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THE EFFECTS OF DAILY DRIVEN DISTANCE AND AGE FACTOR ON THE TRAFFIC ACCIDENTS

ABSTRACT

Based on Turkish traffic survey data (n=5,520), driver accident rates per million kilometre-driver were compared according to the daily driven distances (DDD) for each age group as very old (65+, n=39), old (56-65, n=183), above middle-aged (36-55, n=1,875), middle-aged (26-35, n=2,204), and young (25-, n=1,219). When the accidents-per-km comparison was made in groups matched for daily exposure, there was no evidence of higher risk with increasing age. In all age groups, risk per km decreased with increasing daily driving distance. With this study the accident involvement prediction models have been obtained related to the daily driven distance with and without considering age. These models have been applied to some earlier studies. The results are quite satisfactory. The set of data of this study and the analysis controlling the daily (yearly) driving distance might make the "age" effect disappear.

KEY WORDS

traffic accidents; age factor; daily driven distance; involvement in accidents;

1. INTRODUCTION

Annual mileage is one of the stronger predictors of accident involvement [1, 2]. Correlations reported in the literature between annual mileage and accidents are in the range of 0.12–0.35 [3]. At the same time it has been shown that high-mileage drivers have lower accident risk per mile driven than low-mileage drivers [4]. A simple explanation for this last result was suggested by Janke [5]. Low-mileage drivers drive their miles mainly on busy streets in built-up areas with two-way traffic of different types. High-mileage drivers collect their miles mostly on relatively safe highways with limited accessibility and separated lanes. Another possible explanation is that high-mileage drivers have greater driving and safety skills than low-mileage drivers [6].

Older people are the safest group of drivers on the road, with the lowest accident rate per licensed driver [7]. Despite this reassuring evidence, the European governments treat older drivers as a potentially hazardous population [8]. Medical screening programs for older drivers are widespread, even though they may be harmful rather than beneficial [9]. A partial explanation for these prejudiced policies may arise from an over-liberal use (or abuse) of a U-shaped curve of accident risk per km driven against age [10] to illustrate a perceived "older driver problem". Low accident rates per driver despite higher rates per km have been explained by older driver tendency to restrict their driving. However, the very action of reducing their yearly driving distance may in itself contribute to the older drivers' increased crash risk per km. It is a constant finding in road accident studies that the relationship between accidents per km and km driven is not linear but curvilinear: drivers with small yearly mileages have, independently of age, higher accident rates than drivers with large yearly mileages [5]. This ''low mileage bias'' may increase older drivers' risk per km estimates, as they are typically compared with other age groups having larger yearly driving exposure [11].

The widespread claim that older drivers are overly involved in crashes has apparent support from analyses of crash rates (CR), although the estimates vary according to the exposure measure used to calculate risk (for an overview, see [12]. The most marked risk increase is usually shown when using vehicle miles of travel as the exposure measure (for example, [13]). It is widely recognized that this approach needs to be corrected for the so-called 'frailty bias'. Older adults' greater vulnerability to injury, due especially to reductions in bone strength and fracture tolerance [14, 15, 16, 17, 18], leading to a larger share of older drivers' accidents included in casualty crash databases. Even after correction for frailty, however, it appears that older drivers have excess crash involvement rates of around 30–45% [19].

A major source of error in interpreting older drivers' crash risk per-distance, the so-called LowMileageBias, has recently been demonstrated by Hakamies-Blomqvist and her colleagues [11]. They took as starting point the theoretical paper by Janke [5] who recognized that the relationship between travel distances and crash rates is not linear and pointed out that independent of age, drivers travelling more kilometres will typically have reduced crash rates per kilometre, compared to those driving fewer kilometres. Because older drivers typically drive smaller distance per trip and hence have lower-accumulated driving distances per year, they have greater crash involvement per unit of distance compared to drivers with greater accumulated driving distances. Janke subsequently warned licensing administrators against becoming overly alarmed about older drivers' apparent high crash rates when based on distance driven.

