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BRoWSER: Base-lining Road Works Safety on European Roads

Correlation between national standards and injury accident data

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1 Introduction and objectives

1.1 The BRoWSER project

The project Base-lining Road Works Safety on European Roads (BRoWSER) was initiated as a response to the Description of Research Need (DoRN) for the CEDR Transnational Road Research Programme Call 2012 on Safety.

The aim of the CEDR Transnational Research Programme (2012 call) seeks “to significantly reduce risks to road workers with an objective of Zero Harm”. BRoWSER addresses two of the topics within the 2012 Call under the heading of “Safety of road workers and interaction with road users”. These are:

- Collect data on worker injuries and near misses by country, road administration and employer
- Understand the optimum road works layouts that enable road users to approach, travel through and exit works without causing injury to workers and others

The aim of the BRoWSER project is to help National Road Authorities (NRAs) enable a data-led approach to be taken to managing road worker safety. This knowledge of how road workers are exposed to risk from accidents and road user error is essential for effective safety management as it allows the real risks to be managed rather than those perceived to be the problem. The BRoWSER project focuses on the interaction between road workers and traffic and will allow consideration of road worker accidents, incidents and near misses (where available) alongside data for road works practices, network characteristics and road user accident data at road works.

1.2 This document

There are two streams of work within the BRoWSER project – one looking at the collection of road worker incident data, the other looking at the road works standards and operational practices. The aim was to combine these two work streams to identify any relationship between the number of incidents and the provisions of layouts requirements for road works, with the further aim of therefore identifying any recommendations for road works management that may reduce the risk to road workers.

The aim was to carry out a correlation analysis between the incident data and the national standards. Previous work packages on the project have focussed on both these elements. However, it became clear that data levels for road worker incidents do not allow a fully quantitative assessment.

The agreed strategy therefore was to produce a qualitative assessment and to describe the methodological framework for incident rate and works layout correlation with illustrative data where appropriate. It is also worth noting that this lack of data collection provides further evidence of the potential benefit of a EuRoWCas database.

This document outlines this methodological framework. Section 2 looks at the incident data available and the difficulties of calculating the incident rate by country. Section 3 discusses a proposed method for classifying the countries according to their standards and guidance documentation. Section 4outlines the principles between correlation analysis and Section 5 provides an illustrative example of the methodology using hypothetical data.

2 Injury accident rate

2.1 Collected injury accident data

The benefits of a European Road Worker Casualty Database (EuRoWCas) were identified in the project deliverable D1.1 (BRoWSER Benefits Case). In order to realise these benefits, road worker incident data must be collected as specified in project deliverable D2.1 (Input data definition document for EuRoWCas).

However, the collection of these data is not possible with (or without some adaptation to) the existing data collecting processes in the individual countries. Details of the existing data collection and processes in each of the funding countries (plus Slovenia) were provided in the Baseline Report (project deliverable D3.1, D3.2 and D6.1). Therefore it was agreed that a three-month data collection trial would be carried out to demonstrate the feasibility of such data collection.

The results of the data collection trial are shown in the table below:

Country	Number of incidents recorded	Further information
UK (England)	18	Nine of these were near misses, usually incursions into tapers or lane closures by mistake. Nine were collisions in the works (some between vehicles, some between vehicles and barriers/equipment), no injuries to road workers or road users.
Belgium (Flanders)	9	Involved 10 vehicles and 12 people, four vehicles and only one person being from the road worker side.
Slovenia	4	All accidents in the trial period happened during daytime in good weather conditions, none of these was a near miss and no injuries to road workers were recorded.
Ireland	7	14 people were involved, 10 of them with minor injury or without injury sustained. The remaining injury levels were not reported.
Sweden	12	Ten occurred on state-owned roads. Three of these incidents involved motorcyclists overturning on loose gravel or stones within the road works. No information on road worker injuries.
Germany (Hesse)	(0)	Work zone incidents with road worker injury only were available so it is unsurprising that no such incidents occurred over that duration. No information available on near misses.

The trial demonstrated the feasibility of this data collection, using a variety of methods. Due to the innate scarcity of road worker injury incidents, in order to obtain sufficient data levels, this data collection needs to be extended over more countries and on a permanent basis.

2.2 Injury accident rate

Given that each country has different characteristics, e.g. the length of the road networks, the number of road worker injury accidents must be normalised to enable a comparison between countries. In order to normalise the number of incidents there must be an understanding of the exposure of the road workers to the risk of injury. This allows calculation of the incident / accident rate.

The exposure of road workers depends on factors such as the number (and type) of road works, the duration of these works, the Average Daily Traffic (ADT) at each site on the road network and its composition, the percentage of foreign road users, the probability of adverse climatological issues, and the number of daylight hours.

How the incident rate is calculated depends on the level of aggregation of the data available. The simplest metric would be to calculate the number of incidents per ‘road works hour’, i.e. divide the total number of hours of road works activity on the network by the number of incidents recorded. This would require knowledge of the number of road works carried out and the duration in time of each of those works.

However the number of workers in each works will also vary. A more accurate measure of incident rate would be the number of incidents per ‘road worker hour’, i.e. multiply the number of road workers in a works by the duration of the works, sum over all the road works on the network and divide by the number of incidents recorded.

