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Statistical Analysis of a Multi-Criteria Assessment of Intelligent Traffic Systems for the Improvement of Road Safety

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Abstract The aim of the paper is to investigate classify and investigate intelligent transport system (ITS) groups based on their potential to improve road safety. As the first step of the investigation an opinion survey combined with multi-criteria analysis of road safety experts has been carried out. In the second phase of the research, based on the results of the expert evaluation a cluster analysis has been provided to order ITS applications into clusters. Finally, based on the results of the two phase method the paper defines the effective ITS applications from a road safety point of view.

Keywords: *road accident, intelligent transport system (ITS), statistical analysis, analysis, traffic accident, traffic safety, transport*

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1. Introduction

The aim of the paper is to introduece the most relevant results of the research (Á. Török, G. Pauer, 2016) focusing on intelligent transport systems application possibilities in the field of road safety. Beginning with the middle 2000’s, road accident indices are characterized by a permanent improvement. However, in the last two years, this favorable tendency of the decreasing number of injured and dead in road accidents has stopped.

Creating further improvement of road safety is an aim required in the EU documents, in addition, reduction of the material losses due to the damages [15] is of a stressed significance, however, the measures and interventions resulting in decrease of accident numbers have limited safety improving potential. In light of the above, the innovative IT solutions for the improvement of safety have become more important today. The new, intelligent methods assist in improvement of the road safety circumstances primarily by the avoidance of accidents or the significant reduction of their seriousness. Accordingly, the road safety is a stressed part of the ITS Action Plan developed by the EU Committee.

Aim of our study – by a statistical analysis of a multi-criteria expert assessment of intelligent traffic systems for the improvement of road safety – is to identify the target areas where the intelligent traffic systems can play a significant role in the future [18]. Assessment of the ITS solutions enables those tendencies of development to be assigned which have an outstanding effect from road safety, economic and strategic considerations.

2. Methodology

First step of the study was a classification of the intelligent traffic systems having road safety functions, taking the fundamental aims and characteristics of them into account. The paper classifies Intelligent Transportation Systems following the most important strategical, professional and scientific classification orientations [3,5,7,9,12,16,18,19] with the aim of realizing which group of ITS is the best to invest in. The below presented classification groups are based on the literature review carried by the author. This means according to the processed literature materials the groups mentioned in this chapter cover ITS systems framework considering the whole functional space.

The first identified ITS group is that of the intervention systems depending on the driver’s condition. All control and intervention systems belong to this group, which could provide an opportunity to control, prevent and/or log into a central data base every driving attempts made in an influenced or exhausted condition. As a further function, the shadowing of the drivers with an infringement record and their “follow-up”, as well as enabling the analytic assessment of the drivers’ attitude affecting the compliance behaviour with respect to the “influenced” driving [3].

The following separate group of systems is that of the systems assisting in compliance to the Highway Code rules, including the velocity control and affecting systems and devices helping the detection of traffic control signs important with respect to road safety. Elements of this group of systems include both the monitoring systems outside the vehicle, and those inside it and occasionally blocking the infringing action. Data we collected provide opportunity to filter out and shadow the road users presenting a protection risk, to carry out the analytical assessment of the drivers' attitude affecting the compliance willingness and profile characteristics, as well as to explore the reasons related to the increases in the territorial frequency of accidents [5].

Systems providing an individualized, real-time, continuous following and assisting the participant's traffic behaviour mean every supporting applications developed to smart devices used permanently by drivers and improved continuously and gaining higher and higher prevalence. Primary function of the ITS group of systems, improvement of the individual culture of transport can be achieved through the awareness-raising effect of the communal system. As a secondary function, the analytic assessment of the drivers' attitude affecting the compliance behaviour and the profile characteristics by methods of data mining can be mentioned [1].

Group of systems for forecasting the dangerous traffic situations include ITS solutions, which – by systems outside an inside the vehicles [9], as well as through smart devices used by the traffic participants – forecast the predictable conflicts. To perform this, they may use static geospatial road information and dynamic parameters, characteristics of the traffic participants' motions. The systems provide a real-time information affecting the road safety. What can be performed by data mining methods based on the number of forecasted conflicts are an identification of focal spots and the analytical assessment of the drivers' attitude, as well as the profile characteristics [16].