Hakamies-Blomqvist et al. [11] empirically tested this hypothesis by using Finnish survey data to compare older and young middle-aged drivers' crash rates, controlling annual distances driven. When older drivers were compared with younger drivers who had equivalent driving exposure, there was no age-related increase in crashes per distance driven. The disappearance of any age-related effect occurred without correcting for the frailty bias and related to crashes of all severity levels (both casualty and non-casualty). Thus, the apparent age-related risk was in fact related to yearly driving distances, in accordance with the reasoning by Janke, and not to age per se, a phenomenon that the authors call LowMileageBias. "These findings cast serious doubt on any previous reports of age differences in accident risk per distance driven" [11].

After the original study by Hakamies-Blomqvist et al., these findings were independently replicated using a French data set, which lends credibility to the robustness of the phenomenon they demonstrated [20].

In empirical science, replication of findings is recognized as a critical step in accumulating new scientific evidence. The claim by Hakamies-Blomqvist et al. [11] that correction for low mileage bias makes older drivers' apparent over-representation in crashes disappear, puts into question many of the conclusions drawn from previous studies which presented older drivers as overly crash-prone. This amounts to something close to a paradigm shift in older drivers research [21]. Given these far-reaching consequences, it is essential to ensure that the new findings are not an aberration due to undetected methodological flaws or high sensitivities of the sample .

This paper is intended to present a modelling effort using non-linear models to estimate the involvement in traffic accidents using independent variables of driver age and daily driven distance.

2. METHOD

2.1 Sample

A questionnaire survey was carried out among 5,520 drivers in Turkey. The Traffic Safety Questionnaire was prepared to measure the quality of drivers, usage characteristics of vehicles, driving safety information and tendency and habit to take risks in the traffic. A Personality Inventory was also developed to determine the role of Personality Structure which affects behaviours and attitudes of drivers in traffic accidents. The questionnaire and inventory were applied to 5,520 drivers chosen randomly in 30 cities in Turkey. The final sample comprised 93% males and 7% females. Fifteen per cent had a college/ university education, 28% vocational or senior high school, 19% junior high school, 33% primary school and the remaining were without any diploma. The ratio of gender reflects approximately the actual gender mix of drivers involved in traffic accidents in Turkey. The age groups and (number of drivers) are; under 25 (1,219), 26-35 (2,204), 36-55 (1,875), 56-65 (183), and above 65 (39). The research was conducted on the sample of all drivers, not just on those who had a car accident.

The sample size (SS) formula (Eq.1) is used to determine how many drivers had to be interviewed in order to get results that reflect the target population as precisely as needed. The next formula is well known:

$$SS = \frac{Z^2 \cdot (p) \cdot (1-p)}{c^2} = \frac{2.576^2 \cdot (0.5) \cdot (1-0.5)}{0.02^2} = 4,147 \quad (1)$$

where:

Z = Z value (e.g. 2.576 for 99% confidence level);

p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed as maximum sample size)

c = confidence interval, (0.02) expressed as a decimal

The numbers of drivers registered in total in Turkey, and the gender structure of the drivers are given in *Table 1*.

2.2 Overview of travel survey respondents

The total of 5,520-driver database has been divided into 5 subgroups according to the driven distance per day for each age group. There were 1,137 drivers

Table 1 - The driver numbers and gender distribution by years in Turkey

year	total drivers	male	%	female	%
2003	15,488,493	13,163,460	85.0	2,325,033	15.0
2004	16,151,623	13,658,571	84.6	2,493,052	15.4
2005	16,958,895	14,239,014	84.0	2,719,881	16.0
2006	17,586,179	14,713,228	83.7	2,872,951	16.3
2007	18,422,958	15,355,462	83.3	3,067,496	16.7
2008	19,377,790	16,073,831	82.9	3,303,959	17.1
2009	20,460,739	16,871,100	82.5	3,589,639	17.5
2010	21,548,381	17,457,486	81.0	4,090,895	19.0
2011	22,798,282	18,270,284	80.1	4,527,998	19.9
2012	23,760,346	18,848,281	79.3	4,912,065	20.7