Arguably therefore, the minimum required information to consider the exposure of road workers are:

1. Number of road works: The larger the amount of road works, the larger the possibility of accidents or near misses.
2. Duration of the road works: A relationship exists between the duration of a given road works and the likelihood of an incident. This relationship is not linear because after a short period of time, road users know the existence of works, which can a positive aspect. However, after a larger time period they can become used to the works, possibly resulting in an increase of the likelihood of an incident.

A proper normalisation of the injury accident data should consider at least these factors. However investigations during the project showed that these data are not generally or easily available. Whilst this was only investigated for the countries involved in the data collection trial, it is believed that there is likely to be a similar lack in other European countries.

1. Number of road works in a country

   None of the countries investigated collect this information in a reliable and consistent way, and many do not collect it at all. The most useful source is ‘road space booking’ systems used by the road works contractors themselves, however these tend to be inaccurate as ‘block bookings’ are often made long before the specific time and duration are known and are not subsequently updated, leading to overestimation.

   There were two suggestions for estimating the number of road works in a country:
   - Firstly, the budget devoted to road works. In some countries this figure is easily accessible; in others it is not. Even where the figure is available, there is inconsistency between exactly what this figure represents. For example in

some countries there is a budget specifically for road works: in others capital costs (i.e. building of new infrastructure) is budgeted separately from maintenance costs – and neither are restricted to road works activities. In addition 'maintenance costs' can cover many different elements in many different countries.

- This would also assume that the 'average cost' for a set of road works is similar in different countries – this would not be the case as different approaches will have different associated costs, e.g. use of two protection vehicles is more expensive than using only one.
- Secondly, the increase in the total length of the roads in the country. Although this would arguably provide a useful proxy for building of new roads, in the majority of the European countries the most common type of road works is maintenance and rehabilitation works (especially in Western Europe).

2. Duration of the road works.

   As well as the overestimation through booking systems mentioned above, other reasons make it almost impossible to assess this factor; such as some major road works, with a long projected duration, are divided in several discontinuous stretches and smaller road works are sometimes within other infrastructure projects making it difficult to reliably estimate the total duration of the road works.

In order to accurately calculate the incident rate in a country, this information as a minimum needs to be collected by national road authorities or others.

More detailed data can provide more accurate metrics of incident rate. For example, the risk for road workers is likely to vary depending on where in the road works they are working or what activity they are carrying out. If data are available about the length of time workers are engaged in traffic management activities for example, then separate incident rates can be calculated for traffic management activities (often on the live carriageway) versus works activities (in the works zone). Note however that in order to calculate such incident rates, the incident data would need to be similarly disaggregated – i.e. it would be necessary to know how many of the incidents happened in each location. The more detailed the data that are collected (both for incidents and for road works) the more informative and accurate the incident rate can be.

One other important factor that is worth considering is the average daily traffic (ADT) of the road network and its composition; the risk the workers are exposed to will vary as high levels of traffic flow increase the possibility of an incident. Moreover, the percentage of trucks increases the likelihood of severe consequences in the event of an incident. Data on the flow on the network and composition of the traffic is more easily available as many national authorities collect this information, although it should be noted that this by no means true of all. Additionally, for more accurate exposure calculations, the average flow at the specific road works site (and at the time of the works) would be required.

3 Classification of the countries according to the standards

3.1 Criteria

In work package 7 of the project, different national performance standards and guidance documents were collected and analysed to determine similarities and differences for advance warning, geometry of the transition area, work zone safety distance and delineation, speed limit, etc. across European countries.

In order to use this information in a correlation analysis, a method needed to be defined for classifying the countries according to the level of (mandatory) provision for road works layout / signing standards. This classification allows the identification of any possible correlation in accident rates between countries with similar practices and the comparison between countries with similar and different levels of provision. The classification method proposed is presented below.

Classifying the road works layout and signing standards is possible through the use of six matrices, one per combination of road/road work type discussed in the *D7.1 Report on national performance standards, guidance and contract documents*, namely,

(a) major road works (on 3 lanes) motorway with crossover,
(b) minor road works on (3 lanes) motorway (right lane closed),
(c) mobile road works on (3 lanes) motorway (right lane closed),
(d) major road works on single carriageway (80/90 km/h) road,
(e) minor road works on single carriageway (80/90 km/h) road, and
(f) mobile road works on single carriageway (80/90 km/h) road.

Each matrix presents different criteria, depending of the type of road / road works, all of which are key elements for road workers and road user safety. These matrices are shown below.

