SURVEY OF FREE SPEEDS ON ROADS OUTSIDE BUILT-UP AREAS WITH ELEVATED SPEED LIMITS IN HUNGARY

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ABSTRACT:

In Hungary since 2008 some roads operate with posted speed limits which are higher than the general 90 kmph outside urban areas. The goal of the current study was to explore how well road users can recognize various types of roads. An on-line picture-show survey was made about the speed choices of 170 drivers at 35 different road scenes. The comparison with existing speed measurements showed a quite good match. Therefore the survey method is appropriate to estimate the drivers' speed behaviour. The results show on one hand that on the usual road categories like motorways and normal two-lane primary roads the speed choice is clear for road users, i.e. these roads are self-explaining. On the other hand, there are also road categories, which are not self-explaining and therefore road users have difficulties to choose the appropriate speeds.

KEYWORDS: posted speed limit, preferred speed, safe speed choice, self-explaining roads

1. INTRODUCTION

Studies revealed that driver related factors were solely to blame for around 50% of accidents on roads. When combinations of driver factors and environment or vehicle are added, the driver was involved in more than 90% of accident causation factors *(Treat et al., 1977).*

Speed is at the core of the road safety problem. Strong relationships have been established between speed and both crash risk and crash severity. Even if inappropriate speed is the direct cause of an accident, the specific site obviously provokes this unsafe behaviour *(Weller et al., 2006).*

A self-explaining road is a road designed and built in such a way as to induce adequate behaviour and thereby avoid driving error. A perfectly designed self-explaining road would not require speed limit signs or any warning signs *(Lippold, 2009).*

According to main principles of safe road design, the function, design and use of the road should be coherent with each other. To reach the right road usage and to avoid driving errors, layout of the road has to meet with the function of the road.

2. PREVIOUS STUDIES

Speed limits are generally meant to provide information to the driver about the speed (s)he can drive safely in average conditions.
However, setting a limit does not automatically result in the required speed behaviour. If drivers consider a posted speed limit incredible or inappropriate for a given road section, they may well ignore that limit and form their own decision as to what speed is appropriate. This assumption is affirmed by several survey studies.

2.1 Study about the credibility of speed limits from Netherlands *(Goldenbeld, van Schagen, 2007)*

In 2007 600 Dutch car drivers were asked in a form of questionnaire to judge 27 photographs of (different) roads with a posted speed limit of 80 kmph. To determine the degree of credibility, for each road scene the respondents filled in the preferred speed and the speed limit they considered to be safe. The results show large differences in both preferred speed and the safe speed limit between the road scenes, both below and above the limit of 80 kmph. These differences were related to a number of characteristics of the road and the road environment, such as the presence or absence of a curve and characteristics concerning the field of view (sight distance, clarity of situation). Subjects were influenced by more or less the same road features.

2.2 Study about the attitudes towards speed limits in Australia *(Lahausse et al., 2010)*

In Australia an online survey was administered, with a total of 4100 respondents recruited. The survey focused on attitudes towards speed limits for four different road types, and the sample was stratified according to age, gender, and area of residence. It was found that most respondents were able to correctly identify the speed limit for local residential streets and major urban arterials, although their knowledge of rural speed limits was considerably lower.
The majority of respondents were in favour of the proposed lower speed limits on 100 kmph two-lane undivided rural roads and on rural gravel roads, but only about one-third supported lower limits in urban areas. A cluster analysis revealed that there were varying characteristics between respondents who were more or less likely to support speed limit reductions, across a number of demographic, socio-economic status, and driving behaviour variables.

2.3 Study about the effects of centreline on the speed choice from the United States *(Garrick, 2011)*

In February 2011 Professor Norman W. Garrick made a smaller survey amongst his students during a university lesson at University of Connecticut. Students were divided into two groups. They were shown separately 12 - 12 different road scenes and their task was to choose the speed that they feel adequate and safe at actual situation. One group got road scenes with centerline, the other got the same pictures without centerline, erased with an image editor program.

Taking the means and medians of answers of two matching images, the result shows differences considering other parameters of the road section. Most results show that road with the centerline looks more like a rural highway, as higher speed results proving about, while without it looks more like a residential area; thus, the slower speeds were chosen. The double yellow centerline makes road seem much more like a rural highway. There were also scenes, when respondents seem to be affected more by context and parking cars than

by the presence or absence of painting in the middle.