Table 2 - Crash involvements for subgroups according to the daily driven distance (km)

Age Groups Years (drivers)	Daily Driven Distance km	Drivers	Total km	Crashes	Crash rates
<25 (1219) DLP: 4 years	<20	324	3,240	238	50.3
	21-50	367	12,845	296	15.8
	51-150	302	30,200	332	7.5
	151-300	173	38,925	217	3.8
	>500	53	26,500	89	2.3
26-35 (2204) DLP: 12 years	<20	423	4,230	302	16.3
	21-50	613	21,455	524	5.6
	51-150	622	62,200	672	2.5
	151-300	400	90,000	515	1.3
	>500	146	73,000	204	0.6
36-55 (1875) DLP: 27 years	<20	363	3,630	234	6.5
	21-50	588	20,580	471	2.3
	51-150	503	50,300	532	1.1
	151-300	271	60,975	285	0.5
	>500	150	75,000	186	0.3
56-65 (183) DLP: 42 years	<20	23	230	21	6.0
	21-50	68	2,380	63	1.7
	51-150	58	5,800	67	0.8
	151-300	20	4,500	25	0.4
	>500	14	7,000	16	0.1
>65 (39) DLP: 52 years	<20	4	40	2	2.6
	21-50	15	525	18	1.8
	51-150	9	900	17	1.0
	151-300	6	1,350	8	0.3
	>500	5	2,500	10	0.2

who reported daily driving distance of 20 km or less; 1,651 reported that they drove between 20 and 50 km; 1,494 reported that they drove between 50 and 150 km; 870 reported that they drove between 150 and 300 km; and 368 drove more than 300 km per day. The survey respondents reported that they were involved in 5,344 crashes of any severity level. *Table* 2 shows the annual crash rates per million driver–kilometres for different driver ages within each mileage group.

The crash rates may be calculated using the crash rate formula (Eq. 2).

$$CR = \frac{Crashes}{DLP \cdot Total_{km} \cdot 365} \cdot 10^6 \qquad (2)$$

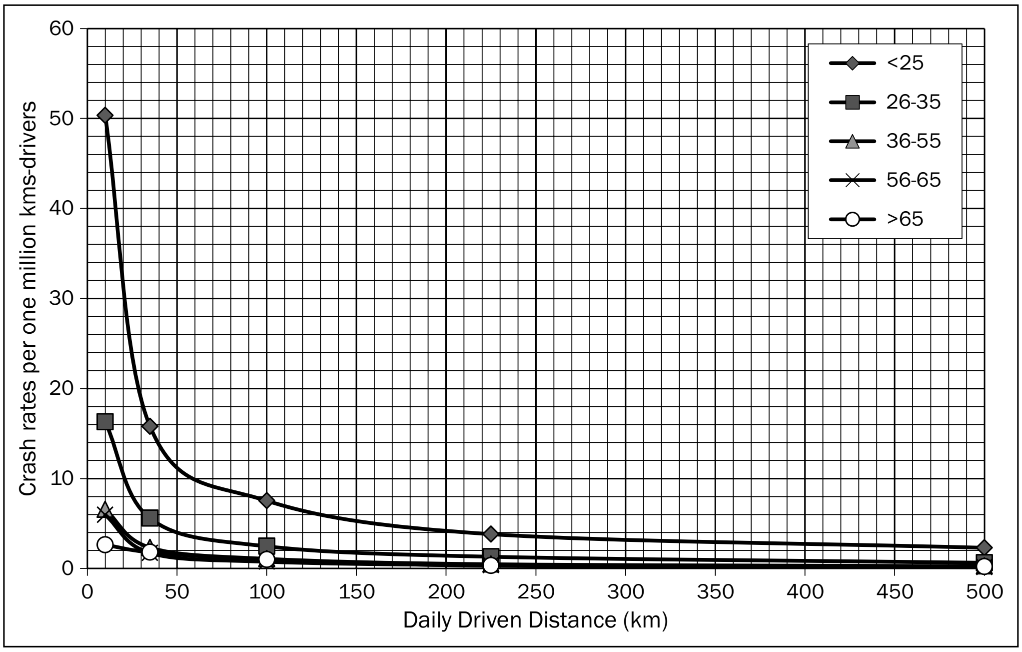

Figure 1 - Annual crash involvement in relation to daily driven distances, controlled by driver ages

