the road, closing the drainage channels. Therefore, before starting road construction, the ground should be thoroughly analyzed and slopes should be constructed accordingly.

The pavement of the road is comprised of one or more layers placed on base ground to bear traffic load. There are generally two types of pavements: flexible or rigid. Flexible pavements resist traffic and environmental effects; distribute stresses caused by traffic load along the layers and prevent excessive load tension. They provide close contact with the base surface at each point of the road. In comparison, rigid pavements have a high bending strength; they distribute the load to the base ground through a single layered concrete plate. Rigid pavements have a high-standard and are used in highways with dense traffic, to provide driving comfort and safety for vehicles.

In flexible pavements, the base or sub-base layers are pavement works constructed below pavement layers. They have less tension than pavement, but have higher tension than the compacted ground. They should be constructed in such a way as to have lower stability than pavement, but a higher-quality and more resistant structure than the compacted ground. There are two types of flexible pavements which are surfaced pavements and bituminous hot mixtures. Surfaced pavements are economical and are widely used in roads with relatively low-density roads. Bituminous hot mixtures, on the other hand, are used in high-standard highways and are produced with moderate quality.

The most important property of surfaced pavements is that they have very high slip resistance. High slip resistance is achieved by the high friction force caused by aggregate particles by creating a spaced surface texture. Thus, it helps anti-slip properties of vehicles and improves driving safety (Kılınç, 2007).

As bituminous hot mixtures produce smooth surfaces, they reduce driving safety particularly in rainy weather in sharp curbs and steep slopes. Slip resistance

can be increased in these kinds of sections by laying one dimensional silica crushed stone aggregate with high wear strength and embedding this into the pavement using cylinders, or by applying surfaced pavement over the worn layer.

Rigid pavements have some advantages and disadvantages when compared to flexible pavements. The advantages include high resistance, less thickness and longer durability. Maintenance and repair costs are relatively low. These pavements are constructed in temperatures higher than 5^0C and in humid weather, so the construction season for this type of pavement, is longer. Rigid pavements have a higher slip resistance in rainy weather. They also provide better visibility at night. The disadvantages of this type of pavement include high construction costs. This requires service roads to be constructed and further increases repair costs. The grouts between concrete plates reduce driving comfort and increase road-noise.

The driving comfort of concrete pavements is slightly lower than those of concrete and asphalt pavements. However, concrete surfaces provide greater driving safety in rainy weather, as they have higher slip resistance.

The aim of the present study is to provide technical information about the effects of structural properties of Turkey's highways on traffic safety; and to determine the influence of highways infrastructure on traffic accidents using linear regression analysis. The study compared information collected from various sources with statistical data and attempted to reach a solution.

MATERIAL AND METHOD

Material

Data sources were monthly and annual traffic bulletins, published by the General Directorate of Security (GDS, 2006), General Directorate of Highways (GDH, 2006) and Turkish Statistical Institute (TSI), national and international scientific studies, books, reports, magazines and various other publications.

Highways and Traffic Safety in Turkey: In terms of transportation, Turkey has a number of characteristics which are typical of developing countries: Rapidly growing population and number of vehicles, resulting in a significant increase in transport demand. In the last 20 years, intercity passenger transport increased by 2.5 times, while car transport increased by 4 times. In the same period, Turkey's population grew by 50%. Similarly, the use of motor vehicles in inner-city transport and the number of routes showed a sharp increase. Considering Turkey's economic growth and improvements in Gross National Product (GNP), it is understood that the increases in economic parameters are exceeded by growth in transport demand (Ceylan and Haldenbilen, 2005).

Traffic safety is an indication of highway traffic quality. While selecting subgrade investments, a balance should be achieved between highway safety and other components such as service quality, accessibility, environmental effect and costs. When deciding subgrade projects, traffic safety should be discussed as clearly as possible during the planning stage of the project. With this aim, a Road Safety Impact Assessment system was developed.

