# Simplification of Road Transport Infrastructure Layout for Better Self-Explanation

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**Abstract**  Improving road safety is a primary goal in the European Union. Authors are investigating road transport as a complex system consisting of infrastructure, vehicles and the human side. This is a complex system that is designed, built, and managed by people. This article aimed to investigate the cross-sectional layout of road transport infrastructure and the statistical analysis of the results. The national road infrastructure building standards formed the basis of investigation. The author has formulated the hypothesis that local planning regulations in Hungary must be simplified and road types should have been merged. The cross-sectional layout is very important from the driver's point of view regarding the appropriate choice of speed, which is dependent on the psychological schema corresponding to the given road layout and is important for proper behavior in traffic.

*Keywords: cross-sectional layout of road infrastructure, statistical analysis, factor analysis, self-explaining roads*

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## 1. Introduction

Despite the progress in road safety conditions in Hungary in the last decade, the situation is still significantly worse than the EU average. In terms of the various specific indicators used in the EU (Road fatalities per million inhabitants, Road Fatalities per 10 billion pkm, Road fatalities per million passenger cars), there are very few countries with higher fatality rate than Hungary (Figure 1) [9,12,20]. Fatality rate is used to compare sector of the society (transport, industry, healthcare).
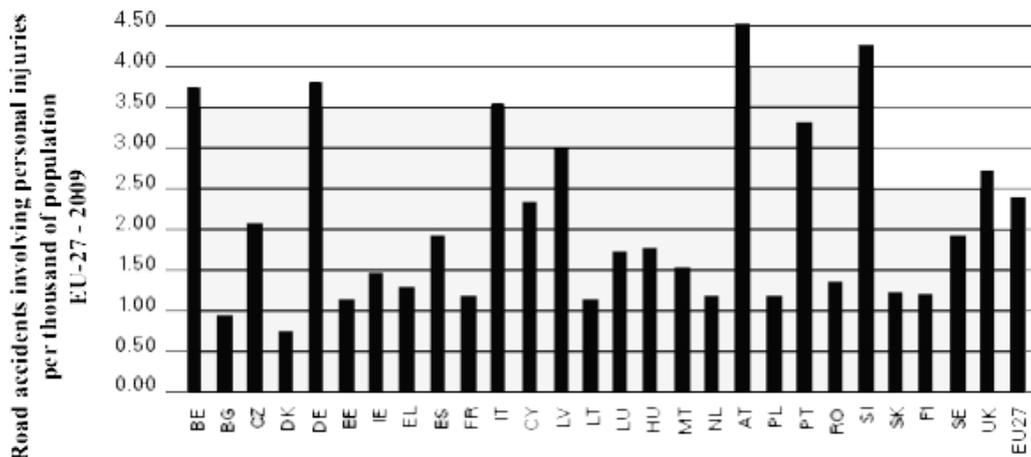


(source: ERF 2011 European Road Statistics)
**Figure 1.** Road accidents involving personal injuries per thousand of population EU-27 - 2009

With above Figure 1. author want to emphasize that Hungary needs further improvement in order to reach the EU target (50% decrease in the number of road fatalities between 2010 and 2020.). Regardless, the continuous improvement in road safety is evidenced by several indicators in Hungary [1,16,21]. This article focuses on general, large-scale problems that effect human behaviour and the solutions to which could aid prevention activities.

To provide safer road infrastructure, the behaviour of road users needs to be known. „*The road users - during their journey - unwillingly make mistakes: the task of road planners and operators to minimise that possibilities of mistakes and accidents. If errors still occur and the accident happens, it must be ensured that the consequences are minimized. The road infrastructure and its environment should be forgiving those who made*

