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Traffic Engineering
Original Scientific Paper
Submitted: Apr. 1, 2014
Approved: Feb. 3, 2015

STANDARDIZATION OF ROAD DANGER SIGNS IN THE EUROPEAN UNION

ABSTRACT

The aim of this research is to find a solution for the standardization of road signs in the EU zone by a comparative analysis of different national sign systems to establish a common set from a single country. This work is based on the idea that road sign standardization might increase the safety level of transnational journeys and foster the relationships among the various members of the EU Community. This paper presents the outcome of the first step of the research, which focuses on the harmonization of danger signs. In more detail, a multicriteria approach is applied to rank 19 EU Member States on the basis of three main aspects: the installation cost of new signs, new sign learning issues and the effectiveness of sign systems. The study allows for the installation cost by quantifying the degree of similarity among road sign systems and the roadway network extension, on which new signs should be placed.

KEY WORDS

road signs; multicriteria analysis; graphical analysis; visual perception;

1. INTRODUCTION AND BACKGROUND

Road signs were initially introduced as written messages placed on metal structures and situated on the road side to provide information to road users. Due to the increase in vehicle speed, it was preferred to use pictorial signs rather than words to standardize road signs and favour travels.

Every country developed its own road sign system, taking into account the existing ones used in other nations. Nowadays, the process of the European unification has not yet included the road signs. The ambitious project of Trans European Road Network (TERN) lies on a complex integration of national transport networks, characterized by discontinuity of regulations and signalling systems.

Hence, a policy of sign harmonization could promote mobility within the EU zone as a contribution to its political unity in the long term. Regarding road safety, the statistics on transport in the EU-28 shows that in 2012 road accidents caused more than 28,000 deaths and 1,484,000 injuries [1]. So, the improvement of road safety is the central goal of the European transport policy and refers to road users, freights and dangerous goods [2].

Our study is fully in line with this guideline, since it rests on the idea that strong harmonization of road signs is the basis for the improvement of road traffic safety. Some studies on the topic [3, 4, 5] have concluded that 5,000 lives a year could be saved with further updates of the Vienna Convention including the rules for harmonizing the road signs and road markings in terms of contents, type and size of the font.

Other works [6, 7, 8, 9, 10] have shown that an improvement in the safety of road infrastructures including road signs produces a reduction in the number and severity of accidents.

Based on literature about the visual perception of road signs by drivers [11, 12], further analysis on the TERN network has been carried out within a study of the European Commission under the 6th Framework Programme [13], which emphasizes the need for the European guidelines to support the design of road sign pictograms. It aims at reducing the misunderstandings and facilitating the interpretation of signs, so as to obtain the so called "self explaining roads".

Another important European work highlights the actions to be taken to facilitate the detection of traffic signs, with particular regard to the adoption of high reflecting films on the surround of signs [7]. In the end, other studies suggest criteria for the evaluation and design of symbols and pictograms [11;,14, 15, 16, 17 18]. The present study addresses the issue of standardizing traffic signs across the EU road network, considering only the danger signs in this first phase. The method used to compare the graphic characteristics of the signs is inspired by the real perception of images, which is a multi-stage process taking into account several aspects, such as colour, form, border, background, etc. [19, 20, 21, 22, 23].

2. IDENTIFYING A COMMON SYSTEM OF DANGER ROAD SIGNS FOR THE EUROPEAN UNION

In order to identify the set of danger signs for the EU area, nineteen EU member states have been compared (the necessary data for the remaining eight member nations were not available). To find the best solution, a multi-criteria approach has been applied allowing for three main issues [19]: the installation cost of new road signs in different contexts, the necessity for road users to become familiar with the new signs, and the level of accident occurrence in each country.

Throughout the paper, the criteria are presented of the analysis used to consider the above issues, the indicators chosen to measure the performance in relation to these criteria and also the method to select a system of danger road signs for the EU zone.

2.1 Evaluation criteria for the comparison of European danger road signs

The national road sign systems have been compared, taking the danger sign set of every country in turn as a reference system (group leader) for the study area. The comparison of each reference sign set with the ones of other Nations has been based on four evaluation criteria: how similar the road sign system of each country is to the system chosen as reference, which affects the substitution cost; the extension of the roadway network on which the reference road sign system is located, which affects the installation cost of new road signs in other countries; the amount of travellers that should make an effort to become familiar with the new traffic signs; the level of accident occurrence.

In order to evaluate the performance of the considered European countries with respect to the above criteria, the following indicators have been used:

- The number of signs, that due to the similarity with those of the reference country (group leader), would be maintained on the roadway network of other European countries. The higher the value of this parameter, the lesser the number of panels to be substituted, thus reducing the installation cost. A more accurate estimate of the number of signs that should be changed would be possible if data on the density of road signs by category and road type were available for each European country.
- The extension of the roadway network in km of the reference country. The higher the value, the lesser the length of the roadway network on which the sign posts of the reference country will have to be placed.
- The road users of the reference country travelling by car, bus or motor vehicles (passenger-km). The maximization of this indicator could reduce the difficulties for the European road users to become familiar with the new road signs.
- The total number of accidents per km in the reference country, correlated to the degree of road sign effectiveness. Recent studies [24, 25] have showed that an improvement in the road sign identification and comprehension guarantees a non-negligible reduction in accident occurrence, which is also influenced by many other elements.