According to Sümer (2000), traffic accidents are the primary cause of death in Turkey. Considering the number of accidents per vehicle, the number of deaths per one million cars during a death incidence is 905. This figure is 12 times higher than the European average.

According to Aydın (1997), one of the reasons for the high number of traffic accidents in Turkey is that transport activities are mainly based on highway transport. While in 1960, 24.3% of passenger transport and 47.7% of cargo transport were done by railway, today this has decreased to 3% of passenger transport and 6% of cargo transport. As indicated by the figures, highway transport, which is less safe, is preferred over railway transport, which is safer.

Çakır (1996), established that traffic accident reports in Turkey mostly blame humans, without thoroughly analyzing environmental factors such as vehicle control, road markings, road width and structural deformations. In developed countries, humans are not considered as the sole factor in traffic accidents. For example, subgrade deformations are also considered as an important cause of accidents. The effect of subgrade on accidents is 30% in USA, 70% in Russia, 26% in France and 22% globally.

Kiper (1996), reported that although traffic safety is perceived as a social problem in many countries,

there is quite an indifference towards this issue. The reduction of traffic casualties is not a priority of daily life. This situation can be explained in various ways. When compared to the importance attached to plane and ship accidents, the majority of traffic accidents are not a concern for the public and media. In addition, the causes of road accidents and necessary preventative measures are quite complicated. It is impossible to show only one reason as a cause of accidents.

Method

Adaptation of the Data for Analysis: Monthly data sets of accidents between 1989 and 2006 were analyzed in terms of general road defects causing traffic accidents and the accidents caused by the road defects. Four seasonal periods were formed (Spring (March-April-May), Summer (June-July- August), Autumn (September-October-November) and Winter (December-January- February)), to analyze seasonal effects on traffic accidents. Thus, 72 observation-time data series were collected, comprising data for 4 time periods over 18 years and two different causal factors (factors causing accidents and accidents caused by road defects) cross sectional data expressing the factors in traffic accidents were taken into account.

Data Analysis: Considering time series and horizontal sets, Stepwise and Enter methods were used in SPSS statistics program. The factors causing traffic accidents and the factors effecting traffic accidents caused by road defects were analyzed with a regression model. The least squares method was used for the estimation of the model. The Shazam package software was used in multiple variance analysis.

Function determination coefficient (R^2), standard error and the F-test were used to identify the type of function to be used in the regression analysis. The most appropriate models were chosen, after accounting for the potential effects of auto-correlation, multiple variance and multiple linear problems in the data. In addition, the significance of independent variables in explaining the dependent variable was determined using a t-test. The models were statistically and technically analyzed by examining whether or not the parameter markers were technically significant.

The regression model used for determination of the main defects causing the total number of accidents and for measurement of the significance of these factors can be explained as follows: ***TTA: f (DRD, RRD, VRD, PedRD, PasRD, u)***. As a result of application of various alternative models, a logarithmic-linear regression model was found to be the most appropriate.

$$\text{Log TTA} = \alpha + \beta_1 \text{DRD} + \beta_2 \text{RRD} + \beta_3 \text{VRD} + \beta_4 \text{PedRD} + \beta_5 \text{PasRD} + u$$

Dependent Variable

TTA: Number of total traffic accidents (number)

Independent Variables

DRD: Driver-related defects (number)

RRD: Road-related defects (number)

VRD: Vehicle-related defects (number)

PedRD: Pedestrian-related defects (number)

PasRD: Passenger-related defects (number)

u: The random error

The regression model used for determination of accidents caused by road defects and for measurement of the significance of these factors can be explained as follows:

RDA: f (VPD, RDD, LMD, UD, RMD, RD, SSD, D_1, u). As a result of application of various alternative models, a logarithmic-linear model was found to be the most appropriate.

$$\text{Log RDA} = \alpha + \beta_1 \text{VPD} + \beta_2 \text{RDD} + \beta_3 \text{LMD} + \beta_4 \text{UD} + \beta_5 \text{RMD} + \beta_6 \text{RD} + \beta_7 \text{SSD} + \beta_8 D_1 + u$$