DLP: Average driving license period for groups e.g. for 26-35 Age Group

$$DLP = (26 + 35)/2 - 18$$

The age of 18 is the age at which one is able to get a driving license

All survey respondents regardless of age were allocated to five groups according to their daily kilometres driven. Crash rates per million kilometre-drivers for less than 20 km (average annual driven distance AADD: 7,300 km), 20-50 km (AADD: 7,300–18,250 km), 51-150 km (AADD: 18,250-54,750 km), 151-300 km (AADD: 54,750-109,500 km), and greater than 109,500 km drivers are shown in *Figure 1*. For each driver's age group, as daily driven distances increased, the crash rate per distance travelled declined.

3. AGE AND CRASH RATE (for different annual mileages)

All survey respondents were first classified by age and then were allocated to five groups according to their daily driven distances. For the drivers' age group of under 25, those who drove less than 20 km per day (CR is 50.3), have a seven-fold crash rate, relative to

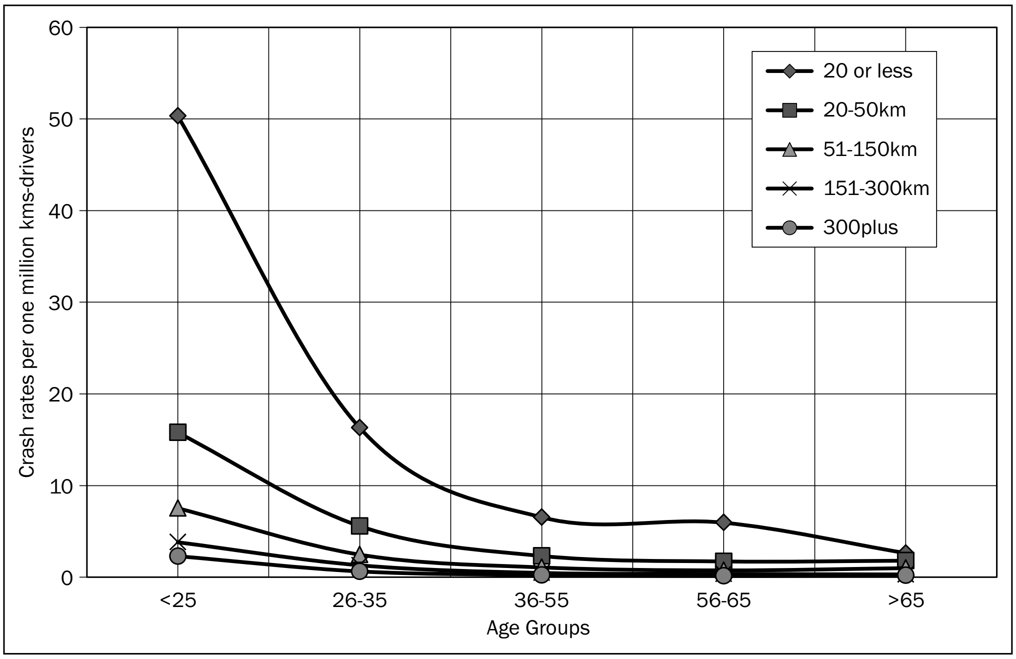

Figure 2 - Annual crash involvement for driver ages, controlled by daily driven distances (km)

drivers with a daily distance exceeding 50 km (CR is 7.5). It follows from this strong association, that if distances driven vary with the age of the driver, the crash rates per distance cannot be used for valid age comparisons. Annual crash rates per million driver–kilometres were calculated for different driver ages within each mileage group. The results are shown in *Figure 2*. For drivers covering above lower distances each day, the middle-aged, the above middle-aged, and the older age groups have a lower crash involvement. The only apparent increase in crash involvement occurs for drivers of general age groups covering less than 20 km per day.