Matrix for Major RW (on 3 lanes) Motorway with Crossover

Criteria	**Country A**	**Country B**	**…….**
Far-advance warning (type of signs & distance)			
Near-advance warning (type of signs & distance) - around last 300 m			
Crossing of the central reserve/Lane shift geometry (angle, opening width, length, lane width, safety area) Delineation and marking in the transition area (taper)			
Work zone delineation			
Work zone lateral safety distance			
Physical separation of the opposite traffic flows			
Work zone speed limit (scheme/reduction)			
Temporary lane width			
Total of ratings			

Matrix for minor RW on (3 lanes) Motorway (right lane closed)

Criteria	Country A	Country B	…….
Far-advance warning (type of signs & distance)			
Near-advance warning (type of signs & distance)			
Lane shift geometry (angle, length)			
Work zone delineation			
Work zone lateral distance			
Work zone speed limit (scheme/reduction)			
Temporary lane width			
Total of ratings			

Matrix for mobile RW on (3 lanes) Motorway (right lane closed)

Criteria	Country A	Country B	…….
Lane shift geometry			
Advance warning: sign & distance			
Safety vehicle(s): presence, number, type & characteristics			
Distance between the Work vehicle and the Safety vehicle(s)			
Work zone speed limit (scheme/reduction)			
Total of ratings			

Matrix for major RW on single carriageway (80/90 km/h) road

Criteria	Country A	Country B	…….
Far-advance warning (type of signs & distance)			
Near-advance warning (type of signs & distance)			
Lane shift geometry (angle, length)			
Work zone delineation			
Work zone lateral safety distance			
Work zone speed limit (Scheme/reduction)			
Temporary lane width			
Total of ratings			

Matrix for minor RW on single carriageway (80/90 km/h) road

Criteria	Country A	Country B	…….
Far-advance warning (type of signs & distance)			
Near-advance warning (type of signs & distance)			
Lane shift geometry (angle, length)			
Work zone delineation			
Work zone lateral safety distance			
Temporary lane width			
Work zone speed limit (scheme/reduction)			

Total of ratings			

Matrix for mobile RW on single carriageway (80/90 km/h) road

Criteria	**Country A**	**Country B**	**…….**
Lane shift geometry			
Advance warning: sign & distance			
Safety vehicle(s): presence, number, type & characteristics			
Distance between the Work vehicle and the Safety vehicle(s)			
Work zone speed limit (Scheme/reduction)			
Total of ratings			

For each country, all the criteria in each matrix should be rated from 1 to n, where n depends on the number of ratings deemed appropriate. For example, if n=3, the levels may be ‘low’, ‘medium’ and ‘high’; if n=5 the levels may be ‘very low’, ‘low’, ‘medium’, ’high’ and ‘very high’, respectively. This depends on the relative differences observed between the national standards. The main issue in developing this classification method is how to decide on the boundaries between successive levels. The most relevant option seems to be to identify the range of values a specific parameter takes across the set of countries and decide on the level thresholds ensuring they discriminate between significantly diverging practices

For example, for n=3, some possible thresholds for three of the criteria are:

1. Far-advance warning - Distance
   - Level 1: first sign location <= 1000m
   - Level 2: 1000m<first sign location <= 2000m
   - Level 3: first sign location > 2000m

2. Near-advance warning (around last 300 m) - Lane management warning
   - Level 1: standard static warning sign
   - Level 2m: static warning sign with flashing lights and/or physical traffic management (e.g. rumble strips) and/or other warning device
   - Level 3: dynamic lane management and/or speed display and/or dedicated VMS

3. Work zone lateral safety distance
   - Level 1: <= 0,5 m
   - Level 2: > 0.5m & <=1.5m
   - Level 3:> 1.5m

Therefore, the individual score of each country *i* according to a given individual criteria *c* is denoted as $S_{c,i}$.

3.2 Level of provision

With the aim of obtaining an overall level of mandatory provision for each country, M_i, the following formulation is applied

$$M_i = \sum_{c=1}^{k} W_c S_{c,i} \qquad (2)$$

where W_c is the weight given to each criterion and k is the number of criteria. It is clear that the selection of the weights will influence the final classification and the eventual correlation analysis. This aspect will be discussed in Section 5.3.

3.3 Classification

To identify any possible correlation in accident rates between countries with similar practices and to compare between countries with different levels of mandatory provision, a previous classification of the countries according their level of mandatory provision is required.

The number of groups in the classification will depend on the number of countries involved. Note that this number should guarantee a minimum number of countries to carry out a proper correlational analysis. The higher the number of elements involved, the more reliable the analysis is. (This fact will be explained in detail in Section 4.2).

Choosing the threshold values which define the limits of each group is critical (as shown in the example below). The choice will depend on the range of *Mi* and the distribution of the data.

Illustrative example

To illustrate the rationality behind the classification process, Figure 1 shows a comparison between 12 hypothetical countries with different road works standards and injury accident rates. Although, in this example, a marked tendency is exhibiting that the stronger the level of mandatory provision, the lower the accident rate, the linear correlation between the two variables is not so clear, especially for low levels of mandatory provision.