Dependent Variable

RDA: Number of accidents caused by road defects (number)

Independent Variables

VPD: Defects caused by various potholes (number)

RDD: Defects caused by road depressions (number)

LMD: Defects caused by loose material in surface of the road (number)

UD: Defects caused by undulation (number)

RMD: Defects caused by deficient road markings (number)

RD: Defects caused by rutting (number)

SSD: Defects caused by soft shoulder (number)

D_1: Effects of autumn, summer, spring and winter on number of accidents (summer; spring and autumn were nominally marked as: 1 and winter was nominally marked as:0. A dummy variable was used to measure the effect of winter months on accidents.

u: The random error

STUDY FINDINGS AND DISCUSSION

Traffic Accident Statistics: Table 1 shows the number of traffic accidents reported in Turkey between 1989 and 2006. Table 2 presents the types of highway defects related to these accidents.

The data in Table 1 indicate that the most significant factors in traffic accidents were driver and pedestrian. This finding indicates the major role of human factor in traffic accidents. Another interesting indication from the data is that road factors have a low significance in traffic accidents. When compared to the data of other countries, road defects have insignificant ratios. The reason for the relatively low number of accidents attributed to road defects in Turkey might be that the officers issuing the accident reports lack the technical support to help them distinguish between road factors and other factors when assessing the causes of accidents.

Table 2 indicates that the number of road defects varied according to years. However, the most common road defects were potholes, road depressions, undulation, rutting, soft shoulder, loose material and missing road signs. When these defects were analyzed in Table 4, it was found that "rutting" was the most common road defect related to traffic accidents. Lack of design

Table 1. The ratios of main factors (number) causing traffic accidents in Turkey (%)

Year	Driver Error		Road Defect		Vehicle Defect		Passenger Error		Pedestrian Error		Total
	Number	%	Number	%	Number	%	Number	%	Number	%	
1989	145080	82.69	1086	0.62	2610	1.49	995	0.57	25675	14.63	**175446**
1990	159930	84.43	971	0.51	2833	1.50	848	0.45	24845	13.12	**189427**
1991	195074	87.53	934	0.42	3276	1.47	690	0.31	22884	10.27	**222858**
1992	232910	90.10	533	0.21	3176	1.23	493	0.19	21391	8.27	**258503**
1993	283804	91.69	586	0.19	3638	1.18	503	0.16	21000	6.78	**309531**
1994	298911	92.90	1729	0.54	2825	0.88	478	0.15	17801	5.53	**321744**
1995	356707	93.26	5759	1.51	2948	0.77	507	0.13	16559	4.33	**382480**
1996	398782	94.94	572	0.14	1692	0.40	2.288	0.54	16702	3.98	**420036**
1997	649955	97.31	28	0.00	2725	0.41	894	0.13	14297	2.14	**667899**
1998	505961	96.48	31	0.01	2803	0.53	1.116	0.21	14517	2.77	**524428**
1999	505285	96.59	23	0.00	2361	0.45	949	0.18	14522	2.78	**523140**
2000	532217	96.22	3692	0.67	2534	0.46	921	0.17	13777	2.49	**553141**
2001	503392	96.82	1681	0.32	1638	0.32	828	0.16	12386	2.38	**519925**
2002	483115	96.99	827	0.17	1227	0.25	588	0.12	12357	2.48	**498114**
2003	506025	97.11	855	0.16	1156	0.22	482	0.09	12543	2.41	**521061**
2004	569578	97.33	825	0.14	1086	0.19	375	0.06	13332	2.28	**585196**
2005	640951	97.68	931	0.14	986	0.15	358	0.05	12973	1.98	**656199**
2006	751189	98.17	586	0.08	1072	0.14	361	0.05	11964	1.56	**765172**
Total	**7718866**	**95.36**	**21649**	**0.27**	**40.586**	**0.51**	**13674**	**0.17**	**299525**	**3.70**	**8094300**