4. CRASH INVOLVEMENT RATE MODELLING ACCORDING TO AGE AND DAILY DRIVEN DISTANCE

Two models were estimated to investigate the relationship between traffic accident involvement rate and daily driven distance or both daily driven distance and driver age. It was decided that it is sufficient for the purpose of this study to divide age into five categories with the shown cut-off values. The daily driven distance was divided into five categories, too. The models were developed using the database explained above with the following variables:

Model_1 considers the age groups:
- young (<25 years old)
- middle-aged (26–35 years old)
- above middle-aged (36–55 years old)
- old (56–65 years old)
- very old (65+)

Model_2 considers both the daily driven distance categories and age groups:
- less than 20 km
- 20-50 km
- 51-150 km
- 151-300 km
- more than 300 km

According to the age groups five different sub-models have been organized. For this purpose, a power trend line by using the following equation to calculate the least squares fit through database output points (Eq. 2):

$$CR(DDD)=\begin{cases}190\cdot(DDD)^{-0.788}, & Age<25\\ 212.33\cdot(DDD)^{-0.819}, & 26<Age<35\\ 205.43\cdot(DDD)^{-0.835}, & 36<Age<55\\ 344.46\cdot(DDD)^{-0.921}, & 56<Age<65\\ 143.34\cdot(DDD)^{-0.688}, & Age>65\end{cases}$$

$$r^2=0.99 \qquad (3)$$

Using the developed Model_1, when the accidents by driver age in groups matched the yearly driving exposure [11] are compared with those obtained from Model_1, the result is very satisfactory with the coefficient of determination about 99.68% (*Table 3*). Hence, the traffic involvement ratio may be estimated using the independent variable of daily driven distance.

Table 3 - Comparison of Model_1 outputs estimated using DDD and earlier study outputs [11]

Age	Daily Driven Distance (DDD)	Accidents per 1 million km-drivers	
		L. Hakamies-Blomqvist et al. (2002)	Model-1 f(DDD)
26-40	3.48	72.4	76.46
	23.2	14.7	16.17
	70	5.8	6.54
65+	4.32	48.6	52.38
	22	11.6	17.09
	56	6.2	8.99

In Model_2 of traffic accident involvement, two independent variables (daily driven distance and age) were employed. The model uses curve fitting method of a power type trend line. In the main model independent variable is the daily driven distance. But the constants (r and s) of the main model are related to the driver's age. The main model is correlated about 98% with the crash rates of the survey.

$$\begin{aligned}&CR=r(DDD)^{s} && r^2=0.9833\\ &r=100857(AGE)^{-1.982} && r^2=0.918 \quad (4)\\ &s=7e^{-05}(AGE)^2-0.0021(AGE)+0.8106 && r^2=0.9639\end{aligned}$$

Using Model_2, a comparison has been made between the results of this study and the earlier studies of [22], [23], and [24]. The regression coefficient of determination is about 74%, and 85% respectively (*Table 4*). Hence, the traffic involvement ratio may be estimated using the independent variables of daily driven distance and the driver's age.

5. CONCLUSION

This paper presents two models of accident involvement for two factors: age and daily driven distance. This study confirmed some of the results reached in previous studies. The first study belongs to L. Hakamies-Blomqvist et al. [11]. Model_1 obtained from survey [25] significantly correlated at 99% with accidents by driver age in groups matched for yearly driving exposure. The second study belongs to the Langford et al. [23]. Model_2 significantly correlates with crash rate per 1 million driver–kilometres obtained from the study by Langford et al. The correlation of determination is 85% without the value of the crash rate of driver 75–plus and mileage of 3,000 km or less. The third study belongs to Staplin et al. [22]. The correlation of determination is 74%. The crash rates of the drivers whose age group is 65-74 and over 75 the driving annual distance less than 3,000 km is not used in the

