INVESTIGATION OF ROAD ENVIROMENT EFFECTS ON CHOICE OF URBAN AND INTERURBAN DRIVING SPEED

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Received 14 February 2011; accepted 21 March 2011

Abstract: Human factor plays the most determinant role in traffic accidents. Speeding is a dominant cause of accidents in road transport. However, in order to improve safety, this is not the only element of the road transport system that should be considered. The road and/or environment influence that behaviour as well, but they can be modified more quickly than drivers' behaviour, and their effect can also be demonstrated. This paper describes the effect of road environment on chosen driving speed. Decisions of drivers are influenced by environmental impacts. Some of these impacts are planned, deliberate stimuli, being a part of the telematic systems of traffic control. In this paper the measure of road vehicles speed was analyzed on certain road urban and interurban sections which can be characterized by different design speed and construction parameters. Methods of mathematical statistics have been used to prove the hypothesis; the driving speed chosen by the driver depends heavily on the characteristics of urban and interurban road section. The aim of the author is to prove this hypothesis and the difference between urban and interurban decision environment.

Keywords: road safety, driver behaviour, choice of driving speed.

1. Introduction

An accident cost - having internal as well as external components - contains a considerable amount of social transport costs. This fact has been investigated and verified by several authors, even in Hungarian R&D practice (Bokor and Tánczos, 2003; Rune, 2000). Numerous research works have already proved that human factor plays the most determinant role in traffic accidents. However, in order to improve safety, this is not the only element of the road transport system that should be considered. Changing drivers' behaviour is a slow and gradual process. The road and/or environment influence that behaviour as well, but it can be modified more quickly and its effect can also be demonstrated. An important road safety benefit is achieved by the appropriate use of the interfaces MAN-VEHICLE-ROAD system (Treat et al., 1979; Dekker, 2002). Drivers, although guided by learned and enforced rules of the Highway Code, make their own decisions when participating in road traffic. Reaching a destination is usually the main goal of driving. In the decision-making process to achieve this goal, feedback is usually self-evident as the driver navigates towards and approaches her or his destination. Subsumed under this goal are a variety of secondary goals among which there has been a lasting controversy regarding

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the role played by the risk of collision (Fuller, 2005). The basic goal of traffic safety is the formation of an ideal driver with predictable and Highway Code respecting behaviour. Most accidents are caused just because road users do not meet these criteria. Drivers' decisions are highly influenced by environmental impacts. Some of these impacts are planned, deliberate stimuli, being a part of the telematic systems of traffic control. These devices are designed for getting the human attitude closer to the ideal one considered in the model. Moreover, there are also unplanned, spontaneous effects, which from the aspect of traffic safety may be advantageous, disadvantageous or neutral (Berta, 2007). Driving speed is an important factor in road safety. Speed not only affects the severity of a crash, but is also related to the risk of being involved in a crash (Aarts and Van Schagen, 2006; Garber and Gadiraju, 1989). The speeds of road vehicles were measured and analyzed on certain road sections of different design speed and construction parameters, in the analysis we used methods of mathematical statistics. According to our basic hypothesis, the driving speed chosen by the driver depends heavily on the characteristics of the road section and the actual traffic on it. The aim of the author is to prove this hypothesis. The study of the traffic flow requires several pieces of information about the driving of vehicles on the road, e.g. the number of vehicles, their composition by types, their velocities and the speed distribution (Ambrus-Somogyi, 2007). The achievable speed of some vehicles or vehicle groups and the predictable characteristic values to be counted with on the planned infrastructure element are important criteria in the planning phase of the traffic engineering facilities (Bakó, 2004). The vehicles' speed depends on the road characteristics, the categories and the actual condition of vehicles, the driver, the time period of the day, the weather (Török, 2005). In case of measurements carried out on the same site, we can observe higher density at a certain speed value (which mostly depends on the value of the highest permissible speed, this can be considered characteristic). The process of changing the drivers' behaviour is slow and gradual. In comparison with this, the road and/or environment can be modified more quickly and the effect of such interventions can also be demonstrated. Drivers in traffic flow, although guided by rules, make their own decisions when choosing their actual speed. Speed measurement which provided the data was carried out on road sections built according to different design speeds and parameters, and the results have been investigated using the methods of mathematical statistics. According to our assumption, the actual speed selected by the driver depends to a large extent upon the layout and the actual conditions of the road section. The analysis of the measured data shows that speeding drivers adjusted their speed in compliance with the actual conditions of the roadway instead of respecting the maximum permissible speed prescribed by the Highway Code. Unforeseeable sudden changes of traffic conditions, or other risks were deliberately neglected. Our assumption, according to which drivers adapt their speed first of all to the road and traffic conditions perceived, has been justified.