Systems assisting the rescue activities have also been studied as a separate ITS group of systems. Primary aim of these systems is the transfer of location and characteristics of the road accidents with a car participation to the officials. This improves the duration and efficiency of the rescue, thereby contributes to the reduction of toll number and relieving the injury outcomes. The group of systems also include the solutions providing a road safety and protective functions of the vehicles on roads open to the public (complex video-surveillance, data registering, following/alarming modules) [7].

The unified electronic driving licenses and registration system in the EU is listed among the intelligent traffic systems. The control system to be formed by using the database can partly be used to assist in controlling the road drivers by the police and it is also useful for improving the opportunities of imposing sanctions against the drivers of foreign nationality. In the long run, automation of the real time processes of verification, authorization and identification related to the use of the traffic system can also be implemented by means of that control system. The system is extremely suitable for filtering out traffic participants presenting a protection risk, as well as for their following.

The next group in the ITS system is represented by the traffic control systems. Primary goal of these systems is to realize the local/systemic traffic control that depends on the traffic, taking into account the impacts of the traffic characteristics to the road safety. By recording the traffic data, an estimation of the "from where – to where" matrices becomes possible; in special circumstances the system is also suitable to follow the traffic participants presenting a risk to protection.

The group of systems for generation of road safety characteristics of the traffic infrastructure consists of GIS-based ITS systems providing assessments and analyses repeated periodically or performed continuously. Its primary function is to qualify the traffic network from the road safety aspect, as well as doing the tasks related to the safe infrastructure management processes. As a secondary function, the following can be mentioned: study of the relations between the infrastructural features and the accident data; formation of the accident evaluation model; as well as identification of places where the accidents become more frequent based on application of a territorial auto-correlation model.

Elements of the next separate group of systems are the in-vehicle active road safety systems. Solutions belonging to this category are the systems assisting the driving actions with an enhanced road safety significance. At present, majority of them operates autonomously, however, a strategic goal is to bring about their operation in network and spreading systems providing for the whole processes associated with the vehicle movements.

Last of the categories studied are represented by monitoring systems within the vehicle with obligatory use, assisting the road safety. At present, main work of these systems is control of the professional drivers and supply of feedback; this may be supplemented by systems monitoring the inexperienced drivers or those with a "record". Aim of the ITS solutions can be defined as a comprehensive implementation of a system, which is suitable for the central logging of the driving activity, for realization of an automatic control, for the permanent control of driving styles of the involved driver groups and for providing feedback on the typical issues. In addition, the system can function as an accident black box as well [18].

To perform the examination, the methodology of the mult-criteria analyses were applied [10]. System of assessment criteria to the system groups was generated by the involvement of 6 experts. Members of the group were experts of various areas (road safety, transport economy, system planning). The experts specified the aspects that were of enhanced significance upon the road safety assessment. Upon weighing, the impact on safety, the number of the involved participants and the implementation expenses were indicated by the experts. Though with a lower weight, they also considered the facts that study of the safety system characteristics is closely related to the examination of their role in security, in concordance with the modern international system development trends and the development goals of the European Union, furthermore, the introduction may meet with difficulties due to the data protection risks inherent in the particular provisions.

Aspects, evaluation scales and weights of the analysis are summarized in Table 1. Forming the evaluation scales was carried out in a way that the preferred value is the higher score in each case. Weights of the aspects were generated based on the average of the expert weights, their values were applied to determination of the measurement scale of the KIPA method.

Table 1. Characteristics of the assessment criteria system

Assessment criteria	Assessment scale	Weight of criteria
Implementation expenses	1: very high- 10: very low	0.246
Number of involved traffic participants	1: very few- 10: all participants	0.25
Effect on road safety	1: no effect- 10: significantly improves safety	0.304
Protective effect	1: none- 10: very high	0.075
Social/legal factors presenting difficulties	1: significant obstacles to be released- 10: none	0.125

3. Analysis

As a first step to the road safety evaluation of ITS system groups, experts assessed the described categories according to the determined criteria and scale [16]. When performing the analysis we worked with the average scores summarized in Table 2.. Results of the evaluation provided basis for the fundamental Table of the KIPA analysis and preparation of the cluster analysis.