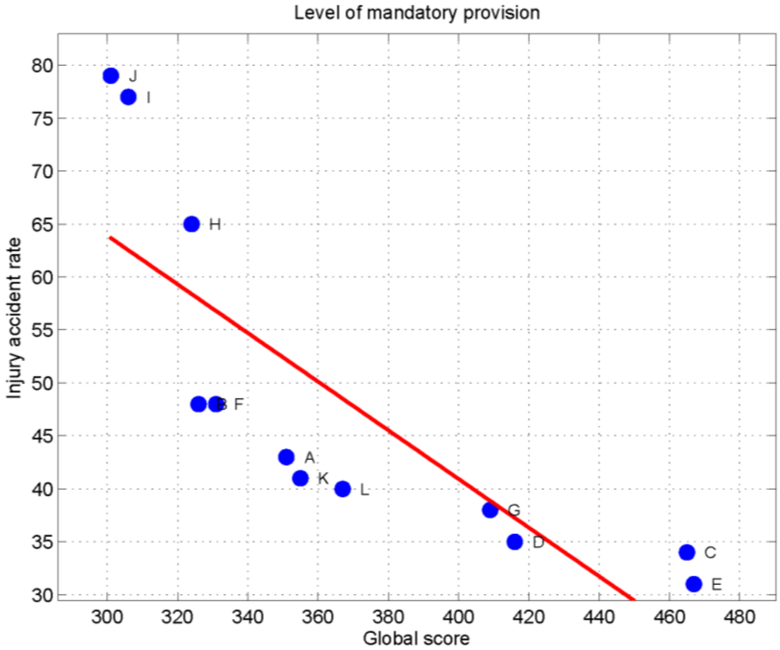


Figure 1. Comparison between 12 countries with different road works standards and the injury accident rate

After classifying the countries into two groups, using the value of 400 to limit each subset of data (see Figure 2), the linear correlation between the two variables becomes much clearer in both cases. Note that this classification example generates two subsets, one of them with only 4 countries. Involving only 4 countries in a correlational analysis will result in an unsatisfactory conclusion, as explained in Section 4.2.

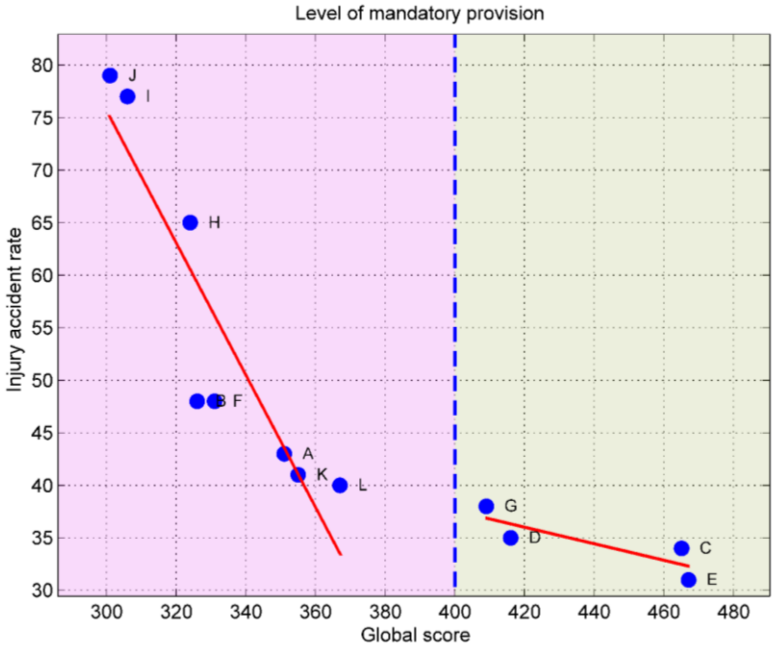


Figure 2. For the classification 1, correlation in accident rates between countries with similar levels of mandatory provision and comparison between countries with different levels of mandatory provision

However, when classifying the countries into two groups, using the value of 340 to limit each subset of data as shown in Figure 3, the number of countries involved in each group is more balanced, allowing a proper correlation analysis within each group. Moreover, the comparison between the two groups can be carried out, as they exhibit different tendencies.

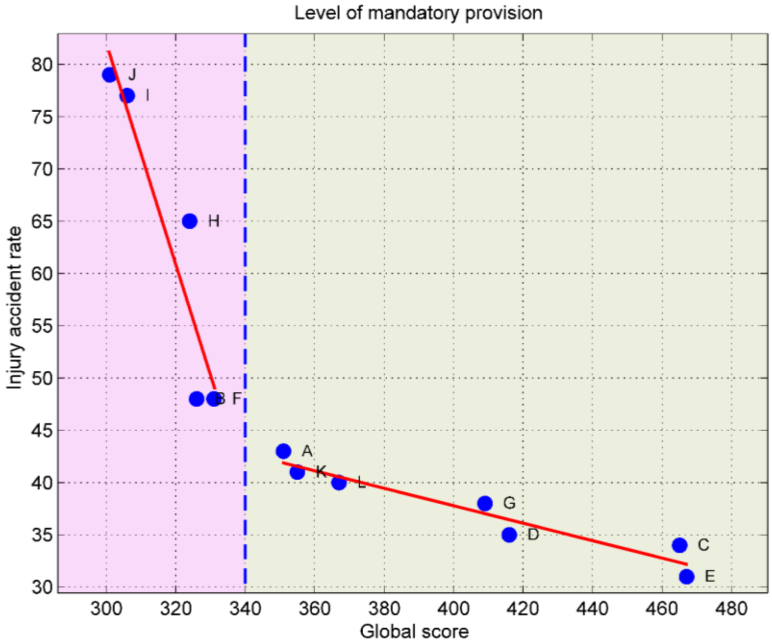


Figure 3. For the classification 2, correlation in accident rates between countries with similar levels of mandatory provision and comparison between countries with different levels of mandatory provision

4 Correlation Analysis

This section outlines the theory behind the correlation analysis used in the illustrative example in Section 5.

4.1 Mathematical background

The aim of a correlational study is to determine the degree of association between two variables. i.e., the extent to which a subject's score on one variable can be predicted if one knows the subject's score on the second variable.