2. Theoretical background

Vehicles' velocities were measured and analysed on road sections of different design speed and construction parameters, using the methods of mathematical statistics. According to our hypothesis, the driving speed chosen by the driver depends heavily on the characteristics of the road section and the actual traffic on it. Speed can be expressed by the length of distance covered during one time unit. The design speed is the speed taken into account when the extreme values of the technical characteristics are determined in the layout of a planned road. The design speed should be selected according to the anticipated future traffic of the road, its category and network role, as well as in conformity with the actual terrain conditions. Cross-sectional or spot speed is the speed calculated from the running time measured on a short road section. The running speed of road vehicles, as a probability variable, follows the Gauss' normal distribution. Given the relative frequency of velocities and summarizing them, the result is the speed distribution curve, integral of the speed density function, Eq. (1):

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{t^2}{2}} dt \qquad (1)$$

where:

$F_{(x)}$: density function of Gauss distribution

x_i: measured speed values [km/h]

$$t = \frac{(x_i - \bar{x})}{\sigma}$$ normalised value of x_i [-]

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$ average speed [km/h]

$$\sigma = \sqrt{\frac{(x_i - \bar{x})^2}{n-1}}$$ deviation of speed [km/h]

First, the results of the measurements have been examined, whether they are complying with the Gauss' normal distribution. In Fig. 1 the measurements are compared. Measurements were carried out on 25 different sites, and nearly 188,000 measured data were processed. It can be demonstrated that these measurements have a normal distribution. The counter hypothesis is not significant at confidence level of 95%. The value at a given percentage of the speed distribution function means that a given part of the vehicle flow proceeded at that, or lower speed. Depending on the traffic flow or on the technical condition of the roads, different values are obtained using the speed distribution curve. In accordance with the international scientific literature the 85% cross-sectional speed value has been used in this article (Fig. 1). Only 15% of the vehicles exceeded this speed value.

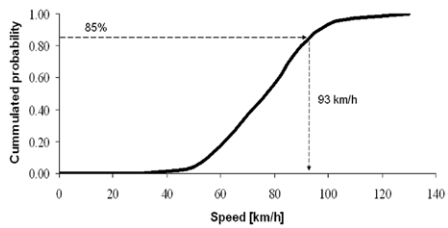

Fig. 1.
Determination of 85% characteristic speed at rural area (Source: the author's own research)

The aim of this article is also to examine the relationship between the running speed, the width of lane and sight of driver using mathematical statistical methods. On the basis of the measured data Table 1 summarizes the v85 (85% critical speed) and characteristic for all measurement sites.