*mistakes and not penalizing them"* [14]. In 1932, Sir Frederic Charles Bartlett, a British psychologist introduced the concept of schema in psychology. The schema contains all things a person knows. If new information could not be incorporated into a scheme then distortions will arise. The scheme represents an organized structure, which includes knowledge about our world and our expectations. People remember new things with the help of existing structures. In order to improve safety, the adequate scheme needs to be activated in drivers through infrastructure. This article aims to compare Hungarian rural road construction standards with the standards of the Germany by mathematical and statistical tools. The hypothesis of the author is that the scheme of rural Hungarian road network elements are diverse due to their design, making them more accident-prone [15] (e.g. through inappropriate choice of speed). This article aims to investigate improvement opportunities to have a simpler and more straightforward system such as the German one. As it can be seen from Figure 2. the number of registered motor vehicles are increased significantly in the recent years in Hungary. It has to be emphasized that parallel with this the number of fatal accident significantly decreased in Hungary.
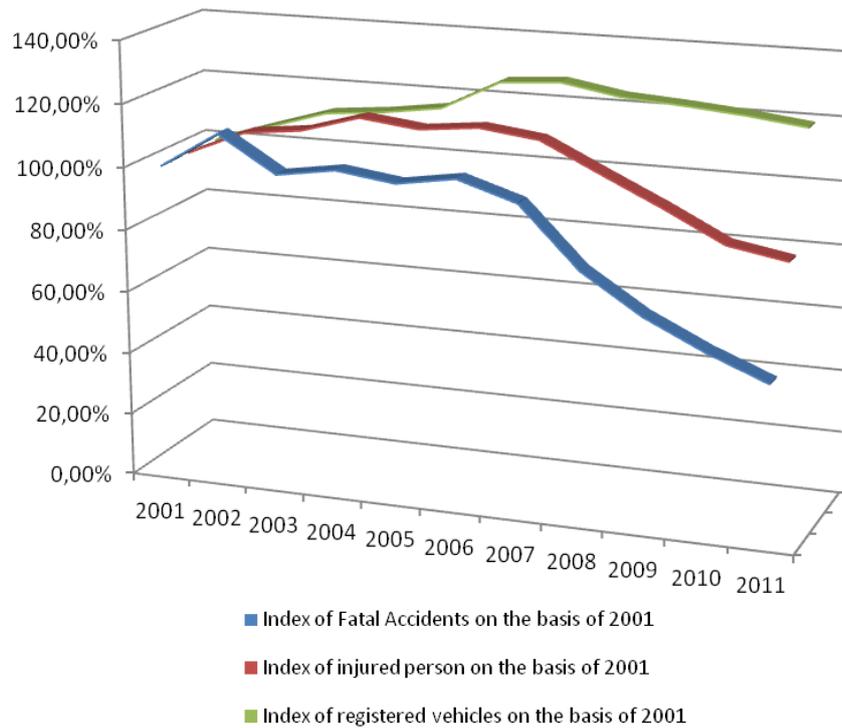


(source: own edition based on dataset of Central Statistical Office for Hungary )
**Figure 2.** Number of registered vehicles, number of accidents and people killed in road accidents in Hungary

## 2. Methodology

This article investigates rural roads only. Cross-sectional conceptual designs of road infrastructure have been studied with the tools of mathematical statistics (quantitative multivariate data analysis, multidimensional scaling, hierarchical cluster analysis, principle factor analysis were used to prove the hypothesis - these mathematical methods are well known and have been used in several statistical analyses) extending to the following physical parameters:
- Maximum speed [km/h]
- Lane width [m]
- Rounding radius [m]
- Maximum slope [%]
- Curve radius [m]

The author considered these to be the major physical parameters of a rural road that influence the schemes in the driver's mind. These are the physical parameters that influence the self-explaining roads.

A database had been built up by the described parameters in case of Hungarian and German rural roads. The parameters of Hungarian and German technical specification of rural roads had been used. The database includes the road type related physical parameters for each type of roads.

Quantitative multivariate data analysis was used for the empirical analysis of systematically collected data. Existing research indicates that these parameters determine speed choice [5,7,11,19] and risk-taking behaviour [4,6]. A comparative analysis of vectors generated from these parameters has been performed. A vector is a quantity that has a magnitude and a direction. In its simplest form, the vector is a directed line segment. The vector can also be considered as a special group of numbers. In this case, five-dimensional vectors have been compared. To do this, the length of five-dimensional vectors and the difference between each pair were calculated (1):

$$\sqrt{\sum_{i=1}^{s} (x_i - y_i)^2} \qquad (1)$$

where:
  $x$: one type of investigated infrastructure
  $y$: other type of investigated infrastructure
  $i$: parameter of investigation