The last three indices are based on socio-economic data of the years 2006 and 2007; the first, instead, is based on information acquired between 2008 and 2009 on danger road signs of 19 EU Member States. Particularly, given the reference country, graphic representations of its danger road panels have been compared with those of the other states, in order to identify the signs that should not be replaced. The following section details the methodology followed to perform this analysis.

2.2 The methodology to estimate pictorial differences among danger road signs

As stated above, different European danger road sign systems have been compared in order to identify a European model conjugating various interests, one of them being the traffic sign substitution expenditure. This has been considered by using two evaluation criteria: the similarity degree of a specific road sign system compared to the others and the roadway network extension on which panels are placed. The evaluation

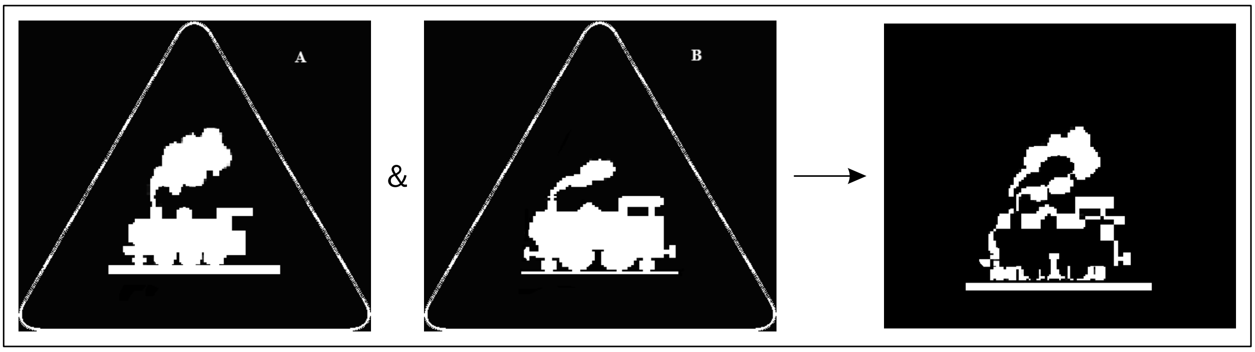

Figure 1 – Example of determination of the DS parameter

of the EU countries performance, with respect to the first criterion, has been carried out through an original methodology. This can establish whether a given road sign is similar to another by means of a model simulating the human perception of shape features. This model processes graphic parameters that quantify the similarity degree between two images in relation to different aspects. The methods to calculate these graphic parameters can be described as follows:

2.2.1 AR Parameter (area calculated in pixels)

This parameter is the absolute value of the difference between the area (in pixels) with a specific colour in figure i (A_i) and the area (in pixels) with the same colour in another figure j (A_j):

$$AR(i,j) = |A_i - A_j| \tag{1}$$

2.2.2 DS Parameter (Symmetric Difference)

This parameter determines the quantity of pixels that results from the difference between the union and the intersection of two compared figures that are superimposed maintaining their positions on a reference surface. It is a common procedure extensively used in the Set Theory, defined as Symmetric Difference. In *Figure 1*, an example is given that defines with A_{ds} (white image) the pixels deriving from the difference between the joining of figures A and B and their intersection.

The described parameter can be formulated as follows:

$$DS(i,j) = A_{ds} = XOR(img_i - img_j) \tag{2}$$

where XOR is the operator that performs the symmetric difference, while $img_{i(j)}$ is the matrix that represents image $i(j)$ in white on black background.

2.2.3 RET$_x$ and RET$_y$ Parameters (Rectangles)

These parameters determine the difference in dimensions between the rectangles that circumscribe the compared figures (see *Figure 2*), thus emphasizing if a given pictogram i has different length (y) and/or width (x) compared to another one j.

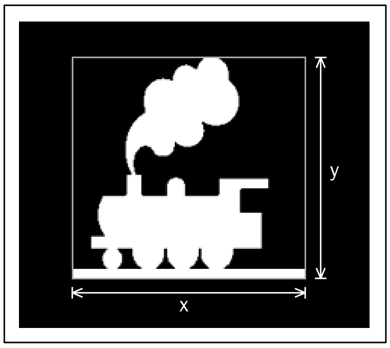

Figure 2 – The rectangle circumscribing an image

The formulas defining these parameters are the following:

$$RET_y(i,j) = |y_i - y_j| \tag{3}$$

$$RET_x(i,j) = |x_i - x_j|. \tag{4}$$

2.2.4 DIM$_v$ and DIM$_h$ Parameters (Difference in the mean number of colour changes occurring vertically/horizontally between two compared figures)

These parameters contribute to the evaluation of the difference between two figures using the colour change.