Table 1
v_{85} characteristic speeds

	v_{85} [km/h]	Speed limit [km/h]	Average speed [km/h]	Deviation [km/h]	Median [km/h]	Number of taken measurements [pieces]
1.Measurement series (rural)	89	60	71	19	74	65
2.Measurement series (rural)	92	60	73	19	72	26
3. Measurement series (rural)	105	60	92	14	91	96
4. Measurement series (rural)	112	60	90	25	89	144
5. Measurement series (rural)	101	60	85	16	86	75
6. Measurement series (rural)	82	90	70	14	72	42
7. Measurement series (rural)	99	90	85	18	82	105
8. Measurement series (rural)	110	90	97	24	93	110
9. Measurement series (rural)	111	90	91	19	87	221
10. Measurement series (rural)	101	90	85	13	84	111
11. Measurement series (rural)	81	60	72	12	72	517
12. Measurement series (rural)	67	40	50	15	51	93
13. Measurement series (rural)	64	70	57	7	57	40
14. Measurement series (rural)	72	60	64	13	58	62
15. Measurement series (rural)	61	60	50	16	53	114
16. Measurement series (rural)	86	60	72	13	74	90
17. Measurement series (rural)	53	40	46	8	45	224
18. Measurement series (rural)	62	40	55	11	55	269
19. Measurement series (rural)	56	40	49	7	49	251
20. Measurement series (rural)	71	60	67	12	68	429
21. Measurement series (rural)	85	60	73	14	73	155
22. Measurement series (rural)	61	40	51	12	52	331
23. Measurement series (inner city)	59	50	51	12	51	62313
24. Measurement series (inner city)	60	50	50	15	52	60032
25. Measurement series (inner city)	63	50	53	11	53	62095

(Source: the author's own research)

3. Analysis of Results

From Table 1 it can be seen, that speeding drivers adjusted their speed in compliance with the actual conditions of the roadway instead of respecting the maximum permissible speed prescribed by the Highway Code. Detailed statistical analysis has been made separately for urban and for interurban conditions so as to be able to look deeper into the reasons of exceeding speed limit. The speed limit, the sight of the driver, the width of the lane and driving speed have been examined thoroughly. For this reason a regression model has been built on 3572 interurban and 183,632 urban measurements separately, Eq. (2) and Eq. (3).

$$v_{inter}=spl_{inter}*w_{11}+wol_{inter}*w_{12}+sil_{inter}*w_{13}+e_1 \quad (2)$$

where:

v_{inter}	measured velocities at interurban section [km/h]
spl_{inter}	speed limit of interurban section [km/h]
w_{11}	factor of speed limit at interurban section [-]
wol_{inter}	width of lane at interurban section [m]
w_{12}	factor of width of lane at interurban section [km/h/m]
sil_{inter}	sight length at interurban section [m]
w_{13}	factor of sight length at interurban section [km/h/m]
e_1	error coefficient of inter urban modell

$$v_{urban}=spl_{urban}*w_{21}+wol_{urban}*w_{22}+sil_{urban}*w_{23}+e_2 \quad (3)$$

where:

v_{urban}	measured velocities at urban section [km/h]
spl_{urban}	speed limit of urban section [km/h]
w_{21}	factor of speed limit at urban section [-]
wol_{urban}	width of lane at urban section [m]
w_{22}	factor of width of lane at urban section [km/h/m]
sil_{urban}	sight length at urban section [m]
w_{23}	factor of sight length at urban section [km/h/m]
e_2	error coefficient of urban modell

3.1. Analysis of Interurban Results

The analysis of variance resulted in R2=0.498 (see Table 2) for interurban dataset which means that environmental circumstances (sight of driver, width of lane and speed limit) describe more than 49% of total variance of driving speed.

Note that this fraction (701095.6/1409040 = 0.498) is the most widely used R2 value. A large ratio of the mean squares (the F-statistic) implies that the amount of variation explained by the sight of driver, the speed limit and the width of lane is large in comparison with the residual error. For this example, the F-statistic is 1177.828, with an associated p-value of 0.0. Since the p-value is less than 0.05, the sight of driver, the speed limit and the width of lane effect is statistically significant at the a = 0.05 level. Therefore, the sight of the driver, the speed limit and the width of the lane are important factors of speeding in interurban, rural areas.