The author assumed that if two vectors are different, then the two infrastructures are also different and activate different schemes in the driver - if the difference between the two vectors is greater than 5% of the smaller vector (5% tolerance is commonly accepted in engineering) (2):

$$\left| \min\{x, y\} \right| \cdot \varepsilon \geq \left| \overline{x} - \overline{y} \right| = \beta \qquad (2)$$

where

$\varepsilon$: equivalence parameter [-], in this case 5%

$\beta$: binary coefficient {0,1} of reduction [-], 1 if two infrastructure types can be consolidated

Other statistical methods were also used to prove the hypothesis. The vectors created from physical parameters are five-dimensional; therefore the graphical representations are very difficult. This problem can be solved by multidimensional scaling. Multidimensional scaling (MDS) is a method of multivariate statistical analysis, a procedure by which geometric representations can be created on the basis of perceived similarities and differences [2,13,18]. In our case, the observed five dimensional similarities of the five-dimensional vectors were transformed into a two-dimensional "map" in which the observed differences and similarities remain.

A hierarchical cluster analysis - also a method of multivariate statistical analysis - was also performed to confirm the hypothesis, providing a dimension-reducing grouping for the vectors representing infrastructure elements so that similar elements in the reduced space are next to each other.

Factor analysis was also performed to verify the reduction hypothesis, since in the factor analysis models it is possible to explore relationships between variables. If there is a strong relationship between the components or there are dominant components present, then simplification is possible while retaining information contained by the vector components through the linear combination of smaller number of uncorrelated vectors. With this method, there is an opportunity to reveal the weights of combining factors and to discover hidden relationships between components. The dataset can be characterized by a linear function of several dominant factors. In this article, author has performed main factor analysis so the factor vectors will be eigenvectors of a correlation matrix. During the analysis, the varimax rotation strategy was chosen, where the number of explanatory variables are minimised.

## 3. Results

The vector reduction model described above (2) merged the initial 14 different road categories into seven categories. The generally accepted limit of 5% difference was used. Either some of these categories should be merged, or more significant differences should be introduced to separate them better so that drivers would be less likely to recall an inappropriate psychological schema. Similar results were found in the multidimensional scaling (Figure 3). The number of categories should be decreased as follows:
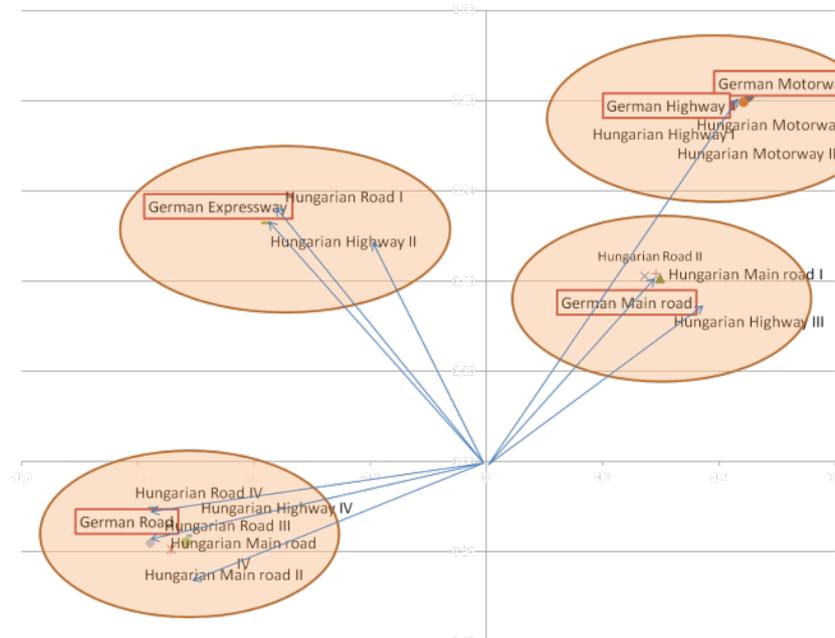


\* For a better overview, only selected road infrastructure categories are shown
**Figure 3.** MDS based reduction\*

The MDS-based reduction (Figure 4.) yielded five groups.