Table 4 - Model_2 outputs with daily driven distance and age as independent variables

Driver's age (years)	Annual distance driven	No. of drivers	Average annual no. of crashes (rounded)	Crash rate Langford et al. (2006)	Crash rate Model-2 f(DDD,AGE)	Crash rate Staplin et al. (2008)
Less than 20	3,000 km or less	580	42	53.4	93.54	28.9
	3,001–14,000 km	358	90	33.3	23.83	25.6
	14,000–plus km	161	58	13.1	8.51	14.6
21–30	3,000 km or less	2,268	128	39.3	57.01	21.8
	3,001–14,000 km	3,674	450	14.6	13.85	11.7
	14,000-plus km	4,188	796	6.6	5.15	6.9
31–64	3,000 km or less	4,667	165	22.8	20.03	15.7
	3,001–14,000 km	13,037	756	6.7	4.74	5.8
	14,000-plus km	14,075	1579	4	1.77	4.2
65–74	3,000 km or less	422	17	23.7	4.72	not used* 17.6
	3,001–14,000 km	2,119	111	6	0.91	5.5
	14,000-plus km	1,153	91	3.8	0.38	4.2
75–plus	3,000 km or less	98	8	not used 50.3	3.35	not used 26.5
	3,001–14,000 km	516	23	5.2	0.55	5
	14,000–plus km	186	10	2.8	0.23	4.2

**not used: this value is not used for the regression analysis between the models and the literature*

model estimation because the tendency of the results from this study that daily driven distance increased, the crash rate per distance travelled declined as independent of the driver age.

With this study, low-mileage drivers of any given age had a significantly higher crash rate than drivers of the same age with middle mileages, and middle mileage drivers of any given age had a significantly higher crash rate than drivers of the same age with high mileages. When older drivers with high mileages were compared with those younger drivers only who had similar yearly driving exposure, there was no age-related risk increase in accident rates per km. It is clear, however, that low mileages represent the most risky environments, e.g., urban and rural roads rather than motorways. Drivers of any age with large yearly mileages accumulate, in addition to the mileage and exposure typical of older drivers, a large number of km associated with a minimal exposure to accident, such as driving on motorways [11].

With the set of data of this study and analysis controlled by daily (yearly) driving distance might make the ''age'' effect disappear. This study makes a little contribution to the statement of "Wider replication and dissemination of these findings should lead to a review of ageist policies towards older drivers which exist in many countries in the developed world [8]."

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ÖZET

GÜNLÜK YAPILAN YOL VE YAŞ FAKTÖRÜNÜN TRAFIK KAZALARINA ETKISI

Türkiye için yapılan trafik güvenliği anket verilerine dayanarak (n= 5520), her bir yaş grubu için, çok yaşlı (65+, n=39), yaşlı (56-65, n=183), orta yaşlı (36-55, n=1875), yetişkin (26-35, n=2204), ve genç (25-, n=1219) olmak üzere, günlük yapılan yolculukların sürücü kaza oranları üzerine olan etkileri incelendi. Yapılan günlük yolculuklara göre km başına kaza oranları karşılaştırıldığında artan yaş ile daha yüksek risk açısından hiçbir bulgu olmadığı görüldü. Her yaş grubu için, günlük yapılan kilometrenin artması ile kilometre başına kaza riskinin azaldığı görüldü. Bu çalışmada, günlük yapılan yolculuk mesafesine bağlı olarak yaş etkisinin dikkate alındığı ve alınmadığı, kazaya karışma tahmin modelleri elde edilmiştir. Bu modeller daha önceki çalışmalarda elde edilen veri ve modeller ile karşılaştırılmıştır. Sonuçlar oldukça tatmin edicidir. Çalışmada kullanılan veri tabanı ve günlük yapılan yol dikkate alınarak yaş etkisi incelenebilmektedir.

ANAHTAR KELIMELER

trafik kazaları; yaş etkisi; günlük yapılan yol; trafik kazasına karışma

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