The analysis of regression coefficients (results of t-tests) led us to the conclusion that the coefficients of speed limit, sight of driver and the coefficient of width are positive. This means that the longer the sight of the driver, and/or wider the lane the higher speed will be chosen by the driver in interurban environment. The significance test implies that all described parameters have an important role in speed choosing behaviour.

Table 2
Results of ANOVA for interurban dataset

ANOVA					
	Sum of Squares	**Degrees of Freedom**	**Mean Squares**	**F-Statistic**	**P-Value, Significancy**
Regression	701095.6	701095.6	233698.541	1177.828	0
Residual	707944	3568			
Total	1409040	3571			

(Source: the author's own calculation)

Table 3
Table of regression coefficients of interurban dataset

	Coefficients	**Std Error**	**t**	**Sig.**
	w_{1i}			
e_1 (error)	29.022	0.800	36.380	,000
SPL_{inter}	0.661	0.023	29.041	,000
WOL_{inter}	1.674	0.147	5.896	,000
SIL_{inter}	$5{,}817 \cdot 10^{-3}$	0.183	10.264	,000

(Source: the author's own calculation)

3.2. Analysis of Urban Results

The analysis of variance resulted in R^2=0.006 (see Table 4) for interurban dataset which means that environmental circumstances (sight of driver, width of lane and speed limit) describe more than 0.6% of total variance of driving speed.

Note that this fraction (28951399/178055= 0.006) is the most widely used R^2 value. A large ratio of the mean squares (the F-statistic) implies that the amount of variation explained by the sight of driver, the speed limit and the width of lane is large in comparison with the residual error. For this example, the F-statistic is 378.776 with an associated p-value of 0.0. Since the p-value is less than 0.05, the sight of the driver, the speed limit and the width of lane effect is statistically significant at the a = 0.05 level. Altogether the sight of the driver, the speed limit and the width of the lane are less important factors of speeding in urban areas.

The analysis of regression coefficients (results of t-tests) led us to the conclusion that the coefficients of speed limit, sight of driver and coefficient of width are positive. This means that the higher the allowed speed by the speed limit, the higher speed will be chosen by the driver in urban environment. The significance test and analysis of variances imply that none of the described parameters have an important role in speed choosing behaviour in urban areas in Budapest.

Table 4
Results of ANOVA for urban dataset

ANOVA					
	Sum of Squares	**Degrees of Freedom**	**Mean Squares**	**F-Statistic**	**P-Value, Significancy**
Regression	178055.3	3	59351.765	378.776	0
Residual	28773343	183629	156.694		
Total	28951399	183631			

(Source: the author's own calculation)

Table 5
Table of regression coefficients of urban dataset

	Coefficients	**Std Error**	**t**	**Sig.**
	w_{2i}			
e_2 (error)	297.138	161.604	1.839	0.066
SPL_{urban}	4.833	3.232	1.495	0.135
WOL_{urban}	0.333	0.023	14.478	,000
SIL_{urban}	$4.02*10^{-3}$	0.000	33.673	,000

(Source: the author's own calculation)

4. Discussion

The process of changing drivers' behaviour is slow and gradual. In comparison with this, the road and/or environment can be modified more quickly and the effect of such interventions can also be demonstrated. Drivers in traffic flow, although guided by rules, make their own decisions when choosing speed. Speed measurements were carried out on different urban and interurban road sections according to different design speeds or parameters, and the data were investigated using mathematical statistical methods. According to the basic assumption, the driving speed selected by the driver depends on the actual conditions of the road environment. The analysis of the weightening factors of the decision model shows that the drivers adjusted their speed in compliance with the actual environment of the roadway instead of respecting the maximum permissible speed in interurban, rural environment. In built, urban environment the choice of speed is rather independent from the sight of the driver, from the width of the line due to the very low traffic speed (Fig 2). Conclusions from the analysis of the measured data:

- Selection of the speed by drivers mostly depends on the layout and conditions of the road section and the actual traffic conditions on it.
- Influencing the speed selection of the drivers by the road signs or general rules of the Highway Code could be inexpensive, quick and efficient solutions to achieve appropriate road safety aims, in case the 'prestige' of the signs is improving and the field of regulation becomes more consistent.
- Planning (design speed) of a given road and its expected/desired network function should be harmonized in Hungary, because roads built with more than necessary safety reserves consume significant resources, while the road safety increments are questionable.