The decreasing of eigenvalues of eigenvectors in the factor coefficient matrix can be seen in Figure 5. The figure shows that vector space made from the vectors of the cross-sectional design of the infrastructure elements can be simplified and the main components can be determined. Our analysis identified four main components,

one of which was significantly different and determined the system. We believe that the four groups should be:

- Motorways (High-speed roads with an M prefix or (M) suffix. e.g. M1 or A1(M). The speed limit is generally 130 km/h. There is a physical separation between directions, no level crossing and one emergency lane per direction),
- Expressways (High-speed roads with an M prefix or (M) suffix. e.g. M1 or A1(M). The speed limit is

generally 110 km/h. Does not necessarily exist a physical separation between directions or one emergency lane per direction)

● Main roads (roads with the speed limit of 90 km/h. There is no existing physical separation between directions, there could be level crossing and no emergency lane)

● Roads (all the other mainly regional roads in nature and used to connect areas of lesser importance. Usually shown as brown or yellow on maps.)
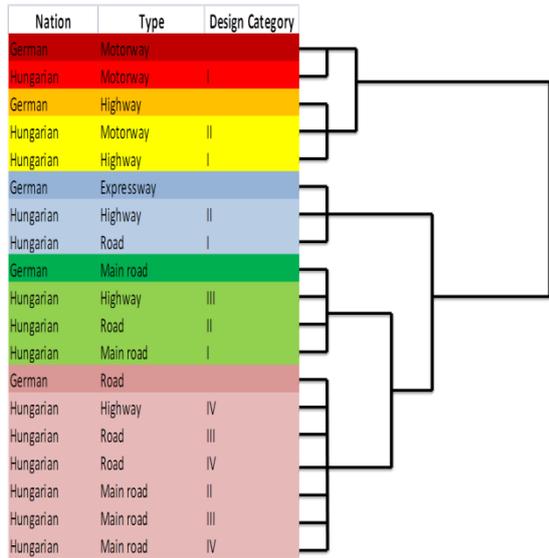
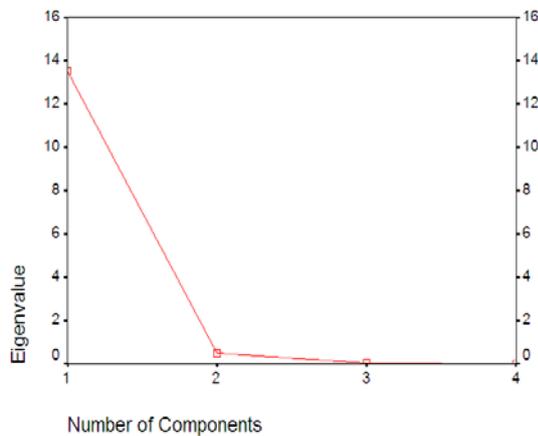

**Figure 4.** Hierarchical cluster analysis



**Figure 5.** Decreasing the eigenvalues of eigenvectors in the factor coefficient matrix

# 4. Analysis and Conclusion

As it can be seen from Table 1, 4 aggregated vectors determine the vector space, so the original 19 vectors (different infrastructure layout) could and should be reduced.

**Table 1. Table of variance**

| Reduced group | Eigenvalue | |
| --- | --- | --- |
| | variance [%] | Total variance [%] |
| 1 | 94.324 | 94.324 |
| 2 | 2.879 | 97.203 |
| 3 | 0.166 | 97.369 |
| 4 | 2,61E-03 | 97.371 |

Author has used different mathematical and statistical tools verify a hypothesis on reduction. It has already been turned out that Hungarian rural road network design should be simplified [8]. The calculations described above show that the 14 different cross-sectional road infrastructure designs available in Hungary can be aggregated into 4 and the simplified layouts are similar to German standards – *see* Figure 3. According to decision theory and psychology, fewer schemas would increase the identification possibility of safe behaviour in traffic [3,10,17]. Further research would be necessary to crosscheck the mathematical results through road tests with real drivers. The existing Hungarian Public Roads Design Rules are overly complex. Based on the calculations described in this article, four cross-sectional designs would be necessary and sufficient in Hungary.

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# References

[1] *Bogdevičiusa, Prentkovskis, Vladimirovc* (2004): Engineering solutions of traffic safety problems of road transport, Transport, 19(1) p43-50.

[2] *Borg, Groenen, (1997)*: Modern multidimensional scaling: theory and applications. New York: Springer.