3. SPEED LIMITS IN EUROPE (EU 2011)

As Table 1 shows, there are no uniform speed limits in Europe. For motorways most countries apply the 130 km/h limit, but a number of countries use lower values. Germany is a special case with no general speed limit but a recommended speed limit 130 km/h on motorways. It must be noted that more than half the network has a local speed limit of 120 km/h or less.

For roads outside built-up areas the table contains two columns. The higher figures generally refer to the speed limit on dual carriageways that are not motorways.

The speeds inside built-up areas are not subject of this paper.

In Hungary, similarly to the majority of the EU countries, the general speed limit on roads outside built-up areas is 90 km/h, while on motorways it is 130 km/h.

According to the Highway Code in Hungary, the speed limit on expressways, marked with a special sign (see Fig. 1) is 110 km/h. However the parameters of an expressway are not clearly defined, it can be anything from a two-lane road with level crossings to a dual carriageway road with completely grade separated junctions. The only indication to the speed limit is the "expressway" sign as you enter the road.

Furthermore, since 2008 the highway authorities may apply "elevated speed limits" of 100 or 110 km/h on roads which they think are appropriate. These roads also can be anything from a two-lane road with level crossings to a dual carriageway road with grade separated junctions. The indication to the permitted speed are the "speed limit" signs as you enter the road and after each junction.

Table 1. Speed limits in Europe

Country	Outside built-up areas		Motorways	
Austria	100		130	
Belgium	90	120	120	
Bulgaria	90		130	
Cyprus	80		100	
Czech Republic	90		130	
Germany	100		(130)	
Denmark	80		110	130
Spain	90	100	120	
Estonia	90	100	120	
France	80	110	110	130
Finland	80	100	100	120
United Kingdom	96	112	112	
Greece	90	110	130	
Hungary	90	110	130	
Italy	90	110	130	
Ireland	80	100	120	
Luxembourg	90		130	
Lithuania	70	90	110	130
Latvia	90		110	
Malta	60	80		
Netherlands	80	100	100	120
Portugal	90	100	120	
Poland	90	110	130	
Romania	90	100	130	
Sweden	70	90	100	120
Slovakia	90		130	
Slovenia	90	100	130	
Croatia	90	100	130	
Macedonia	80	100	120	
Turkey	90		130	
Iceland	80	90		
Norway	80		90	100
Switzerland	80		120	

3. THE SURVEY

In our questionnaire survey students had to judge photographs of road scenes. The participants were asked to state what speed they preferred for each road scene. Participants were not informed about the actual speed limit.

The aim of the study was to explore how road users can recognize the various types of roads. Furthermore we would like to find out if there is any difference between the posted speed limit and the chosen speed and how much this difference is.

3.1 Respondents

The target group of the current survey was a specific group of society. The sample was 215 students, from a university lesson at Széchenyi István University in Hungary, in the city of Gyor. Their average age was 25. Most of them own a driving licence. The average period of driving licence possession was 7 years. 80% of participants were male, 20% female. This sample is not representative of the Hungarian population of license holders in terms of age and gender, but can be used for defining differences between road types.

3.2 The questionnaire

Participants completed the questionnaire at home at their own computers. The questionnaire consisted of two parts. The first part contained questions on age, gender, driving licence possession and the number of years of licence possession, about the driving practice and style. The second part of the questionnaire consisted of 35 photographs of real life road scenes from Hungarian roads. Respondents got randomized sequence of photographs in order to rule out possible sequence effects.

Photographs depicted motorway scenes, expressway scenes, primary roads with elevated speed limit and normal primary road scenes outside urban areas. Some of them had physical separation between traffic directions, others didn't. There was almost no traffic in the pictures in order to estimate the free speeds. Most of the pictures were taken in tangent sections, so that the cross section would influence the drivers rather than the curvature. The seven categories and their main characteristics are shown in Table 1. and in Figure 1. Each category had 5 photographs in the questionnaire. Some samples from the photos are shown in Figures 2-5. For each of the 35 photographs the respondent had to fill in the speed that (s)he would like to drive in that situation. From the sample participants were deleted whose average preferred speed differed from the average value at least with the twice of the standard deviation and also those, who didn't own a driving licence. The final sample contained 170 persons.