Table 2. Average of the expert assessments to the ITS system groups

	Implementation expenses	Number of involved traffic participants	Effect on road safety	Protective effect	Social/legal hindering factors
1. Intervention Systems Influenced by the Condition of the Driver	5.33	4.83	5.83	2.50	5.67
2. Systems Assisting to Keep the Highway Code	4.67	8.33	7.33	4.33	7.83
3. Individualized, real-time, continuous following and evaluating the participant's traffic behaviour	4.67	7.00	3.83	7.33	4.67
4. Forecast of dangerous traffic situations	5.33	7.00	6.00	3.50	6.83
5. Systems assisting the rescue activities	4.50	5.00	7.33	3.83	8.00
6. Unified electronic driving licenses and registration system in the EU	5.67	9.50	3.83	7.83	4.67
7. Traffic control systems	3.83	6.33	4.83	2.33	6.00
8. Generating road safety characteristics of the road infrastructure	6.17	3.83	5.17	1.50	9.00
9. Active in-vehicle road safety systems	7.00	8.00	8.00	5.50	8.50
10. In-vehicle monitoring systems assisting the road safety and to be used compulsorily	5.00	3.83	4.67	4.67	6.67

In order to study the appropriateness of analyses based on average expert opinion values, we examined relative dispersion values of the average scores and weights related to the ITS system groups and the study aspects, these are summarized in Table 3 and Table 4.

Table 3. Relative dispersions of weight numbers given to the assessment criteria

Assessment criteria	**Implementation expenses**	**Number of involved traffic participants**	**Effect on road safety**	**Protective effect**	**Social/legal hindering factors**
Relative dispersion	0.208	0.179	0.081	0.211	0.379

Table 4. Relative dispersion of the average scores given to the ITS system groups

ITS system group	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Relative dispersion	0.247	0.089	0.251	0.247	0.176	0.136	0.237	0.227	0.251	0.172

In some cases, relative dispersions had values higher than the expected number of 0.2, demonstrating the heterogeneous structure of the scoring system, however, no extreme values were observed, so we accepted the dispersions in our primary studies and considered the sample well characterized by the average values.

The KIPA procedure is suitable for comparison of complex systems, by using it we will be able to rank the determined 10 ITS system groups supporting road safety, by considering all the studied aspects, thereby we will be able to identify the types of provisions application of which the most advantageous effects can be reached [8]. Characterization of the alternatives takes place on scales formed based on the assessment criteria, based on the principle of even comparison [4]. Basis for the qualification of the alternatives according to the scale formed is the average of the expert scores. Main steps of the procedure are as follows:

1. designing the measurement scales of the assessment factors (by considering the weights);
2. preparation of the basic table of the KIPA method (by projecting the expert qualifications of the alternatives to the scale described previously);
3. preparation of the KIPA matrix (comparison in pairs);
4. specifying limit values of preference and disqualificance;
5. drawing an assorting graph;
6. determination of the preference order.

The scales of measurement can be formed based on weight factors of the assessment criteria. When preparing the scales, a value of 50 was assigned to the score 5 in each case. Increments of the scale corresponding to the aspect with the lowest weight factor are size 1, and increments for scales of the other criteria increased according to the weigh factor differences. Values of the measurement scales assigned to the integer scores are shown in Table 5.

Table 5. Measurement scales for the assessment factors of the KIPA analysis

		Assessment criteria and their weight				
		Implementation expenses	Number of involved traffic participants	Effect on road safety	Protective effect	Social/legal hindering factors
		0.246	0.25	0.304	0.075	0.125
Scores	**10**	66.4	66.67	70.27	55	58.33
	9	63.12	63.33	66.21	54	56.67
	8	59.84	60	62.16	53	55
	7	56.56	56.67	58.11	52	53.33
	6	53.28	53.33	54.05	51	51.67
	5	50	50	50	50	50
	4	46.72	46.67	45.95	49	48.33
	3	43.44	43.33	41.89	48	46.67
	2	40.16	40	37.84	47	45
	1	36.88	36.67	33.79	46	43.33

Basic table of KIPA can be prepared based on the expert score averages described in Table 2, by using the measurement scale. Values assigned to the non-integer scores have been calculated by means of interpolation, by using interpolation based on values assigned to the integer scores. Values of the basic table were summarized in Table 6.