[3] *Charlton, Mackie, Baas, Hay, Menezes, Dixon* (2010): Using endemic road features to create self-explaining roads and reduce vehicle speeds, Accident Analysis & Prevention, 42(6), p1989-1998.

[4] *Čokorilo:* Quantified risk assessment modelling of aircraft landing operations, Scientific Research and Essays 6 (20), p4406-4413.

[5] *Haglund, Åberg (2000):* Speed choice in relation to speed limit and influences from other drivers, Transportation Research Part F: Traffic Psychology and Behaviour, Vol 3(1) pp39-51.

[6] *Hamish W. Mackie , Samuel G. Charlton , Peter H. Baas, Pablo C. Villasenor* (2013): Road user behaviour changes following a self-explaining roads intervention, Accident Analysis & Prevention, Volume 50, January 2013, p742-750.

[7] *Hauer, Ahlin (1982):* Speed enforcement and speed choice, Accident Analysis & Prevention, Vol 14(4) pp267-278.

[8] *Hlédik; Logo, Torok* (2012)*:* Mathematical evaluation of cross-sectional layout of Hungarian road infrastructure [in Hungarian: Közúti közlekedési infrastruktúra keresztmetszeti kialakításának értékelése matematikai módszerekkel], Scientific Review of Transport [in Hungarian: Közlekedéstudományi Szemle] (ISSN: 0023-4362) 62: (6) pp. 15-20.

[9] *Holló, Eksler, Zukowska* (2010): Road safety performance indicators and their explanatory value: A critical view based on the experience of Central European countries, Safety Science, 48 p1142-1150.

[10] *Hóz, Sipos (2012):* Validation possibilities of the principles of self-explaining roads and forgiving road environmen in the Hungarian road infrastructure development [in Hungarian: Önmagát magyarázó út és a megbocsátó útkörnyezet alapelveinek érvényesítési lehetőségei a hazai közúti infrastruktúra kialakításában, fejlesztésében], research report [in Hungarian: kutatási jelentés], KTI.

[11]  *Iván* (2012): Survey of free speeds on rural roads based on road scene photographs, Pollack Periodica: An International Journal For Engineering And Information Sciences 7(1) p 65-74.

[12]  *Koren et. al. (2005)*: Road Safety Audit Guide [in Hungarian: Közúti biztonsági audit útmutató], research report.

[13]  *Kruskal, (1964)*: Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis, Psychometrika, 29, p1-27.

[14]  *Road Directorate, Denmark (1997)*: Manual of Road Safety Audit, (2nd edition).

[15]  *Samuel G. Charlton, Hamish W. Mackie, Peter H. Baas, Karen Hay, Miguel Menezes, Claire Dixon (2012):* Using endemic road features to create self-explaining roads and reduce vehicle speeds, Accident Analysis & Prevention, Volume 42, Issue 6, November 2010, Pages 1989-1998.

[16]  *Sesztakov, et. al. (2011)*: The analysis of age distribution of victims in Hungarian road accidents [in Hungarian: A közúti közlekedési balesetek korfájának elemzése], Roadsafety – Offical Journal of Hungarian National Transport Authority [in Hungarian: Közlekedésbiztonság - A Nemzeti Közlekedési Hatóság Szakmai Lapja] Vol. 1 No. 5 p42-46.

[17]  *Theeuwes, Godthelp (1995):* A. Generic method and technique Phase 4: Implementation: Road design: Self-explaining roads, Safety Science, 19(2-3), p217-225.

[18]  *Torgerson, (1952).*: Multidimensional scaling: I. Theory and method. Psychometrika, 17, p401-419.

[19]  Török, Berta (2009): Layout effect of roadway on road vehicle speeds, Pollack Periodica: An International Journal For Engineering And Information Sciences 2009/4 p115-120.

[20]  *Török, Prentkovskis:* Road safety in Hungary and Lithuania: Investigation of seasonal transport demand, TRANSBALTICA 2011. Vilnius, Lithuania, 2011.05.05-2011.05.06., p232-235.

[21]  *Vesper, Taneerananon, Kanitpong, Iamtrakul, Brannolte, Koren,* (2010): Approach of a methodology for road design guideline implementation in thailand based on international technology and knowledge transfer, Journal of Society for Transportation and Traffic Studies Vol. 1 No. 3, p54-67.