It is remarked that correlation does not imply causation; such studies only provide the statistical association between the independent and dependent variables. This is due to the possible existence of confounding variables, i.e., variables that systematically vary with the different levels of the independent variable.

The most commonly employed correlational measure is the Pearson product-moment correlation coefficient, r, which is in the range of values [-1, 1]. This correlation coefficient assumes that a linear function best describes the relationship between the two variables. The absolute value of r indicates the strength of the relationship between the two variables. As the absolute value of r approaches 1, the degree of linear relationship between the variables becomes stronger. When $r = 0$, the prediction of a subject's score Y from the subject's X is based purely on chance. Finally, the sign of r indicates the direction or nature of the relationship that exists between the two variables. A positive sign indicates a direct relationship, whereas a negative sign indicates an inverse relationship.

The Pearson product-moment correlation coefficient is computed using the following expression;

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{\left[\sum X^2 - \frac{1}{n}(\sum X)^2\right]\left[\sum Y^2 - \frac{1}{n}(\sum Y)^2\right]}}, \qquad (3)$$

where *X* and *Y* are the scores of the subjects analysed and *n* is the number of the subjects.

The square of the correlation coefficient is referred to as the coefficient of determination. It represents the proportion of variance of one variable which can be accounted for by variance of the other variable.

The Pearson correlation coefficient is the standard measure of dependence used in statistics – to the extent that it is commonly known as just 'the correlation coefficient'. However when the relationship between the variables is better described by a curvilinear function, the Pearson correlation coefficient may not indicate the actual extent of the relationship between the variables. In such a case, the Spearman rank-order correlation coefficient, *s*, can identify whether a significant monotonic relationship between the two variables exists. A monotonic relationship can be described as monotonic increasing (positive correlation) or monotonic decreasing (a negative correlation). The range of values of *s* is [-1, 1]. Finally, the absolute value of *s* indicates the strength of the relationship between the two variables.

The Spearman rank-order correlation coefficient is computed using the following expression;

$$s = 1 - \frac{6\sum d^2}{n(n^2-1)}, \qquad (4)$$

where *d* is the difference score for each subject. It is noted that the scores of the variables *X* and Y are previously ranked. For more details, see Sheskin (2003).

4.2 Analysis of statistical significance

Once the correlation coefficient is obtained, it is necessary to determine whether or not the obtained value is due to chance or is likely to be due to the presence of a genuine experimental effect. In other words, to what extent the correlation value obtained can be considered as statistically significant. For instance, is a correlation coefficient of 0.70 large enough to state that there exists an actual statistical association? The answer to this question does not only depend on the value of the correlation, but on the number of subjects analysed.

To analyse the statistical significance, the classical hypothesis testing model (i.e., the null hypothesis significance testing model) is used. It consists of stating a null hypothesis, H0, against an alternative one, H1. The decision on whether to retain or reject the null hypothesis is based on contrasting the observed outcome of an experiment with the outcome one can expect if, in fact, the null hypothesis is true. This decision is made by using the appropriate inferential statistical test (Sheskin, 2003).

Within the framework of hypothesis testing, it is possible to commit two types of errors, namely, Type I error and a Type II error. A Type I error is when a true null hypothesis is rejected (i.e., one concludes that a false alternative hypothesis is true). The likelihood of committing a Type I error is specified by the α level, which is defined in the interval [0, 1]. A Type II error is when a false null hypothesis is retained (i.e., one concludes that a true alternative hypothesis is false).

To determine the statistical significance of the correlation coefficient, the following hypotheses are stated:

- Null hypothesis H0: *r=0*
- Alternative hypothesis HI: *r≠0*

Supporting the alternative hypothesis at α level implies that a statistical association can be established between the two variables. Note that in such a case, α represents the likelihood of rejecting the possibility of non-association, therefore the larger the α level, the less confidence in the statement.

Due to the small number of subjects (in this case, countries) studied, the T-student distribution is used for the statistical significance analysis. The α level is obtained applying the following expression;

$$\alpha = 2 * \left[1 - T\left(\frac{r\sqrt{n-2}}{\sqrt{1-r^2}}, \upsilon\right)\right], \quad (5)$$

where $T(x,\upsilon)$ is the cumulative distribution function associated with the T-student distribution, and υ represents the degrees of freedom employed for evaluating the significance of the correlation coefficient, i.e., $\upsilon = n - 2$.

Note that the presented analysis is valid for both correlation coefficients, *r* and *s*.

To conclude this section, it is highlighted that a small sample size will require higher correlation coefficients to be considered as statistically significant. This fact is illustrated in Figure 4, where the minimum correlation coefficient required to be considered as statistically significant at α level is given as a function of the number of subjects. Note that the minimum number of data necessary to analyse the correlation is three, requiring an almost perfect correlation to be considered as statistically significant.