Colour change is when the analysis of a given image, pixel by pixel, along an intersecting straight line, registers a variation in colour (see Figures 3 and 4). If this occurs along lines parallel to the base of the reference frame, it is defined as horizontal colour change; on the contrary it is defined as vertical colour variation. In either case, it is necessary to calculate the difference in the mean number of colour changes between the considered pictograms. This difference, in the case of vertical variations, can be formulated as follows:

$$DIM_v(i,j) = |\overline{inv_{v,i}} - \overline{inv_{v,j}}|. \tag{5}$$

where:

$$\overline{inv_{v,i}} = \frac{\sum inv_{v,i}(y)}{\dim(I)}.$$

(mean number of changes per column) (6)

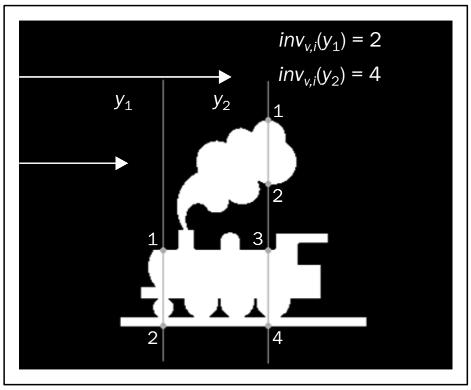

Figure 3 – Example of determination of $inv_{v,i}(y)$

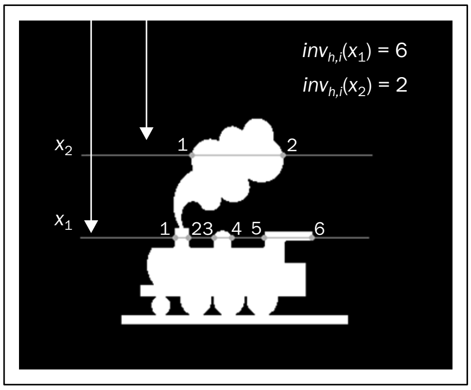

Figure 4 – Example of determination of $inv_{h,i}(x)$

with:

$I = \{y \in N: inv_{v,i}(y) > 0\}$.

(set of columns of pixels with a non-zero number of vertical variations for pictogram *i*) (7)

and $inv_{v,i}(y)$ is the number of vertical changes registered in column *y* of pictogram *i*.

In the case of horizontal variations, the difference between the two compared images can be expressed by the following parameter:

$$DIM_h(i,j) = |\overline{inv_{h,i}} - \overline{inv_{h,j}}|. \quad (8)$$

where:

$$\overline{inv_{h,i}} = \frac{\sum inv_{v,i}(x)}{\dim(I)}.$$

(mean number of changes per row) (9)

with:

$I = \{y \in N: inv_{h,i}(x) > 0\}$

(set of rows of pixels with a non-zero number of horizontal variations for pictogram *i*) (10)

and $inv_{h,i}(x)$ is the number of horizontal changes registered in row *x* of pictogram *i*.

2.2.5 Synthesizing the graphic difference measures

The results of the analysis have been represented by creating, for each type *k* of danger road sign, as many matrices ($\boldsymbol{AR^k}$, $\boldsymbol{DS^k}$, $\boldsymbol{RET_x^k}$, $\boldsymbol{RET_y^k}$, $\boldsymbol{DIM_h^k}$, $\boldsymbol{DIM_v^k}$) as the above parameters. The general entry m_{rs} is the value of the difference between road sign *k* of the country for row *r* and the corresponding sign of the country for column *s*.

For each pair of States and each sign type, the values of various parameters have been integrated through a linear combination, in order to have a synthetic measure of the difference among the road signs.

To obtain this result, a preliminary normalization of the indicators has been carried out:

$$AR_{rs}^k = \frac{AR_{rs}^k}{AR_{\max}^k};\ DS_{rs}^k = \frac{DS_{rs}^k}{DS_{\max}^k};\ RET_{rs}^k = \frac{RET_{rs}^k}{RET_{\max}^k};\ldots \quad (11)$$

The synthetic indicator of the difference among countries in relation to road sign *k* can be expressed, in matrix terms, as follows:

$$\boldsymbol{COMB^k} = a \cdot \boldsymbol{nAR^k} + b \cdot \boldsymbol{nDS^k} + c_x \cdot \boldsymbol{nRET_x^k} + c_y \cdot \boldsymbol{nRET_y^k} + d_h \cdot \boldsymbol{nDIM_h^k} + d_v \cdot \boldsymbol{nDIM_v^k} \quad (12)$$

The higher $\boldsymbol{COMB^k}$ (varying in the [0,1] interval) the greater the global pictorial difference between the type k signs of two countries.

As shown in Formula (12), each component of the synthetic index ($\boldsymbol{COMB^k}$), which is related to a specific aspect of the difference among sign pictograms, is given a weight (*a*, *b*, c_x, c_y, d_h, d_v).

To complete the model, it is necessary to define not only the weights of indicators, but also a discrimination threshold to establish whether the differences expressed by $\boldsymbol{COMB^k}$ are significant or not.

To estimate both the weights and the discrimination thresholds, we have searched for the values of these coefficients that maximise the ability of the simulation model to reproduce the similarity relations found within a sample of road signs by a sample of individuals [26, 27, 28, 29, 30, 31, 32].

To give an idea of the graphic comparisons between different national systems of danger road signs, *Table 1* displays, for each of the considered countries, the basic statistics describing how various graphic parameters change within the set of all the possible binary comparisons.

3. MULTICRITERIA ANALYSIS

To identify a reference danger road sign system among the 19 EU competitors, a multicriteria method was carried out employing the evaluation criteria described in Section 3.1 and the non-compensatory approach of the concordance/discordance analysis.