*Source: TSI, 1989-2006

Table 2. Number of traffic accidents in Turkey caused by road defects

Year	Road Depressions	%	Soft Shoulder	%	Rutting Sinking	%	Loose material in Road Surface	%	Various Potholes	%	Undulation	%	Deficient Road Markings	%	Other Road Defects	%	Total
1989	22	2.03	31	2.85	0	0.00	110	10.13	106	9.76	67	6.17	248	22.84	502	46.22	1086
1990	13	1.34	27	2.78	0	0.00	123	12.67	107	11.02	58	5.97	190	19.57	453	46.65	971
1991	17	1.82	25	2.68	0	0.00	90	9.64	111	11.88	59	6.32	167	17.88	465	49.79	934
1992	19	3.56	13	2.44	0	0.00	50	9.38	89	16.70	35	6.57	88	16.51	239	44.84	533
1993	17	2.90	9	1.54	0	0.00	48	8.19	118	20.14	27	4.61	103	17.58	264	45.05	586
1994	22	1.27	3	0.17	0	0.00	17	0.98	40	2.31	20	1.16	37	2.14	1590	91.96	1729
1995	30	0.52	22	0.38	0	0.00	10	0.17	37	0.64	61	1.06	34	0.59	5565	96.63	5759
1996	238	41.61	25	4.37	0	0.00	46	8.04	109	19.06	0	0.00	117	20.45	37	6.47	572
1997	4	14.29	0	0.00	0	0.00	4	14.29	5	17.86	0	0.00	9	32.14	6	21.43	28
1998	9	29.03	0	0.00	0	0.00	3	9.68	9	29.03	0	0.00	7	22.58	3	9.68	31
1999	7	30.43	0	0.00	0	0.00	0	0.00	8	34.78	0	0.00	7	30.43	1	4.35	23
2000	386	10.46	261	7.07	1619	43.85	426	11.54	966	26.16	0	0.00	0	0.00	34	0.92	3692
2001	90	5.35	104	6.19	796	47.35	242	14.40	351	20.88	0	0.00	0	0.00	98	5.83	1681
2002	107	12.94	59	7.13	254	30.71	176	21.28	217	26.24	0	0.00	0	0.00	14	1.69	827
2003	127	14.85	44	5.15	187	21.87	194	22.69	303	35.44	0	0.00	0	0.00	0	0.00	855
2004	35	4.24	52	6.30	107	12.97	366	44.36	265	32.12	0	0.00	0	0.00	0	0.00	825
2005	57	6.12	115	12.35	58	6.23	238	25.56	455	48.87	0	0.00	0	0.00	8	0.86	931
Total	**1200**	**5.70**	**790**	**3.75**	**3021**	**14.34**	**2143**	**10.17**	**3296**	**15.65**	**327**	**1.55**	**1007**	**4.78**	**9279**	**44.05**	**21063**

*Source: TSI, 1989-2006

and constructions in line with the standards can be considered as the main cause of road defects.

Determination of the Main Defects in Traffic Accidents and their Effects: Considering the auto correlation (d_L: 1.49; d_U: 1.77) critical values in determining the significance of the main defects causing traffic accidents: Durbin-Watson (DW): 1.83 d_L and d_U<DW) and multicollinearity (Collinearity Diagnostics analysis and correlation matrixes r<0.80) problems were not found. However, a multiple variance problem was found (according to df: 5, sig.:0.05 c^2_h: 36.397>c^2_c:1.25). The multiple variance problems were eliminated by Diagnos/Het in the Shazam program and parameter coefficients are given in Table 3.

The multiple determination coefficient was R^2 =0.951. An F-test indicated that it was different from zero at p>0.01 and p>0.05 significance level (F_h: *275.45*>F_c: *3.34)*. Thus, the dependent variables in the equation explain 95% of the variability observed in the independent variables. Furthermore, parameters were found to be statistically and technically significant (Table 3).

According to the results in Table 3, when accidents caused by driver, pedestrian and passenger factors were considered together, these factors were the most common causes of accidents. Furthermore, the fact that a higher number of traffic accidents take place in Turkey and cause material and spiritual losses, indicates that Turkish people are not sufficiently sensitive to this issue.