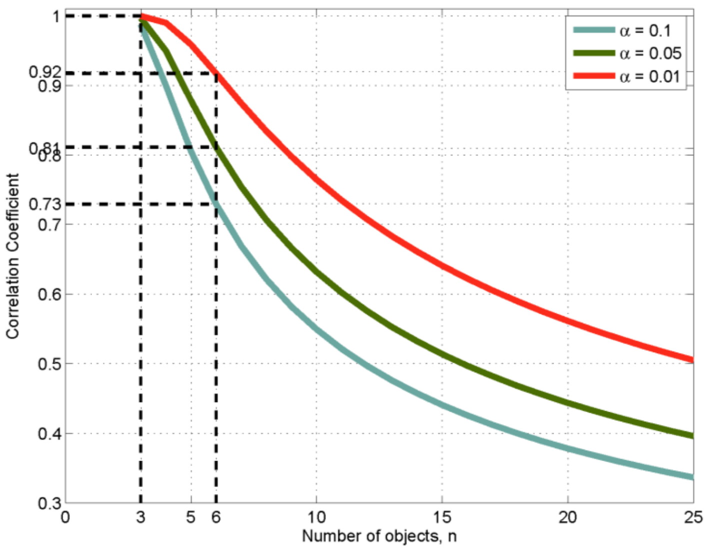


Figure 4. For a given number of subjects, minimum correlation coefficient required to be considered as statistical significant at α level.

5 Illustrative example

5.1 Assumed data

To illustrate the methodology, 6 hypothetical countries have been considered, labelled from A to F. According to the methodology explained in Section 3.1, the *k* criteria associated with the six types of road / road work have been scored from 1 to 5, as a result of the comparison of their respective road works layout / signing standards. The illustrative ratings are shown in Table 1.

Each criteria *c* has associated a weight W_c that measures its level of importance with respect to the road works safety. As mentioned, these weightings would be based on expert opinion. Equation (2) is applied to obtain the global score M_i associated with each country.

Finally, the (hypothetical) injury accident data recorded should be normalised to obtain the injury accident rate, as discussed in Section 2.2. The assumed injury accident rates R_i are indicated in the last row of Table 1.

Table 1. Criteria, weights, ratings and injury accident rate for the illustrative example.

CRITERIA C	Wc	A	B	C	D	E	F
Major road works (on 3 lanes) Motorway with Crossover							
Far-advance warning (type of signs & distance)	1	4	4	2	4	3	4
Near-advance warning (type of signs & distance) - around last 300 m	2	3	2	2	4	2	2
Crossing of the central reserve/Lane shift geometry (angle, opening width, length, lane width, safety area)	5	5	4	2	1	3	1
Delineation and marking in the transition area (taper)	4	4	4	3	2	4	4
Work zone delineation	4	4	4	4	2	4	4
Work zone lateral safety distance	3	2	2	2	1	2	2
Physical separation of the opposite traffic flows	3	2	2	5	4	2	2
Work zone speed limit (scheme/reduction)	5	4	4	5	3	3	1
Temporary lane width	3	3	3	3	2	4	4
Minor road works on (3 lanes) Motorway (right lane closed)							
Far-advance warning (type of signs & distance)	1	3	2	4	3	5	3
Near-advance warning (type of signs & distance)	2	4	2	4	3	4	3
Lane shift geometry (angle, length)	5	5	4	3	2	2	2
Work zone delineation	4	5	4	2	2	1	3
Work zone lateral distance	2	4	4	3	1	4	4
Work zone speed limit (scheme/reduction)	5	3	4	2	1	5	2
Temporary lane width	2	4	2	3	2	4	5
Mobile road works on (3 lanes) Motorway (right lane closed)							
Lane shift geometry	5	5	4	1	2	2	2
Advance warning: sign & distance	2	4	3	4	3	4	4
Safety vehicle(s): presence, number, type & characteristics	2	4	1	2	2	2	2
Distance between the Work vehicle and the Safety vehicle(s)	1	1	4	2	2	2	2
Work zone speed limit (scheme/reduction)	5	2	4	3	5	3	1
Major road works on single carriageway (80/90 km/h) road							
Far-advance warning (type of signs & distance)	1	2	1	2	2	3	2
Near-advance warning (type of signs & distance)	2	5	4	1	2	2	2
Lane shift geometry (angle, length)	5	4	3	4	2	2	1
Work zone delineation	4	3	2	4	3	1	4
Work zone lateral safety distance	3	2	1	5	2	3	4
Work zone speed limit (Scheme/reduction)	5	3	2	4	5	4	2
Temporary lane width	2	4	4	3	1	4	4
Minor road works on single carriageway (80/90 km/h) road							
Far-advance warning (type of signs & distance)	1	2	4	4	3	1	2
Near-advance warning (type of signs & distance)	2	2	1	2	3	2	2
Lane shift geometry (angle, length)	5	1	4	2	4	2	2
Work zone delineation	4	4	4	3	1	3	1
Work zone lateral safety distance	3	4	5	3	2	4	4
Temporary lane width	2	2	4	3	1	3	2
Work zone speed limit (scheme/reduction)	5	4	2	2	2	4	3
Mobile road works on single carriageway (80/90 km/h) road							
Lane shift geometry	3	4	2	1	2	2	2
Advance warning: sign & distance	2	4	5	4	2	2	2
Safety vehicle(s): presence, number, type & characteristics	1	2	4	4	3	1	2
Distance between the Work vehicle and the Safety vehicle(s)	3	2	3	2	4	4	3
Work zone speed limit (Scheme/reduction)	5	1	5	4	3	1	2
Global Score Mi	**124**	**416**	**409**	**367**	**306**	**351**	**301**
Injury Accident Rate Ri		**38**	**40**	**48**	**79**	**43**	**65**

5.2 *Correlation of the level of the mandatory provision with the injury accident rate*

The comparison between EU countries with different road works standards and the national injury accident data for road workers is addressed by means of the correlational analysis of the level of mandatory provision on the injury accident rate of all the countries involved in the study. This will allow the identification of any possible link between the level of legislation and number of accidents within road works.