Table 6. Basic Table of the KIPA analysis

		Assessment criteria and their weight (%)				
		Implementation expenses	Number of involved traffic participants	Effect on road safety	Protective effect	Social/legal hindering factors
		24.6	*25*	*30.4*	*7.5*	*12.5*
ITS system groups	**1.**	51.09	49.44	53.38	47.50	51.11
	2.	48.91	61.11	59.46	49.33	54.72
	3.	48.91	56.67	45.27	52.33	49.44
	4.	51.09	56.67	54.05	48.50	53.06
	5.	48.36	50.00	59.46	48.83	55.00
	6.	52.19	65.00	45.27	52.83	49.44
	7.	46.17	54.44	49.32	47.33	51.67
	8.	53.83	46.11	50.68	46.50	56.67
	9.	56.56	60.00	62.16	50.50	55.83
	10.	50.00	46.11	48.65	49.67	52.78

In order to generate the KIPA matrix the first steps were calculation of the c_{ij} preferency (preference) and d_{ij} disqualificancy (disadvantage), based on comparisons in pairs.

The preference index provides information on the advantage of the *i*th alternative compared to the *j*th one; this index was calculated for each respect. Its value arises by summarizing those assessment criteria (in per cent) for which the particular ITS system group is preferred or neutral (its assigned value in the basic table is greater than or equals the value of the counterpart) over against the compared alternative.

The disadvantage indices were also calculated for each *ij* relations, however, to their determination only that assessment aspect was taken into account, for which the preference intensity is the highest. Thus, in the fist step of generating value of the disadvantage indices the assessment aspect is selected which meets the following two criteria:

- according to the particular aspect, value assigned to the *j*th alternative is higher the the one assigned to the *i*th element.
- absolute value of the difference between the values assigned to the *i*th and *j*th alternatives.

Absolute value of the difference of the numbers according to the aspects selected this way is the maximum scale difference wherein the studied alternative *i* is disadvantageous compared to alternative *j*. To calculate the disqualificancy indices, his value is divided by the volume of the maximum scale (in the present case this is the scale according to the road safety impact), then the result is multiplied by 100 to obtain the per cent form.

The KIPA matrix can be generated by the use of the preferency and disqualificancy indices (Figure 1). First row and column of the matrix contains numbers of the alternatives (i.e. numbers of the studied ITS system groups); in the top of the cell formed by the intersection of row *i* and column *j* (in bold italics) the c_{ij} advantage index, and in the bottom part (in italics) the d_{ij} disadvantage index is shown.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.		***24,6***	***67,5***	***24,6***	***24,6***	***42,9***	***62,5***	***62,9***	***0,0***	***80,0***
		32,0	*19,8*	*19,8*	*16,7*	*42,6*	*13,7*	*15,2*	*28,9*	*5,9*
2.	***75,4***		***92,5***	***75,4***	***87,5***	***42,9***	***100,0***	***62,9***	***25,0***	***67,9***
	6,0		*8,2*	*6,0*	*0,8*	*10,7*	*0,0*	*13,5*	*21,0*	*3,0*
3.	***32,5***	***32,1***		***32,5***	***57,1***	***42,9***	***57,1***	***32,5***	***7,5***	***32,5***
	22,2	*38,9*		*24,1*	*38,9*	*22,8*	*11,1*	*19,8*	*46,3*	*9,3*
4.	***100,0***	***24,6***	***92,5***		***49,6***	***42,9***	***100,0***	***62,9***	***0,0***	***92,5***
	0,0	*14,8*	*10,5*		*14,8*	*22,8*	*0,0*	*9,9*	*22,2*	*3,2*
5.	***75,4***	***42,9***	***42,9***	***50,4***		***42,9***	***75,0***	***62,9***	***0,0***	***67,9***
	7,5	*30,5*	*18,3*	*18,3*		*41,1*	*12,2*	*15,0*	*27,4*	*4,5*
6.	***57,1***	***57,1***	***100,0***	***57,1***	***57,1***		***57,1***	***32,5***	***32,5***	***57,1***
	22,2	*38,9*	*0,0*	*24,1*	*38,9*		*11,1*	*19,8*	*46,3*	*9,3*
7.	***37,5***	***0,0***	***42,9***	***0,0***	***25,0***	***42,9***		***32,5***	***0,0***	***55,4***
	13,5	*27,8*	*13,7*	*13,5*	*27,8*	*28,9*		*21,0*	*35,2*	*10,5*
8.	***37,1***	***37,1***	***67,5***	***37,1***	***37,1***	***67,5***	***67,5***		***12,5***	***92,5***
	9,1	*41,1*	*28,9*	*28,9*	*24,1*	*51,8*	*22,8*		*38,1*	*8,7*
9.	***100,0***	***75,0***	***92,5***	***100,0***	***100,0***	***67,5***	***100,0***	***87,5***		***100,0***
	0,0	*3,0*	*5,0*	*0,0*	*0,0*	*13,7*	*0,0*	*2,3*		*0,0*
10.	***20,0***	***32,1***	***67,5***	***7,5***	***32,1***	***42,9***	***44,6***	***32,5***	***0,0***	
	13,0	*41,1*	*28,9*	*28,9*	*29,6*	*51,8*	*22,8*	*10,7*	*38,1*	

