INVESTIGATION OF ROAD NETWORK EFFECTS ON CHOICE OF DRIVING SPEED

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ABSTRACT

Human factor plays the most determinant role in traffic accidents. However, in order to improve safety, not only this element of the road transport system should be considered. The road and/or environment are influencing that behaviour as well, but they can be modified quicker than drivers' behaviour, and their effect can also be demonstrated. Decisions of the 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 were analyzed on certain road 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 the road section and the actual traffic on it. The aim of the authors is to prove this hypothesis.

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 [1], [2]. Numerous research works have already proved that human factor plays the most determinant role in traffic accidents. However, in order to improve safety, not only this element of the road transport system should be considered. Changing drivers' behaviour is a slow and gradual process. The road and/or environment is influencing that behaviour as well, but it can be modified more quickly its effect can also be demonstrated. Important road safety benefit is achievable by the appropriate use of the interfaces MAN-VEHICLE-ROAD system [3], [4]. 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 the role played by risk of collision [5]. 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 [6]. 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 [7], [8]. The speeds of road vehicles were measured and analyzed on certain road sections of different design speed and construction parameters, 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 authors is to prove this hypothesis. The study of the traffic flow requires several pieces of information about the vehicles running on the road, e.g. the number of vehicles, their composition by types, their speeds and the speed distribution [9]. The achievable running speed of some vehicles or vehicle groups and the predictable characteristic values to be counted with on the planned infrastructure element are important criterions in the planning phase of the traffic engineering facilities [10]. The vehicles' speed depends on the road characteristic, the categories and the actual condition of vehicles, the driver, the time period of the day, the weather [11]. In case of measurements carried out on the same site, we can observe at a certain speed value higher density (which mostly depends on the value of the highest permissible speed, this can be considered characteristic). The process to change 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 a traffic flow, although guided by rules, make their own decisions when choosing their actual speed. The data yielded by speed measurements were carried out on road sections built according to different design speeds and parameters, and the results have been investigated using methods of mathematical statistics. According to our assumption, the actual running speed selected by the driver depends to a large extent upon the layout and the actual conditions of the road section. 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' speeds were measured and analysed on road sections of different design speed and construction parameters, using 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 speeds and summarizing them, the result is the speed distribution curve, integral of the speed density function:

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

where:

$\Phi(x)$:	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 had been used in this article (Fig. 1). Only 15% of the vehicles exceeded this speed value.

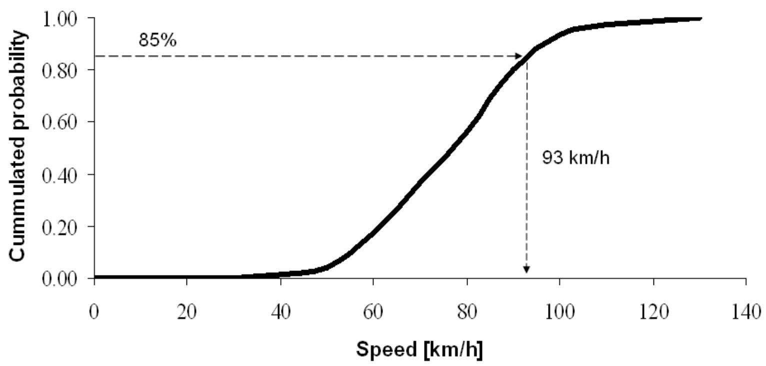

Figure 1 - Determination of 85% characteristic speed at rural area
(Source: own research)

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 v_{85} (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: 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 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 has been examined thoroughly (Fig 2.). For this reason a regression model has been built on 188,010 measurements.

$$v=spl*w_1+wol*w_2+sil*w_3 \qquad (2)$$

where:

- v measured speed [km/h]
- spl speed limit [km/h]
- w_1 factor of speed limit [-]
- wol width of lane [m]
- w_2 factor of width of lane [km/h/m]
- sil sight length [m]
- w_3 factor of sight length [km/h/m]

The analysis of variance resulted R^2=0.4976 (see Table 2.) which means that environmental circumstances (sight of driver, width of lane and speed limit) describes more than 49% of total variance of driving speed.