With this aim, the level of mandatory provision of each country, M_i, and injury accident rate, R_i, (last two rows of Table 1) are introduced into the Equation (3) obtaining the Pearson product-moment correlation coefficient, *r= -0.88*. The negative sign of the correlation means that the larger the level of mandatory provision, the smaller the injury accident rate is.

Applying the hypothesis testing explained in Section 4.2, the alternative hypothesis HI $r \neq 0$ is supported at the 0.05 level. That implies that the hypothesis that a linear correlation exists can be accepted, assuming that there is the likelihood of making a mistake is 5%.

The coefficient of determination is 0.78, that is, the 78% of the variation of the injury accident rate can be accounted for on the basis of variability of the level of mandatory provision.

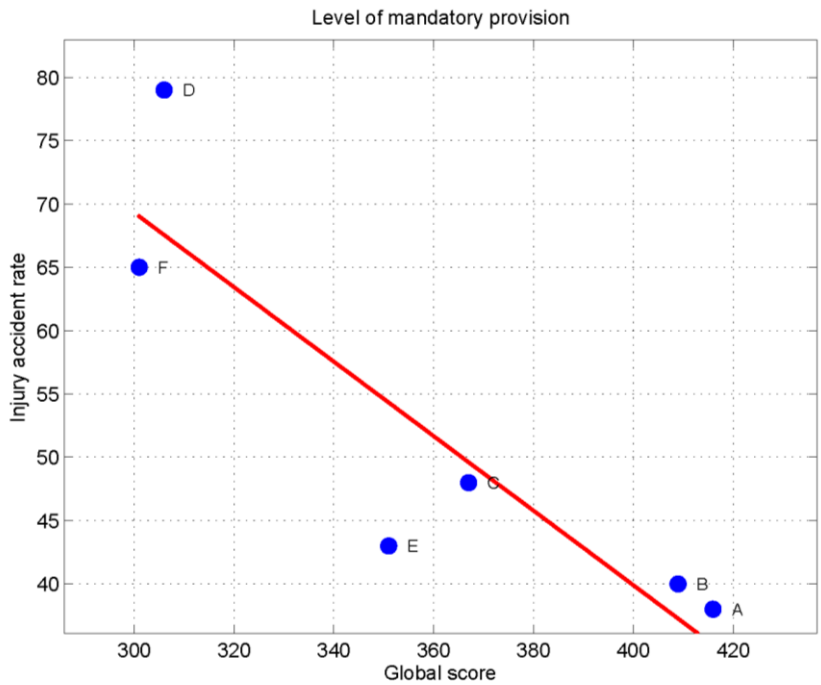


Figure 5. Correlational analysis of the global score M_i and the injury accident rate R_i

The linear correlation can be observed in Figure 5, where the regression line of the global scores M_i on the injury accident rate R_i is represented. This line has been obtained by the method of least squares, and its equation is $R_i = -0.29\ M_i + 157.53$.

To complete the analysis, the monotonic relation between the variables is studied by means of the Spearman rank-order correlation coefficient. Applying Equation (4), the correlation coefficient is obtained, $s= -0.89$. This value is supported at 0.05 level.

The conclusion derived is that a clear relationship exists between level of mandatory provision and the injury accident rate, such that the highest standards of road work safety are associated with greater safety levels. This relationship is not purely linear and, as Figure 5 shows, countries with the lowest levels of mandatory provision seem to have disproportionately high incident rates.

5.3 Correlation of the individual criteria

To explain the importance of the proper selection of the weights W_c, the three first criteria in Table 1 are independently analysed. The statistical analysis carried out is that presented in the previous section, but in this case the sets of data $S_{1,i}$ and R_i are used.

For the first criterion, the data exhibit a linear correlation of $r=0.26$. However this value is not statistically significant. On the other hand, the monotonic relation is measured by the Spearman coefficient $s=0.11$, which is not statistically significant. These results can be easily interpreted when looking at Figure 6, where the individual scores for criterion 1 against the injury accident rate are represented. In this case there is not any clear tendency, as the red curve, obtained by the least square method, shows.