Figure 1. The KIPA matrix

Determination of the order of preference and ranking of the ITS system groups were performed based on the matrix data. The preferency threshold value was taken at a 60% level ($c_{ij} \geq 60\%$) and the disqualificancy threshold value at 30% level ($d_{ij} \leq 30\%$) into account, these limits were satisfied by altogether 34 pairwise comparisons. This made possible to draw the assortational graph (Figure 2); nodes of the graph were formed by the ITS groups studied, edges between the compared pairs of elements are directed, they start from the preferred alternative and point to the other element. The graph can be applied to the determination of the order f versions and the demonstration of the results (the alternative from which all arrows point "outwards" is the best, while the version towards which the highest number of arrows point is the worse).

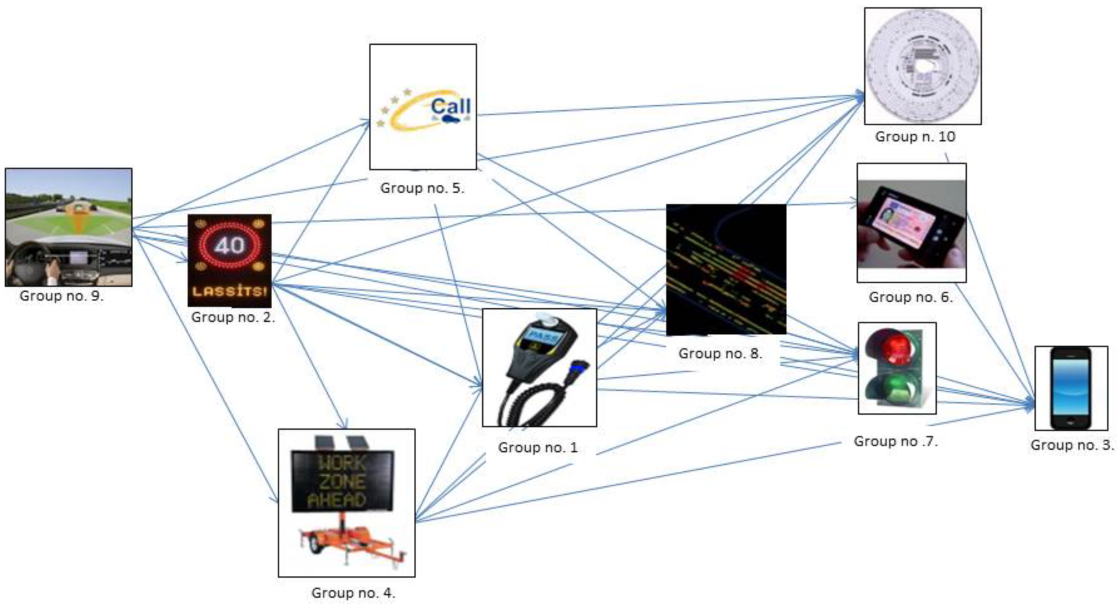

Figure 2. Assortational graph

Rank order of the alternatives became readable by the use of the assortational graph, order of the studied ITS system groups are summarized in Table 7. The order shows solutions for which their introduction, spreading and supporting is recommended the best.