The reason for the lower significance of road defects in traffic accidents when compared to other factors may be that there are relatively few personnel analyzing accidents in terms of road defects and other factors during the preparation of traffic accident reports. It is therefore likely that the reported data under-represent the proportion of traffic accidents caused by road defects. In addition to that analysis indicates that an insignificant proportion of accidents are still caused by road defects (Table 3).

As indicated by Karaşahin and Tığdemir (2001), although existing traffic accident reports contain many details about human, vehicle and road factors, much of these data are not processed appropriately. For example, data indicate that lack of subgrade was of very low significance in traffic accidents. However, in practice, it is widely known that subgrade deficiencies are responsible for many accidents. These defects include loose aggregate on the surface of the road, deep rutting, small-radius horizontal curves, deficient road markings (lack of road lining, deficient warning signage etc.), insufficient sight-lines, low surface friction coefficient. Insufficient drainage, materials falling on the road due to landslide etc. can be listed among these deficiencies. When accident reports were analyzed, it was found that these sections are generally not completed. For example, in Section N of traffic accident reports, under the section "road-related defects"; when rutting is considered as marked the first question coming to mind is to determine the depth of the rutting.

Traffic accident statistics in Turkey indicate that 98.9% of accidents were attributed to human factors;

Table 3. Statistical evaluation of traffic accident parameters and tests

Parameters	Non-standardized coefficients		Standardized coefficients	t-value	p-value
	Beta	Standard error	Beta		
Constant (α)	4.628	0.027	4.628	171.121	0.000*
Drivers defect (DRF)	3.88E-006	0.000	0.928	31.465	0.000*
Road defect (RRD)	2.23E-005	0.000	0.039	1.409	0.163
Vehicle defect (VRD)	9.32E-005	0.000	0.111	2.585	0.010*
Passenger defect (PasRD)	9.72E-005	0.000	0.056	2.008	0.049**
Pedestrian defect (PedRD)	2.76E-005	0.000	0.187	4.233	0.000*
n: 72	k: 5		sd.: 66		
R^2 : 0.951	F_h : 275.45		F_c: 3.34		

*(p>0.01); ** (p>0.05)

0.4% road factors and 0.7% vehicle factor. However, it is widely agreed that these figures do not reflect the reality of accident causes. The most important reason is that, these figures are based on traffic accident reports issued by traffic police, who are not trained in the geometrical or structural properties of highways. Therefore, a traffic or transport engineer should also take part in the process of preparing traffic accident reports (Kalyoncuoğlu and Tığdemir 2001; Karaşahin and Tığdemir, 2001).

In western countries, data indicate that highway defects play a role in 31% of accidents (according to the UN). Although a previous study carried out in Turkey indicated that this proportion was 44% in Turkey, the official accident statistics state 0.22%. According to this result indicates that roads in Turkey are perfect. Since there is a common view in Turkey that "the driver should drive his car according to road and traffic conditions". The proportion of traffic accidents caused by driver error should be considered as 97% to what extent does this result indicate the reality? Knowledge of subgrade issues has an increasing role in transport, which is the primary problem of cities. Considering that the subgrade of Turkey is quite deficient when compared to western countries, lack of information about this issue leads to improper decisions about urban planning, which give rise to mistakes in practice. The correction of these mistakes requires highly expensive solutions and has monetary, time and fuel implications. Apart from some exceptions, in Turkey work on the subgrade is contracted to the control of overseas companies at random, or in an improper manner. On the other hand, traffic subgrade and management is considered and analyzed as a field of engineering (traffic engineering). In foreign countries, survey organizations such as TTRL and BASt issue numerous reports on this issue (Özdirim, 2001).