A multicriteria analysis has the following stages: choosing project options; defining evaluation criteria; choosing the indicators to assess the performance of the options in relation to each criterion; normalization of the performance indicators; choosing a set of weights for the criteria; ranking the options; sensitivity

Table 1 – Estimated values of the graphic parameters for the pedestrian crossing-danger sign and each country

	AR				*DS*				*RET$_x$*				*RET$_y$*				*DIM$_h$*				*DIM$_v$*			
Country	Aver-age	Min	Max	Dev. Std.	Aver-age	Min	Max	Dev. Std.	Aver-age	Min	Max	d	Aver-age	Min	Max	Dev. Std.	Aver-age	Min	Max	Dev. Std.	Aver-age	Min	Max	Dev. Std.
Austria	3.408	0.024	1.000	0.262	0.469	0.135	0.800	0.183	0.524	0.116	1.000	0.205	0.332	0.000	0.970	0.251	0.450	0.147	0.702	0.151	0.379	0.057	0.913	0.245
Belgium	0.451	0.021	0.955	0.253	0.504	0.153	0.840	0.185	0.171	0.015	0.500	0.165	0.361	0.030	1.000	0.253	0.290	0.105	0.519	0.124	0.268	0.057	0.705	0.164
Bulgaria	0.258	0.022	0.683	0.194	0.540	0.281	0.867	0.173	0.288	0.076	0.732	0.169	0.216	0.000	0.780	0.200	0.210	0.012	0.805	0.215	0.246	0.019	0.558	0.136
Finland	0.247	0.021	0.661	0.192	0.456	0.257	0.807	0.149	0.168	0.005	0.520	0.168	0.212	0.030	0.670	0.161	0.203	0.001	0.699	0.180	0.251	0.006	0.642	0.147
France	0.315	0.054	0.054	0.183	0.596	0.384	0.384	0.130	0.288	0.051	0.051	0.159	0.253	0.010	0.010	0.138	0.200	0.001	0.001	0.199	0.307	0.015	0.015	0.220
Germany	0.226	0.029	0.564	0.175	0.476	0.241	0.878	0.175	0.170	0.005	0.535	0.169	0.226	0.050	0.620	0.146	0.223	0.005	0.629	0.160	0.330	0.019	0.711	0.229
Greece	0.468	0.021	0.976	0.259	0.482	0.135	0.812	0.185	0.169	0.005	0.515	0.167	0.274	0.030	0.890	0.229	0.220	0.009	0.639	0.163	0.455	0.030	1.000	0.261
England	0.271	0.023	0.609	0.172	0.695	0.567	0.939	0.086	0.251	0.051	0.667	0.155	0.440	0.000	0.730	0.191	0.572	0.147	0.849	0.195	0.299	0.049	0.786	0.198
Italy	0.231	0.020	0.613	0.184	0.476	0.241	0.879	0.184	0.205	0.046	0.611	0.162	0.332	0.000	0.970	0.251	0.289	0.005	0.945	0.255	0.252	0.029	0.511	0.138
Latvia	0.229	0.009	0.523	0.170	0.477	0.224	0.871	0.180	0.171	0.005	0.540	0.169	0.216	0.000	0.780	0.200	0.200	0.001	0.755	0.199	0.316	0.015	0.691	0.225
Netherl.	0.239	0.021	0.640	0.189	0.463	0.241	0.884	0.188	0.175	0.010	0.551	0.167	0.256	0.030	0.860	0.220	0.294	0.005	0.951	0.256	0.300	0.000	0.662	0.213
Poland	0.565	0.019	1.000	0.254	0.861	0.786	1.000	0.058	0.532	0.076	1.000	0.204	0.695	0.270	1.000	0.213	0.715	0.151	1.000	0.215	0.427	0.030	0.970	0.258
Portugal	0.282	0.023	0.632	0.176	0.469	0.231	0.873	0.187	0.169	0.005	0.530	0.169	0.207	0.020	0.700	0.173	0.341	0.050	1.000	0.259	0.252	0.006	0.648	0.149
Czech Rep.	0.230	0.009	0.514	0.169	0.487	0.288	0.860	0.162	0.233	0.046	0.657	0.163	0.207	0.020	0.740	0.187	0.226	0.005	0.624	0.159	0.300	0.000	0.662	0.213
Romania	0.547	0.019	0.981	0.251	0.766	0.544	1.000	0.089	0.460	0.076	0.924	0.195	0.440	0.000	0.730	0.191	0.253	0.014	0.894	0.243	0.247	0.019	0.539	0.137
Slovakia	0.280	0.037	0.719	0.196	0.451	0.308	0.786	0.134	0.414	0.116	0.884	0.193	0.211	0.020	0.760	0.194	0.203	0.001	0.698	0.180	0.323	0.007	0.835	0.221
Slovenia	0.249	0.056	0.553	0.165	0.498	0.224	0.904	0.174	0.192	0.025	0.566	0.156	0.206	0.020	0.720	0.180	0.221	0.030	0.835	0.224	0.349	0.023	0.733	0.232
Spain	0.407	0.127	0.813	0.208	0.648	0.554	0.791	0.064	0.182	0.025	0.540	0.159	0.332	0.120	0.580	0.145	0.244	0.014	0.880	0.239	0.601	0.267	1.000	0.245
Sweden	0.228	0.020	0.593	0.181	0.522	0.291	0.793	0.108	0.205	0.025	0.591	0.154	0.258	0.010	0.540	0.138	0.206	0.012	0.792	0.211	0.328	0.007	0.842	0.224

analysis. The first three phases have been discussed in the previous paragraphs.