Introduction of the in-vehicle active road safety systems (group 9) proved to be the most advantageous type of provision, edges setting out from which point to all the other groups. These ITS solutions significantly improve the road safety, they have relatively low expenses and present only few difficulties, and at the same time more and more traffic participants can be reached by them as technology develops. Also extremely good results were reached by the group of systems assisting the compliance to the Highway Code rules (Group 2), which is clearly preferred to all of the groups except Group 9 and 6. In addition to this, first part of the rank order contained the systems for prediction of the dangerous situations (Group 4), the systems assisting the rescue activities (Group 5) and the intervention systems depending on the drivers' condition (Group 1). The worst result was shown by the real-time, personalized continuous following of the road behaviour, supplying recommendation and assistance (Group 3); the reason for this is that only a moderate improvement can be expected in its effect on the road safety which was taken with the highest weight into account, moreover, its implementation could involve significant social/legal difficulties, as the related information comprises highly sensitive personal data. Group 7, i.e. the traffic control systems are also not preferred to any other groups of system, primary function of them is not providing for road safety or protection, and their implementation costs showed disadvantageous scores, too. In addition to these, second part of the order of preference consists of the systems generating the road safety characteristics of the infrastructure (Group 8, preferred to Groups 3, 10 and 7), the unified system of EU drivers' licenses and registration (Group 6, preferred only to Group 3), and the monitoring systems to be compulsorily used inside the vehicle (Group 10, also preferred only to Group 3).

Table 7. Order of preference of the studied ITS system groups

Preference order	Number and designation of the ITS system group	Edges starting from a node [pcs]	Edges arriving to a node [pcs]
1.	9. Active in-vehicle road safety systems	9	0
2.	2. Systems Assisting to Keep the Highway Code	7	1
3.	4. Forecast of dangerous traffic situations	5	2
4.	5. Systems assisting the rescue activities	4	2
5.	1. Intervention Systems Influenced by the Condition of the Driver	4	4
6.	8. Generating road safety characteristics of the road infrastructure	3	5
7.	6. Unified electronic driving licenses and registration system in the EU	1	1
8.	10. In-vehicle monitoring systems assisting the road safety and to be used compulsorily	1	6
9.	7. Traffic control systems	0	6
10.	3. Individualized real-time continuous following and assisting of the participant's traffic behaviour	0	7

In relation to the 10 ITS system groups formed based on the ITS solutions improving the road safety we performed a cluster analysis. Clustering is a group-forming procedure which – with taking several aspects into account – the similar elements are classified into the same group and the elements differing from each other to other, differing groups. Aim of the analysis was in part supporting results of the KIPA procedure expressly providing an order of preference, and in part identification of groups suitable for granting and consisting of advantageous measures; this can help decision-makers in the formation of provision packages [17].

Due to the high number of aspects to be taken into account, formation of groups is not an unambiguous task and various methods, based on different distance or similarity measures, can be applied to perform the procedure. An ideal clustering algorithm does not exist, as there is no objective measure to the comparison of results [2], which algorithm is practical to choose depends on the character of each application [13].

In our study, to the cluster analysis we applied the Ward method listed among the hierarchical procedures, regarding that this procedure is very widespread in the economical applications, it can be well interpreted from practical aspects, too, and it results in groups roughly the same size [11]. The method is based on a merger, i.e. initially it regards each element a separate cluster and connects them to form increasingly larger groups. For the Ward procedure, the average (or the sum of the squared variances from the average) is calculated for the points inside the cluster and that point or cluster is included in the formation of the larger cluster, for which the inclusion would bring about the higher increase in the sum of squared variances. This method is thus applicable to our study well, as the ITS system groups forming the database are characterized by the average of points given in the expert-performed classification (1-10 scale), thus these numerical distances can be applied to measure similarity of the elements, the initial variables are not correlated and there are no exceling data.