The Determination of Road Defects Causing Traffic Accidents and their Effects: Considering the auto correlation (d_L: 1.49; d_U: 1.77) critical values in measuring the significance of the main defects causing traffic accidents: Durbin-Watson (DW): 2.07 d_L and d_U<DW) and multicollinearity (Collinearity Diagnostics analysis and correlation matrixes r<0.80) were not found. However, a multiple variance problem was found (according to df: 5, sig.:0.05 c^2_h: 121.687>c^2_c: 2.17)). The problem of multiple variance was eliminated by Diagnos/Het in the Shazam program and parameter coefficients are given in Table 4.

The multiple determination coefficient was R^2 =0. 973. An F-test found it was different from zero at p>0.01 and p>0.05 significance level (F_h: *316.79*>F_c: *2.10)*. Thus, the dependent variables in the equation explain 97% of the variation observed in independent variables. Furthermore, parameters were found to be statistically and technically significant (Table 4).

Table 4. Statistical evaluation of road defects in traffic accidents

Parameters	Non-Standardized coefficients		Standardized coefficients	t-value	p-value
	Beta	Standard error	Beta		
Constant (α)	1.292	0.061	1.292	21.190	0.000*
Pothole (VPD)	0.673	0.045	0.645	14.907	0.000*
Seasonality (D_I)	-0.040	0.032	-0.027	-1.269	0.209
Road depressions (RDD)	0.002	0.001	0.058	2.388	0.020**
Loose material(LMD)	0.003	0.001	0.158	3.441	0.001*
Undulation (UD)	0.010	0.003	0.106	3.527	0.001*
Deficient road marking (RMD)	0.003	0.001	0.078	2.668	0.010*
Rutting (RD)	0.001	0.000	0.483	19.202	0.000*
Soft shoulder (SSD)	0.199	0.017	0.334	11.753	0.000*
n: 72	k: 8		sd.: 63		
R^2 : 0.973	F_h : 316.79		F_c: 2.10		

*(p>0.01); ** (p>0.05)

Table 4 analyzed the defects among the road defects causing traffic accidents and the following results were obtained. According to the analysis of road defects, rutting was the most important road defect in traffic accidents. These defects generally include those caused by high temperature, low viscosity bonding and high bituminous content. In addition, these defects are caused by loss of stability in hot-mixture bituminous layers and insufficient compaction; exposure to permanent deformations under excessive tension of superstructure layers; loss of stability of the saturated foundation and base foundation layers due to cavity pressure under traffic load; insufficient drainage and/or insufficient compaction leading to loss of stability in superstructure layer and low bearing strength.

According to the analysis, potholes road rank second in causing traffic accidents. This type of defect is observed in flexible and rigid pavements. The causes of this defect in flexible pavement include insufficient compaction of superstructure layers and high cavity ratio. In particular, highways which are laid in cold conditions may be subject to water and salt ingress between the layers, which causes deformation of the asphalt in free-thaw cycles. On the other hand, the presence of clay and clay-covered aggregated particles in asphalt prevents proper bonding of the particles and leads to deformation of the pavement due to the effects of water and traffic. In addition, insufficient asphalt thickness and subgrade drainage, the use of inappropriate aggregate and improper construction techniques may lead to the formation of potholes in the road surface. The most important cause of this type of defect in rigid pavements is the ingress of water into concrete and aggregates, which repeatedly freezes and thaws, causing tension and expansion within the layers. The tensions caused by volume dilatations deform the surface of concrete pavement and, over time, forms potholes under the effect of traffic.

The analysis indicates that soft shoulder defects have a significant effect on traffic accidents. The cause of this defect is that the shoulders are not constructed with sub-base and base levels with the road, the drainage of fine leveling surface, slope and pits of the shoulders are insufficient.

Among road defects, surface undulations were a significant cause of traffic accidents. These defects are caused by the following factors: insufficient resistance of asphalt mixture; inappropriate laying and compaction of asphalt; traffic effects, including stopping and starting at junctions, traffic lights and stops; insufficient connection with the superstructure layers (excessive or insufficient application of adhesive layer); instability of the base layer; use of a thick membrane bridge apron to achieve impermeability; and the existence of saturated granular layer under traffic load.