Table 2. Main characteristics of the road categories surveyed

	Road class	Posted speed limit (kmph)	Number of traffic lanes	Separation of directions	Number of road scenes shown
1	motorway	130	2x2 lanes	with median	5
2	primary road with elevated speed limit	110	2x2 lanes	with median	5
3	primary road with elevated speed limit	100	2x2 lanes	with median	5
4	primary road with elevated speed limit	100	2x2 lanes	without median	5
5	expressway	110	2x1 lanes	without median	5
6	primary road with elevated speed limit	110	2x1 lanes	without median	5
7	primary road	90	2x1 lanes	without median	5

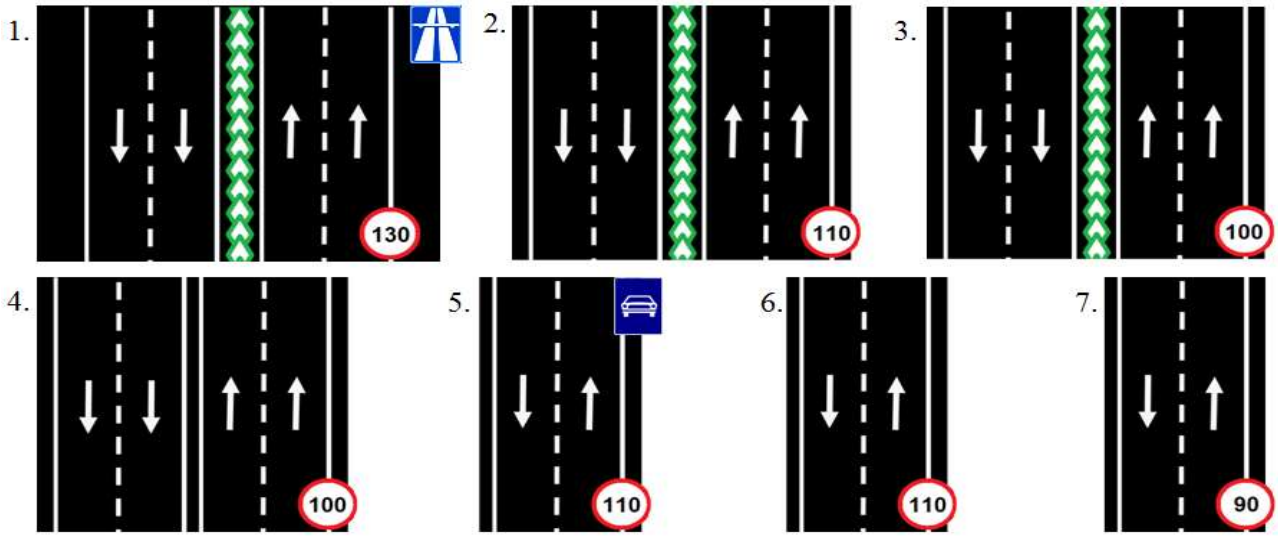

Figure 1. Schemes of seven road categories and their posted speed limits

Figure 2. Motorway M7, v_{perm} = 130 kmph, v_{avg} = 126 kmph

Figure 3. Road N81, v_{perm} = 90 km/h, v_{avg} = 87 kmph

Figure 4. Road N8 with elevated speed limit, v_{perm} = 110 kmph, v_{avg} = 115 kmph

Figure 5. Road N8 with elevated speed limit, v_{perm} = 100 kmph, v_{avg} = 103 kmph

4. RESULTS BY ROAD CATEGORIES

For each picture, the average preferred speed, the v_{85} speed, the standard deviation and the difference from the posted speed limit was calculated. The average results for the seven categories are shown in Table 2.

For motorways (column 1) the average preferred speed is only about 7 kmph lower than the speed limit and speed v_{85} is adequate for this category. The relative standard deviation is only 11%, thus it is clear that people can easily recognise this category. The situation is similar for primary roads with 2x1 lanes (column 7).

As for the primary roads with elevated speed limit 110 kmph divided (column 2), the relative standard deviation is 13%, as drivers choose different speeds due to the unfamiliar situation. The v_{85} speed exceeds the posted speed by 11 kmph.

A bit strange are the results in the case of undivided 2x1 lanes roads: on expressways and primary roads with elevated speed limit 110 kmph (column 5 and 6). Participants might perceived these scenes as normal primary roads, so the preferred speed is lower by more than 10 kmph from the posted speed limit and also the v_{85} speed does not reach the posted speed limit.

The results are worrying in the remaining two cases, on divided 2x2 lanes primary roads with elevated speed limit 100 kmph (column 3) and also on undivided 2x2 lanes primary roads with elevated speed limit 100 kmph (column 4). In these cases the average chosen speed is higher than the posted speed limit and also the v_{85} speed exceeds the posted speed limit by more than 10 kmph, which means that on these roads the driver might feel that, s(he) is passing on a higher road category.