For every alternative (national system of danger signs), the impact measures regarding the different criteria have been normalized dividing each benefit indicator by its highest value (within the set of the alternatives) and subtracting to 1 the ratio of each cost indicator to its highest value.

The normalization allows the comparison among dimensionless impact measures ranging in the [0, 1] interval.

Concerning the choice of a weighting vector for the evaluation criteria, it should be emphasised that this vector should represent the attitudes of the political decision-makers; so, the lack of data in this respect have led the authors to use equal weights for the various criteria and perform a sensitivity analysis.

A classification of the "competing" danger sign systems has been created by means of concordance/discordance analysis that belongs to the ELECTRE (Elimination Et Choix Traduisant la Realité) multicriteria methods [33, 34, 35].

This is a non-compensatory technique which does not assume trade-offs between benefits and costs related to different objectives.

It is based on binary comparisons employing two indicators, the concordance and the discordance indices.

The first one (c_{pq}) quantifies the degree to which one project or option is preferred over another. It can be defined as:

$$c_{pq} = \sum_{m \in S_{pq}} w_m \tag{13}$$

where $S_{pq} = \{m: s_{mp} \geq s_{mq}\}$ is the set of criteria for which project *p* is better or not worse than *q*; s_{mp} (s_{mq}) is the normalized performance score of option *p* (*q*) in relation to criterion *m* and w_m is the weight of objective *m*.

It follows that the higher the weights w_m assigned to the criteria for which *p* is better (higher performance values) than *q*, the closer the c_{pq} index is to 1 and consequently the more option *p* dominates option *q*.

The c_{pq} values are represented by means of a $J \times J$ matrix, called concordance matrix, where *J* is the number of options.

The discordance index (d_{pq}) expresses the degree to which a project is dominated by another. It can be defined as:

$$d_{pq} = \max_{m \in I_{pq}} \left[w_m (s_{mq} - s_{mp}) \right] \tag{14}$$

where $I_{pq} = \{m: s_{mp} < s_{mq}\}$ is the set of criteria for which project *p* is worse than *q*; s_{mp} (s_{mq}) is the normalized performance score of option *p* (*q*) in relation to criterion *m* and w_m is the weight of objective *m*.

The d_{pq} values are in a $J \times J$ matrix, called discordance matrix, where *J* is the number of options. Information in the concordance and discordance matrices can be processed to obtain two classifications of the projects; one based on the net concordance dominance value (or concordance global index) and the other one based on the net discordance dominance value (or discordance global index). The former can be defined as:

$$c_p = \sum_{k=1}^{J} (c_{pk} - c_{kp}) \tag{15}$$

The latter can be formulated as follows:

$$d_p = \sum_{k=1}^{J} (d_{pk} - d_{kp}) \tag{16}$$

with *J* being the number of options.

The net concordance dominance value measures the difference between the extent to which plan *p* is better than other alternatives and the extent to which these are better than *p*.

Thus, a positive value of c_p is a good result; in addition, the higher c_p , the stronger the global preference for *p* and consequently the higher its position in the ranking.

The net discordance dominance value measures the difference between the extent to which plan *p* is worse than other options and the extent to which these are worse than *p*. So, a negative value of d_p is a good outcome; besides, the lower d_p , the higher its global merit. As stated previously, the danger sign set of every country is considered in turn a reference system (group leader) for the study area. For each set analysed, *Table 2* shows the normalized country performance values related to the various evaluation criteria, calculated applying, for each country, the normalization procedure to the corresponding indicators (see Section 3.1 for the explanation of these indices). *Table 3* provides the rankings of the compared European countries based on the net concordance and discordance dominance indicators.

In more detail, for each couple of countries, the concordance and discordance indices have been determined employing Formulas (13)-(14) and assuming equal weights for the evaluation criteria. Afterwards, the concordance and discordance global indices have been calculated for each country using Formulas (15)-(16); on the basis of the resulting two sets of country-specific scores, two lists of nations have been produced showing the country with the best global performance at the first position. From *Table 3* emerges that the concordance/discordance analysis leads to a classification where France is first, followed by Italy and Germany.

4. SENSITIVITY ANALYSIS

In order to study the role of each evaluation criterion, a sensitivity analysis has been performed on the weights. Specifically, the change of the first ranking

Table 2 – Evaluation matrix for the comparison among different European sets of danger road signs

Country	Evaluation criteria			
	Similarity between the signs of the reference nation and other countries	Mobility	Length of road network	Road accidents
Austria	0.85	0.09	0.10	0
Belgium	0.61	0.14	0.15	0.36
Bulgaria	0.77	0.05	0.02	0.61
Finland	0.45	0.08	0.08	0.81
France	0.51	0.83	1.00	0.78
Germany	0.83	1.00	0.63	0.29
Greece	0.96	0.12	0.11	0.72
England + Northern Ireland	0.35	0.79	0.41	0.50
Italy	1.00	0.88	0.47	0.44
Latvia	0.66	0.02	0.08	0.49
Netherlands	0.83	0.17	0.13	0.68
Poland	0.27	0.28	0.20	0.60
Portugal	0.68	0.09	0.07	0.16
Czech Republic	0.90	0.09	0.12	0.46
Romania	0.68	0.08	0.22	0.69
Slovakia	0.83	0.04	0.04	0.48
Slovenia	0.76	0.03	0.04	0.11
Spain	0.73	0.43	0.66	0.49
Sweden	0.44	0.12	0.41	0.66