It was found that loose material on the road was a significant cause of traffic accidents. These kinds of defects are particularly observed in flexible pavement structures. The most common cause is that, the road is opened to traffic before aggregate particles fully adhere to the asphalt, which leads to traffic accidents.

According to the analysis, deficient road markings also have a significant effect on traffic accidents. The most important cause of these types of defects is a lack of inspection by the authorized bodies.

According to the analysis, surface depressions were found to be a significant factor in traffic accidents. The causes of this type of defect in both flexible and rigid pavements are as follows: insufficient compaction between base, sub-base and/or base layers; low load-bearing strength of pavement; insufficient compaction of the structures in approach embankments and insufficient drainage, frost-flushing on the pavement near shoulder, outlets, axis, crack sections, manhole lines and cuts with insufficient drainage, application defects in filling slope and improper construction and maintenance techniques (Table 4).

Analysis of the data indicates that seasonality was not affect traffic accidents. The cause of negative parameter marker of dummy variable is that, in winter, there is a higher risk of traffic accidents. Water and frost on pavement will reduce slip resistance of vehicles and lead to accidents.

As indicated above, highway defects such as potholes, depressions, rutting, loose material etc. have a negative effect on driving safety particularly for the vehicles going fast; they cause traffic accidents and disturb driving comfort.

RESULT AND SUGGESTIONS

Traffic accidents are one of the most important problems of Turkey, and cause spiritual and material

loss each day. To reduce traffic accidents, it is imperative to take appropriate, radical and strategic decisions and to establish a balance between transport types in line with the facts of the country. Transport subgrade should be planned and developed within the framework of these decisions. Furthermore, traffic education should be developed and offered to all sections of the society, using scientific methods. Traffic safety sensitivity should be created in the public, and modern methods and devices should be used in traffic controls.

In the present study, monthly traffic accident data for the years 1989 to 2006 was analyzed using linear regression, to determine the main factors causing traffic accidents. It was found that, among general factors, "the driver" had the highest effect, while "road defects" had the lowest effect on traffic accidents. The reason for this result is that, in Turkey, officers issuing accident reports are not technically supported, and therefore the factors causing traffic accidents are not fully analyzed. As a result, the reliability of accident reports is controversial. In developed countries, human factors are not considered as the sole cause of traffic accidents, and it is observed that road defects have a significant effect on traffic accidents.

Regression analysis of the accidents caused by road defects indicated that potholes, depression loose material, undulations, rutting and soft shoulders have a significant role in accidents. Among these defects, potholes and rutting were found to have a significant effect. The causes of these defects can be listed as follows: insufficient compaction of pavement layers and cavity ratio in the layers. Particularly in cold weather, water and salts enter the layers, and cause asphalt deformation by repeated freezing and melting. On the other hand, clay particles in asphalt used in flexible pavements may prevent good adherence of the particles and may lead to deformation of the pavement, over time, with the effect of water and traffic. In addition, insufficient asphalt percentage, wear layer thickness and infrastructure drainage, the use of improper aggregate and improper construction techniques, may result in the formation of potholes in the pavement. In rigid pavements, this defect is caused mainly by the dilatations caused by water absorption of the aggregate in the concrete, frost and melting of the water; dilatation and repeated freeze-thaw of the water in the concrete. The tensions caused by volume dilatations deform the pavement surface and develop into potholes over time, under the effect of traffic. This defect can be eliminated by digging a large, deep hole inside the pothole, removing the previous materials, filling the pothole with an appropriate mixture and thoroughly compacting the surface.

To reduce road defects which are among the most important factors causing traffic accidents, a road project should be prepared in such a way as to meet all requirements. Prior to the application, all factors constituting the project should be reviewed; the missing parts should be completed. In addition, the road should be properly constructed with subgrade and pavement structures. After the road is opened to traffic, potential faults should be corrected and periodic maintenance works should be organized. Otherwise, material and spiritual losses from traffic accidents caused by road defects will be inevitable.

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