Table 3. Results for different categories

Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Posted speed limit (kmph)	130	110	100	100	110	110	90
Average of answers (kmph)	122.8	107.0	111.4	101.5	98.7	96.2	85.3
Difference (kmph)	-7.2	-3.0	+11.4	+1.5	-11.3	-13.8	-4.7
Standard deviation (kmph)	13.2	13.9	14.5	11.1	10.7	10.5	8.6
Standard deviation (%)	11%	13%	13%	11%	11%	11%	10%
v_{85} (kmph)	136.5	**121.4**	**126.4**	**113.0**	109.8	107.1	94.3

5. COMPARISON OF SURVEYED AND MEASURED SPEEDS

It is of crucial importance, how well the survey results match the real life situations. Therefore a comparison was made with existing speed measurements available at the same sites or at similar locations. As the measurements were conducted at individual locations, whereas the photos were taken at 5 different sites for each road category, the exact matching is not to be expected. The comparison is shown in Table 3.

From Table 3 it is clear that the average speeds from the survey and those from the measurements differ from each other by 2-4 kmph only, the lower being the measured averages. Regarding the totally different

approaches, this can be seen as a good match.

The standard deviations were consequently higher at the actual measurements. This can be well explained by the sample of the survey (i.e. the relatively narrow age distribution of respondents), compared with the actual driver population in the measurements. The values of v_{85} show a similarly good match. Therefore we can consider these kinds of surveys a reasonable approach to collect information about the preferred speeds.

It has to be mentioned that the road category No. 6 showed a larger deviation between measured and surveyed average speeds (6.4 kmph). This can be explained by the fact that two of the five pictures from this road category were taken at locations where some design elements (a junction, a danger sign or a horizontal curve) made the respondents to "slow down". Disregarding these two pictures the difference between measured and surveyed average speeds was only 3.6 kmph.

Table 4. Comparison of measured and surveyed speeds

Category	Variable	Measurement	Survey
1	Average speed (kmph)	120.8	122.8
	Standard deviation (kmph)	17.8	13.2
	v_{85} (kmph)	139.2	136.5
2	Average speed (kmph)	103.6	107.0
	Standard deviation (kmph)	17.7	13.9
	v_{85} (kmph)	121.0	121.4
4	Average speed (kmph)	99.0	101.5
	Standard deviation (kmph)	15.5	11.1
	v_{85} (kmph)	116.0	113.0
5	Average speed (kmph)	96.2	98.7
	Standard deviation (kmph)	12.9	10.7
	v_{85} (kmph)	109.6	109.8
6	Average speed (kmph)	102.6	96.2
	Standard deviation (kmph)	15.6	10.5
	v_{85} (kmph)	118.0	107.1
7	Average speed (kmph)	86.5	85.3
	Standard deviation (kmph)	12.3	8.6
	v_{85} (kmph)	99.2	94.3

6. RESULTS BY USER GROUPS

In order to analyse any differences by driving experience or sex, the drivers were divided in groups (male >5 years, male <5 years, female >5 years, female <5 years, all >5 years, all <5 years). The average speeds were calculated for these groups and the Welch-test was performed.

In statistics, Welch's t test is an adaptation of Student's t-test intended for use with two samples having possibly unequal variances. Welch's t-test defines the statistic t by the following formula:

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{{s_1}^2}{N_1} + \frac{{s_2}^2}{N_2}}}$$

where $\overline{X_1}$, s_1^2 and N_i are the i^{th} sample mean, sample variance and sample size, respectively. Unlike in Student's t-test, the denominator is not based on a pooled variance estimate.
The degrees of freedom ν associated with this variance estimate is approximated using the Welch-Satterthwaite equation:

$$v = \frac{\left(\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}\right)^2}{\frac{s_1^4}{N_1^2 \cdot v_1} + \frac{s_2^4}{N_2^2 \cdot v_2}} = \frac{\left(\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}\right)^2}{\frac{s_1^4}{N_1^2 \cdot (N_1 - 1)} + \frac{s_2^4}{N_2^2 \cdot (N_2 - 1)}}$$

Here $v_i = N_i - 1$, the degrees of freedom associated with the i^{th} variance estimate.

Once t and v have been computed, these statistics can be used with the t-distribution to test the null hypothesis that the two population means are equal (using a two-tailed test), or the null hypothesis that one of the population means is greater than or equal to the other (using a one-tailed test).