Cluster analysis was performed by means of the IBM SPSS Statistics program. Upon the procedure, the program classified the specified 10 elements into 2 to 4 clusters, of which groups with the most homogeneous number of elements were formed for the version with 3 clusters. Individual clusters comprised the following ITS system groups:

1. Cluster: ITS system groups Nos 1, 7, 8 and 10
2. Cluster: ITS system groups Nos 2, 4, 5 and 9
3. Cluster: ITS system groups Nos 3 and 6

Values to the index numbers of the generated clusters were summarized in Table 8.

Table 8. Index numbers of the ward procedure generating the 3 clusters

	Cluster 1			Cluster 2			Cluster 3			All elements		
	Average	Number of elements	Dispersion	Average	Number of elements	Dispersion	Average	Number of elements	Dispersion	Average	Number of elements	Dispersion
Implementation expenses	5.08	4	0.97	5.38	4	1.14	5.17	2	0.71	5.22	10	0.91
Number of involved traffic participants	4.71	4	1.18	7.08	4	1.50	8.25	2	1.77	6.37	10	1.95
Effect on road safety	5.13	4	0.51	7.17	4	0.84	3.83	2	0.00	5.68	10	1.48
Protective effect	2.75	4	1.35	4.29	4	0.88	7.58	2	0.35	4.33	10	2.08
Social/legal hindering factors	6.84	4	1.50	7.79	4	0.70	4.67	2	0.00	6.78	10	1.54

Each cluster can be assessed based on the averages according to the various variables and by using their differences from the averages relative to all the elements. The lowest differences were seen at the scores related to the implementation expenses; more significant differences were found among the other 4 aspects, therefore they also had a higher role in the group formation. Steps of the clustering method are demonstrated in Figure 3.

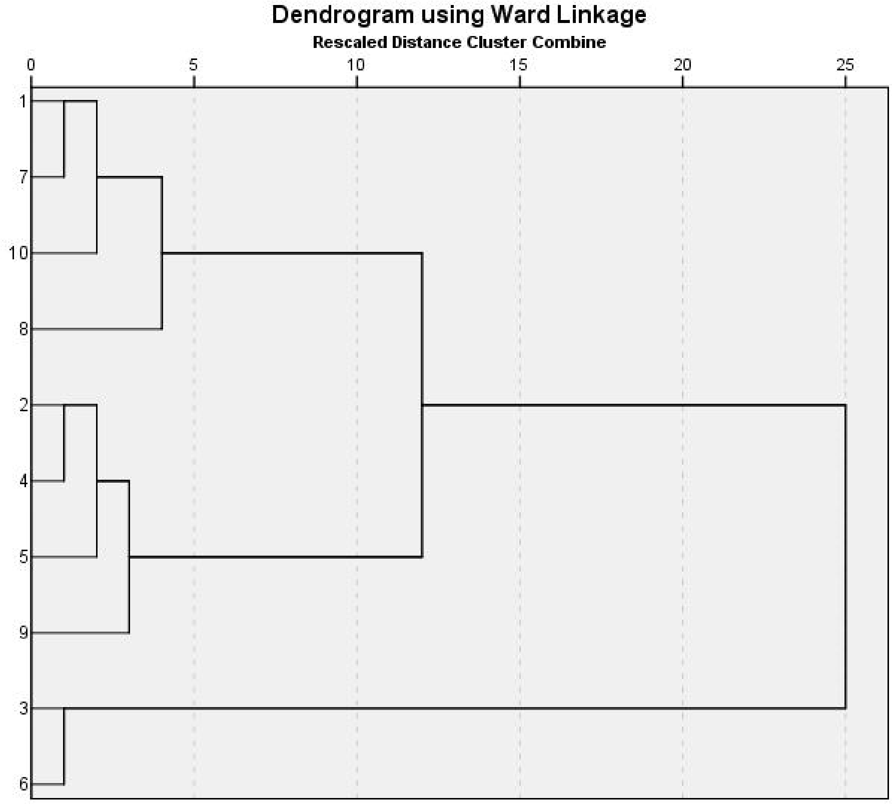

Figure 3. Dendogram of the cluster analysis [1. Intervention Systems Influenced by the Condition of the Driver, 2. Systems Assisting to Keep the Highway Code, 3. Individualized real-time continuous following and assisting of the participant's traffic behaviour, 4. Forecast of dangerous traffic situations, 5. Systems assisting the rescue activities, 6. Unified electronic driving licenses and registration system in the EU, 7. Traffic control systems, 8. Generating road safety characteristics of the road infrastructure, 9. Active in-vehicle road safety systems, 10. In-vehicle monitoring systems assisting the road safety and to be used compulsorily]

The cluster-average-based assessment of the groups formed is summarized in Table9 (the + and - signs symbolize the direction and magnitude of deviations from the average of all elements).