Table 3 – Ranking of the European sets of hazard road signs based on the global concordance and discordance indices

Concordance global index		Discordance global index	
Nation	Value	Nation	Value
France	9.25	France	-2.59
Italy	9.25	Italy	-2.53
Germany	7.00	Germany	-2.40
Greece	6.75	Spain	-1.25
Netherlands	6.00	England + Northern Ireland	-0.76
Spain	5.75	Greece	-0.72
Romania	2.00	Netherlands	-0.39
England + Northern Ireland	1.5	Romania	-0.02
Czech Republic	0.75	Czech Republic	0.16
Sweden	0.50	Bulgaria	0.33
Poland	-0.75	Sweden	0.44
Austria	-3.00	Slovakia	0.49
Belgium	-3.25	Finland	0.52
Finland	-3.25	Latvia	0.92
Bulgaria	-4.75	Belgium	1.12
Slovakia	-6.25	Poland	1.25
Latvia	-7.75	Portugal	1.76
Portugal	-8.50	Slovenia	1.83
Slovenia	-11.25	Austria	1.83

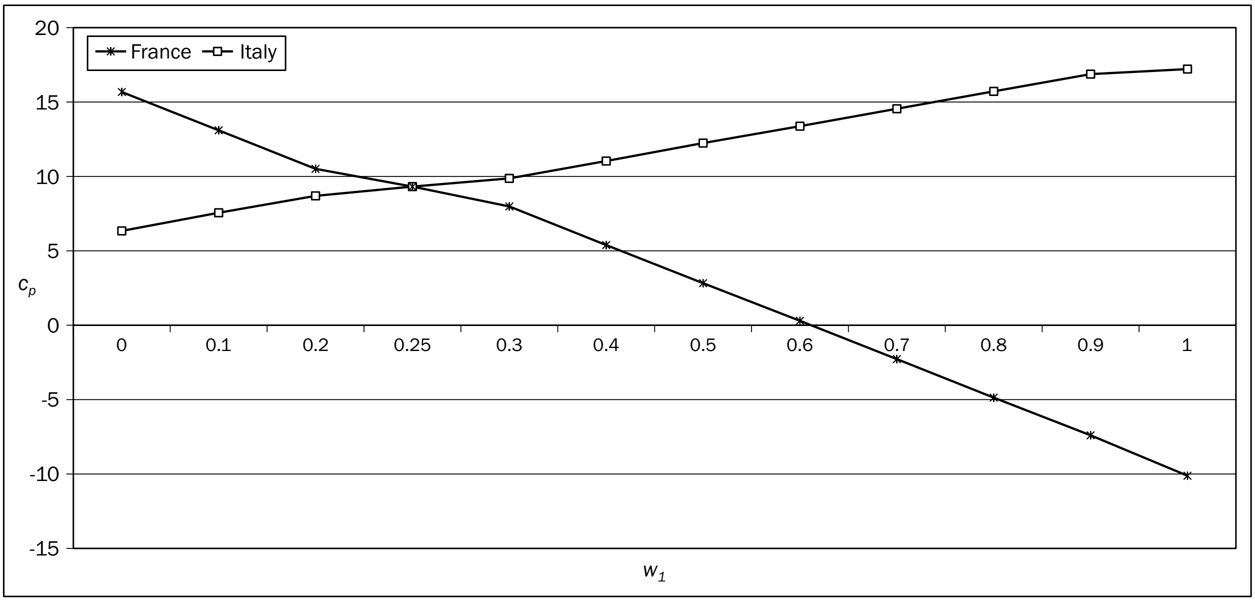

Figure 5 – Changes in the global concordance index of the country at the first position if parameter w_1 increases