Table 2 - Results of ANOVA

ANOVA					
	Degrees of Freedom	**Sum of Squares**	**Mean Squares**	**F-Statistic**	**P-Value**
Regression	3	701135.6	233711.87	1177.641	0
Error	188006	707898.4	3.7652969		
Total	188009	1409034			

(Source: own calculation)

Note that this fraction (701135.6/1409034 = 49.76%) 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 1177.641, 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 α = 0.05 level (0.003 < 0.05). Therefore, the sight of driver, the speed limit and the width of lane are important factors of speeding.

Table 3 - Table of regression coefficients

		Coefficients	***Std Error***	***t***	**Sig.**
Model		β_i			
1	(Constant)	28,255	,767	36,823	,000
	SPL	,661	,023	29,041	,000
	WOL	,167	,028	5,896	,000
	SIL	5,817E-03	,001	10,264	,000

(Source: own calculation)

The analysis of regression coefficients (results of t-tests) led us that the coefficients of speed limit, sight of driver and the coefficient of width are positive. That means that the longer the sight of a driver, and/or wider the lane and higher the allowed speed by the speed limit, higher speed will be chosen by the driver. The significance test resulted that all described parameters have important role in speed choosing behaviour. Therefore the initial assumption has been proven, i.e. the road and its condition/environment, as well as the actual traffic characteristics play greater role in drivers' speed selection than the general regulation (maximum permissible speed) does.

4. DISCUSSION

The process to change 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 road sections built according to different design speeds or parameters, and the data were investigated using mathematical statistical methods. According to the basic assumption, the running speed selected by the driver depends to a great extent upon the actual conditions of the road section. Analysis of the measured data shows that the speeding drivers adjusted their speed in compliance with the actual conditions of the roadway instead of respecting the maximum permissible speed prescribed by the speed limit. 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 (Fig 3.).

Conclusions from the analysis of the measured data:

- Selection of the running 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 an inexpensive, quick and efficient solution 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, because roads built with more than necessary safety reserves consume significant resources, while the road safety increments are questionable.

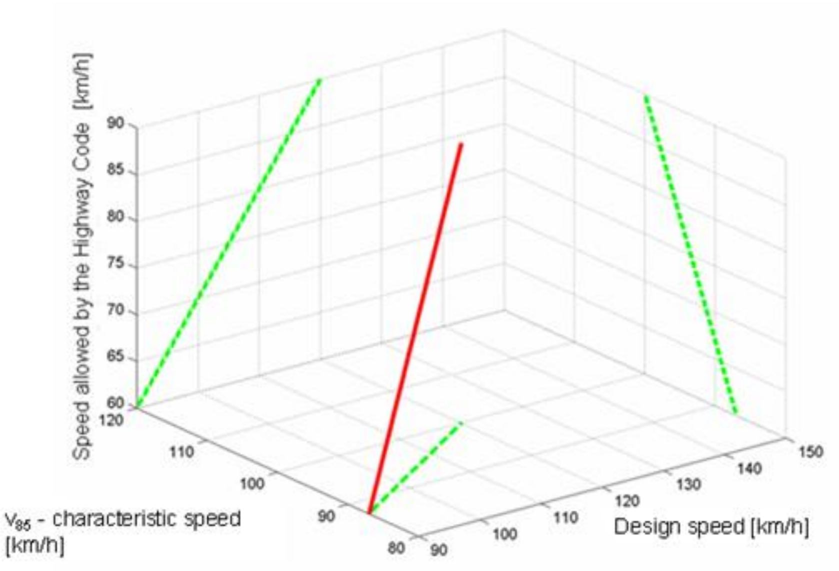

Figure 3 - Relationship between characteristic speeds, the maximum permissible speed set by the speed limit and the design speed [12]

5. ACKNOWLEDGEMENT

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