Table 9. Characterization of the clusters in comparison to the average of all elements

	Cluster 1	Cluster 2	Cluster 3
Implementation expenses	- slightly higher	+slightly lower	- slightly higher
Number of involved traffic participants	----much less	++ more	+++ many more
Effect on road safety	-- lower	+++ much higher	--- much lower
Protective effect	--- much lower	- slightly lower	+++ much higher
Social/legal hindering factors	+ slightly less	++ less	--- many more

Based on the assessment of the above Table, **Cluster 1** – according to the expert scores – comprises the ITS system groups that reached **“lower”** scores in almost all aspects. Cluster elements:

- 1. Intervention Systems Influenced by the Condition of the Driver
- 7. Traffic control systems
- 8. Generating road safety characteristics of the road infrastructure
- 10. In-vehicle monitoring systems assisting the road safety and to be used compulsorily

Characteristics of the group demonstrate that introduction of these types of measures results in the least advantageous effect. The least number of traffic participants can be reached by them and the road safety and preventive effects to be realized by their use is also well below average. Expenses of their implementation is somewhat higher compared with all measures and their risk is somewhat below average with respect of the social/legal difficulties they present. Primary goal of the traffic control systems is not an improvement of road safety while most intervention systems depending on the drivers’ condition (e.g. alcolock) or the compulsory monitoring units (e.g. tachograph) only concerns a small group of drivers. Generation of the road safety characteristics contributes only to indirectly to the enhancement of road safety and it has no preventive functions at all.

Based on the features characteristic to **cluster 2** elements of the group are the ITS system groups **“extremely good”** from the most aspects. Measures in the cluster:

- 2. Systems assisting to keep the Highway Code rules – the velocity control and affecting systems and devices helping the detection of traffic control signs important for road safety.
- 4. Forecast of dangerous traffic situations
- 5. Systems assisting the rescue activities
- 9. Active in-vehicle road safety systems

Implementation of the above types of measures is extremely advantageous and exactly these types of measures constituted the first part of the order of precedence. They result much higher than average improvement in road safety, while the stratum of involved traffic participants is very wide, too. Social/legal difficulties of their introduction is lower than the average and their implementation expenses are advantageous. A slightly lower than average value is only observed in their protective functions. Active systems promoting the compliance with the regulations and those in the vehicle, as well as prediction of the dangerous situations are able to reach most of the traffic participants and probability of the accidents can be successfully reduced by the use of them. Systems assisting the rescue activities reduce the consequences of the happened accidents.

Cluster 3 has **“mixed”** characteristics, from some aspects it is more advantageous and from other ones it is more disadvantageous compared to the average of all the groups. Elements:

- 3. Individualized, real-time, continuous following and assisting of the participant’s traffic behaviour
- 6. Unified electronic driving licenses and registration system in the EU

Elements of the cluster are ITS solutions that affect many traffic participants and have preventive function instead, their effect on road safety is lower than average and risks of difficulties related to their introduction is more significant. Introduction of the electronic driving license affects practically all drivers and the real-time, continuous tracking and assisting is possible through the application of smart devices already used by the majority of people Although these types of provisions are moderately suitable for an increase of the road safety, preventive functions of the unified electronic registration and the continuous following are very significant. At the same time, considerable social and legal difficulties arise upon implementation.

4. Summary

The studies performed help the assessment and ranking of the ITS solutions related to road safety and help in identification of the types of provisions suitable for support.

Results of the KIPA analysis and the cluster analysis pointed to the same direction supporting the conclusion that taking all the specified study criteria into account the most advantageous effect was exerted by elements of Cluster 2 from road safety, economic and strategic aspects. Thus, based on the expert opinions, an extensive introduction and support of the in-vehicle active road safety systems, systems helping the compliance to the Highway Code rules, systems for prediction of the dangerous traffic situations, as well as systems assisting the rescue activities are recommended.

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