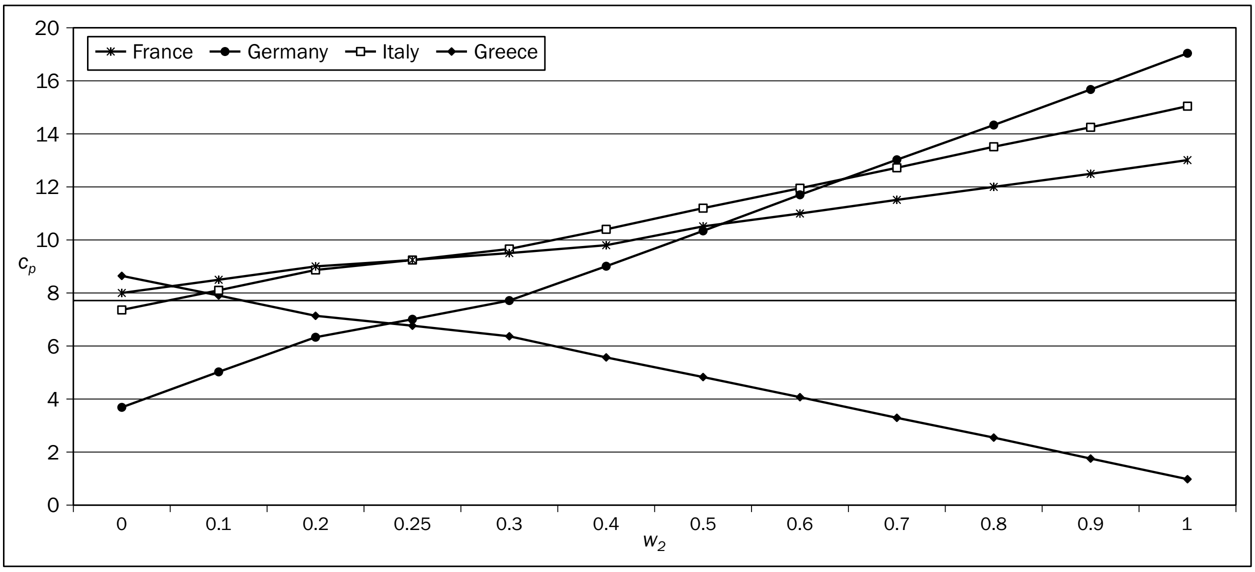

Figure 6 – Changes in the global concordance index of the country at the first position if parameter w_2 increases

due to variations of the weights over the [0, 1] range has been analysed. The outcomes of this sensitivity analysis suggest that the classifications deriving from the concordance and discordance global indices are quite stable, at least with respect to the first position alternately held by France, Italy and Germany. Figures 5-8 show, for the countries that rank first, the variations of the net concordance dominance values produced by the increases in the weights of the following evaluation criteria: how similar the signs of the reference country are to the corresponding signs in the rest of Europe (weight w_1); the amount of road users that would have to adjust themselves to the new danger signs (weight w_2); the roadway network extension on which the new traffic signs should be placed (weight w_3); the accident occurrence (weight w_4).

If generic weight wi is changed, each of other three weights is calculated as follows: $(1 - w_i)/3$. By increasing w_1, from 0 to 1, only one change in the first position of the ranking based on the net concordance dominance value occurs (*Figure 5*):

- $w_1 \leq 0.25$: Italy excels all the other options;
- $w_1 \geq 0.25$: France is the best option.

Varying weight w_2, several changes in the ranking based on the net concordance dominance value occurs (*Figure 6*):

- $w_2 < 0.06$: Greece shows the best performance;
- $0.06 \leq w_2 \leq 0.25$: France shows the best performance;

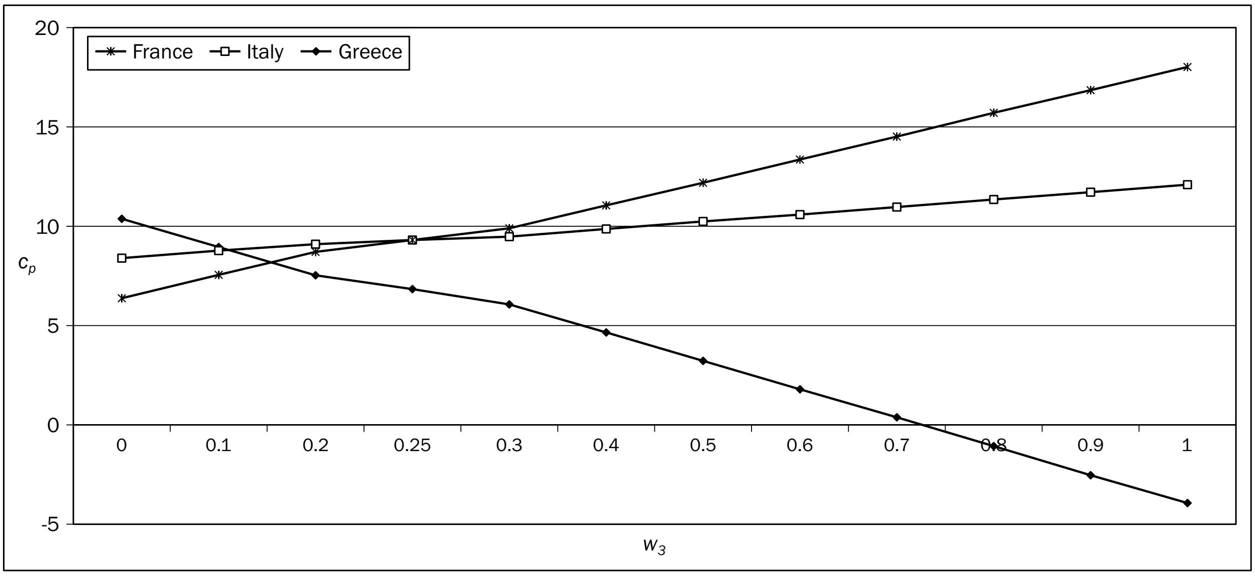

Figure 7 – Changes in the global concordance index of the country at the first position if parameter w_3 increases