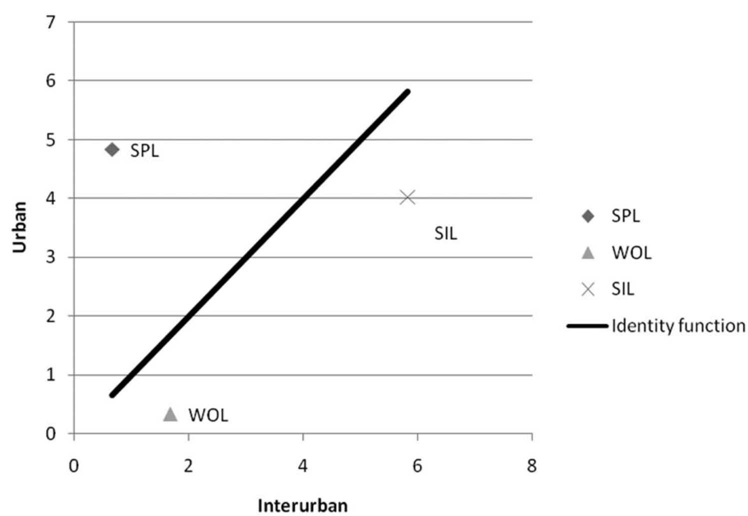

Fig. 2.
Difference between the weightening of speed limit, width of line and sight of driver in urban and interurban environment (source: result of decision model)

Acknowledgements

This work is connected to the scientific program of the "Development of quality-oriented and harmonized R+D+I strategy and functional model at BME" and "Modelling and multi-objective optimization based control of road traffic flow considering social and economical aspects" project. These projects are supported by the New Hungary Development Plan (Project ID: TÁMOP-4.2.1/B-09/1/KMR-2010-0002) and by program CNK 78168 of OTKA.

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ISTRAŽIVANJE UTICAJA PUTNE OKOLINE NA IZBOR BRZINE VOZILA U GRADSKIM I MEĐUGRADSKIM USLOVIMA VOŽNJE

Ádám Török

Sažetak: Ljudski faktor igra najznačajniju ulogu u nastanku saobraćajnih nezgoda. Prekoračenje brzine je dominantan uzrok saobraćajnih nezgoda u drumskom transportu. Međutim, kako bi se unapredila bezbednost saobraćaja, u razmatranje treba uzeti i druge elemente drumskog transportnog sistema. Put i/ili okolina takođe utiču na pojavu nezgode, ali oni se mogu brže modifikovati od ponašanja vozača, a i njihov uticaj se može prikazati. Ovaj rad opisuje uticaj putne okoline na izabranu brzinu vožnje vozila. Na odluke vozača utiče okolina. Neki od ovih uticaja su planirani, namerni podsticaji, koji čine deo telematskih sistema kontrole saobraćaja. U ovom radu analizirana je brzina drumskih vozila na određenim gradskim i međugradskim deonicama koje može da odlikuje različita projektna brzina i različiti konstrukcioni parametri. Metode matematičke statistike su korišćene za dokazivanje ove hipoteze; brzina koju bira vozač u velikoj meri zavisi od karakteristika gradske i međugradske deonice. Cilj autora je da dokaže ovu hipotezu i razliku u donošenju odluka između gradskih i međugradskih uslova vožnje.

Ključne reči: bezbednost drumskog saobraćaja, ponašanje vozača, izbor brzine.