In Table 4 t-values which are significant on the 95% level are written in **bold**. The results show that the assumption that more experienced persons drive faster is only valid for the two traditional road categories (i.e. motorways and normal two-lane roads) and for the 4 lane undivided road. For the other roads with elevated speed limits there are no significant differences depending on the driving experience.

Similar results were found between experienced male and female drivers, only the two traditional road categories showed significant differences between them.

Table 5. t- values of the Welch's test

Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Posted speed limit (kmph)	**130**	**110**	**100**	**100**	**110**	**110**	**90**
female >5 years - female <5 years	1.32	0.29	0.97	0.61	-0.41	-0.38	-0.34
male >5 years - male <5 years	**5.15**	1.11	-0.85	**2.81**	0.87	0.42	**2.74**
female >5 years - male >5 years	**-1.71**	-0.70	0.36	-0.75	-0.81	0.21	**-2.28**
female <5 years - male <5 years	0.11	-0.43	-1.52	0.15	0.11	1.00	-0.50
all >5 years – all <5 years	**4.49**	1.31	0.88	**2.61**	0.04	-0.58	**1.51**

7. CLUSTER ANALYSIS

A cluster analysis was performed in order to identify groups of persons with similar speed choices at different road sections. The PASW Statistics package was used and the K-means method was chosen. Respondents were considered as cases and the speeds given for the 35 road scenes as variables. Having tried 2, 3, 4, 5 and 6 clusters, the 4 cluster version was chosen as the most appropriate one.

Table 5 shows for each cluster the average speeds by road categories as well as the average driving experience and the male/female ratio.
Initially, it was assumed that the cluster analysis divides the respondents in groups

simply as faster and slower drivers. However, the results turned out to be more complex. As expected, Cluster1 shows the highest speeds in each road category. It contains experienced drivers (8.1 years) and the male ratio is as high as 94%. In Cluster2 the average driving experience is also high (8.2 years) and the female ratio is close to the average. Their speed on dual carriageway roads is almost as high as in Cluster1, but on undivided roads they drive 6-10 kmph slower than persons in Cluster1.

In Cluster3 the driving experience is equal to the average of the whole sample; the female ratio is somewhat higher than the average. In each category, they are remarkably slower than Cluster2. Cluster4 contains the less experienced drivers (4.0 years) and the female ratio is the highest in this group. Except from motorways and normal two-lane roads, they do not recognise too much difference between road categories: They drive at 94-98 kmph on each road with elevated speed limit with the surprising consequence that in road categories 5,6 and 7 they are quicker than the more experienced drivers in Cluster3.

Table 6. Cluster characteristics

	Cluster1	**Cluster2**	**Cluster3**	**Cluster4**
Number of persons	33	75	37	25
Average driving experience (years)	8.1	8.2	6.8	4.0
Male/female ratio	94/6	83/17	73/27	68/32
Average speed in Category 1	130.5	125.7	116.3	113.8
Average speed in Category 2	115.1	111.0	98.4	96.6
Average speed in Category 3	118.1	116.0	104.6	98.4
Average speed in Category 4	110.2	103.8	94.2	93.9
Average speed in Category 5	108.1	98.4	91.4	98.1
Average speed in Category 6	105.6	94.5	89.9	98.2
Average speed in Category 7	89.2	86.0	81.9	83.0

8. CONCLUSIONS

An on-line picture-show survey was made about the speed choices of 170 drivers at 35 different road scenes. The results show on the one hand that the usual road categories like motorways and normal two-lane roads outside urban areas are very well understood by road users, the speed choice is clear for them, i.e. they are self-explaining.
On the other hand, there are also road categories, which are not self-explaining and therefore road users have difficulties to choose the appropriate speeds. On roads with elevated speed limit with 2x2 lanes the road users usually exceed the posted speed limit and this can cause safety problems. On two-lane roads with elevated speed limit, road users tend to drive slower than the posted speed limit, as they do not feel safe higher speeds here.

A cluster analysis identified four groups of persons with different speed patterns. The clusters differ from each other not only in their average speeds, but also in their speed difference between divided and undivided roads.

The comparison with existing speed measurements available at the same sites or at similar locations showed that the average speeds from the survey and those from the

measurements differ from each other by 2-4 kmph only, which is a quite good match. Therefore the survey method is appropriate to estimate the drivers' speed behaviour.

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