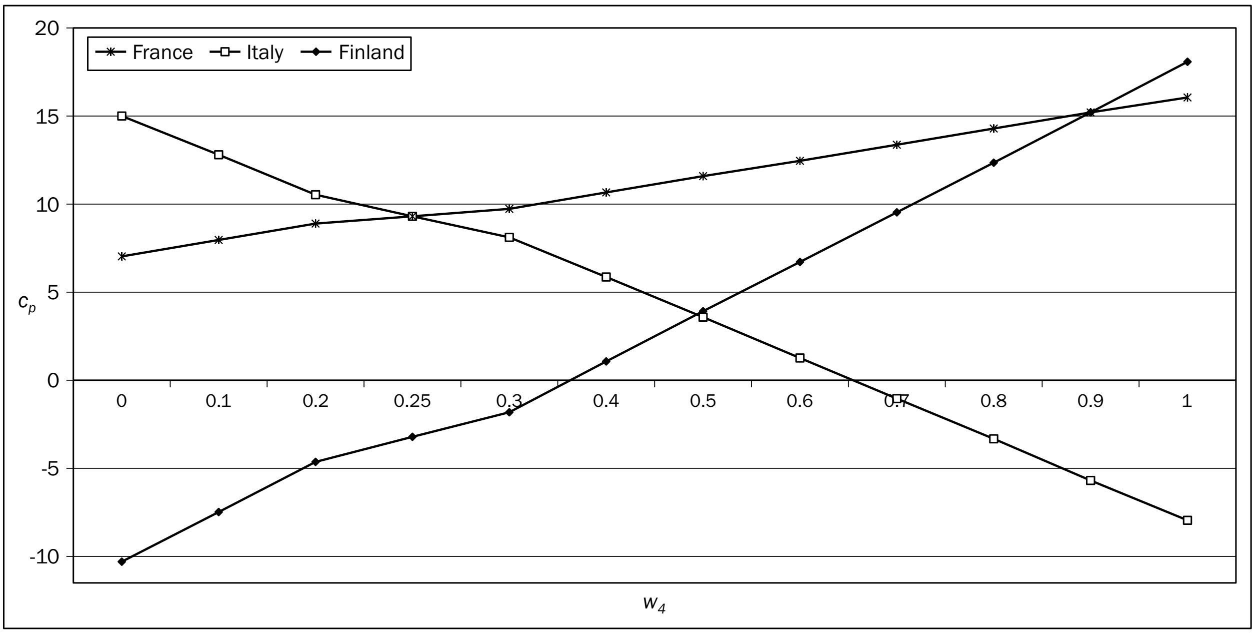

Figure 8 – Changes in the global concordance index of the country at the first position if parameter w_4 increases

– $0.25 \leq w_2 \leq 0.65$: Italy is first in the ranking;
– $w_2 > 0.65$: Germany is first in the ranking.

As regards weight w_3 , its increase over the [0, 1] interval changes twice the first position of the ranking based on the net concordance dominance index (*Figure 7*):

– $w_3 < 0.1$: Greece excels all the other options;
– $0.1 \leq w_3 \leq 0.25$: Italy has the highest score;
– $w_3 \geq 0.25$: France is the leader.

If weight w_4 rises from 0 to 1, the concordance ranking varies twice (*Figure 8*):

– $w_4 \leq 0.25$: Italy has the maximum score;
– $0.25 \leq w_4 \leq 0.9$: France leads the ranking;
– $w_2 \geq 0.9$: Finland gets the first place.

5. CONCLUSION AND FUTURE STEPS

Moving across Europe, a great diversity of road signs can be found requiring travellers to learn an excessive amount of information. This can often cause difficulties due to disorientation and insecurity. Every year, millions of tourists travel throughout the EU zone by car. Road transport is also the most common mode of transferring goods. Therefore, it is of great urgency to begin a harmonization process of different road sign systems. This paper discusses the topic of harmonizing road signs in Europe. It proposes a multicriteria approach for the choice of a sign system comparing different EU road sign sets. Specifically,

the comparison among countries has been based on three main aspects: the installation cost of new signs, new sign learning issues and the effectiveness of sign systems. The analysis has been conducted by applying a non compensatory multicriteria method, only for the danger road signs of nineteen countries of the European Union. The examined countries have been ranked and France has proved to be the reference country for the harmonization process. The study has allowed for the installation cost by quantifying the degree of similarity among road signs and the roadway network extension, on which new signs should be placed. The measurements of the similarity degree have been performed through an original methodology for comparing the pictorial features of corresponding road signs of different countries. This methodology employs a set of graphic parameters to simulate human visual perception. For the future, the study intends a standardization of all road sign categories and investigating more deeply how to measure the effectiveness of traffic sign systems.

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SOMMARIO

LA STANDARDIZZAZIONE DEI SEGNALI STRADALI DI PERICOLO NELL'UNIONE EUROPEA

La presente memoria illustra la metodologia ed i risultati di un'attività di ricerca finalizzata a studiare il problema dell'unificazione europea dei sistemi di segnaletica stradale verticale, la quale rappresenta uno dei presupposti fondamentali per favorire la crescita dei livelli di efficienza e sicurezza della mobilità delle persone e delle merci in ambito UE. Nella prima fase di tale studio, i cui risultati sono riportati in questo articolo, l'attenzione è stata focalizzata sui cartelli stradali di pericolo, utilizzando una base dati relativa a 19 Stati membri dell'Unione Europea. I set di segnali di pericolo di questi Paesi sono stati confrontati tramite un'analisi a molti criteri, basata su tre aspetti fondamentali: il costo di installazione dei nuovi cartelli nei differenti contesti territoriali, l'impegno richiesto agli utenti per apprendere il significato dei nuovi pannelli segnaletici e, infine, l'efficacia della segnaletica.

PAROLE CHIAVE

segnali stradali; analisi multicriteria; analisi grafica; percezione visiva;

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