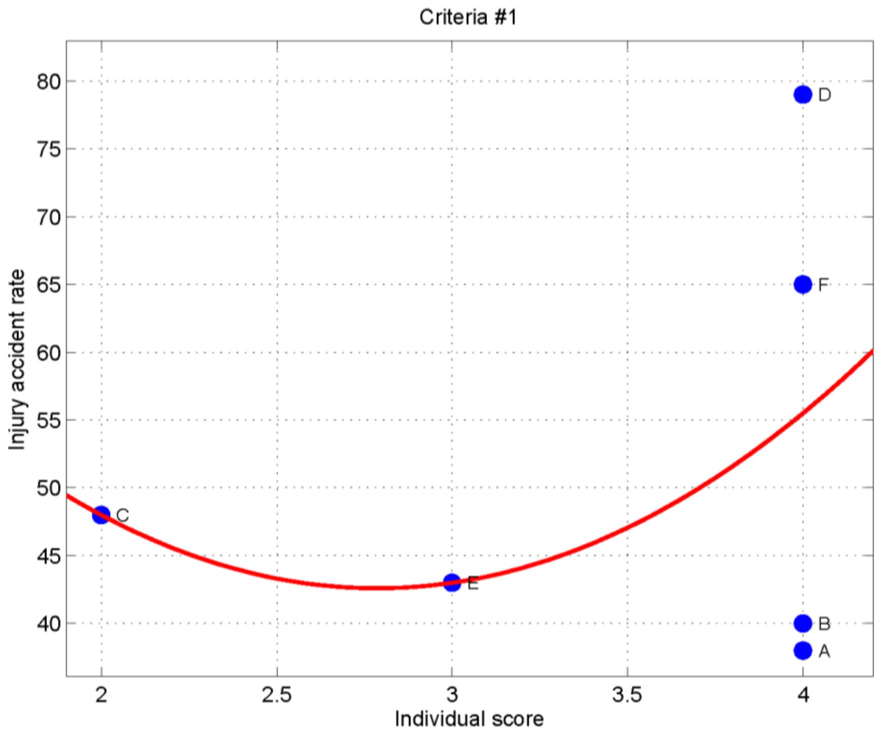


Figure 6. Correlational analysis of the scores associated with the criterion 1, $S_{1,i}$, and the injury accident rate R_i

For the second criterion, there exists a linear correlation of $r=0.58$, i.e. non-statistically significant. The monotonic relation observed is $s=0.28$, which is not statistically significant. These results are shown in Figure 7, where the individual scores for criterion 2 against the injury accident rate are represented. Again, there is not any clear tendency that can be used to derive any conclusion about the behaviour of the injury accident rate given the scores of the criterion 2.

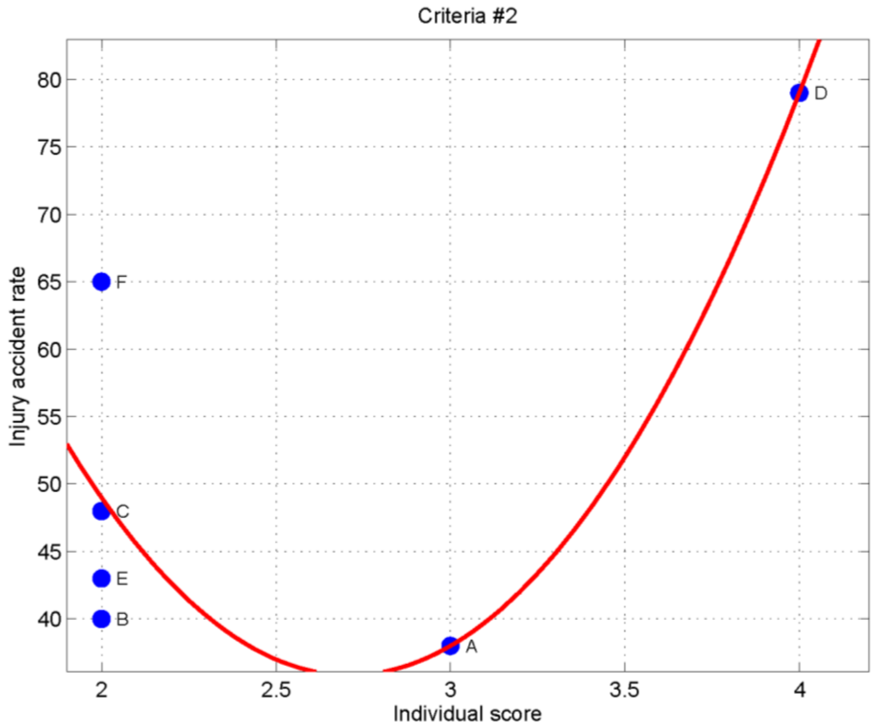


Figure 7. Correlational analysis of the scores associated with the criterion 2, $S_{2,i}$, and the injury accident rate R_i

Finally, when analysing the criterion 3, the linear correlation coefficient is *r=-0.87* and the Spearman rank-order correlation coefficient is *s=-0.96.* Both of these are statistically significant. In this case the tendency is easily appreciated from Figure 8. Moreover, the large value of the Spearman coefficient implies that the relationship is better explained by a non-linear curve.

Three criteria have been independently analysed to show how each criterion is related to the injury accident rate. As only the third one seems to explain the injury accident rate, a set of weights amplifying the third criterion will result in larger correlation coefficients.

Considering the individual analysis of each criterion allows the identification of certain tendencies. However these individual analyses cannot replace the overall analysis, given that a global score of the level of mandatory provision is more realistic because it involves the most important elements affecting the safety in the roads works. Note that safety of a given road is reached through combining different safety measures.

Finally, it is important to weight the criteria according to a rational method, based on experience, avoiding a tailored set of weights. The range used to weight the criteria only affects the linear correlation coefficient. The Spearman coefficient will be able to identify the existing correlation as long as the order of the level of mandatory provision of the countries remains.

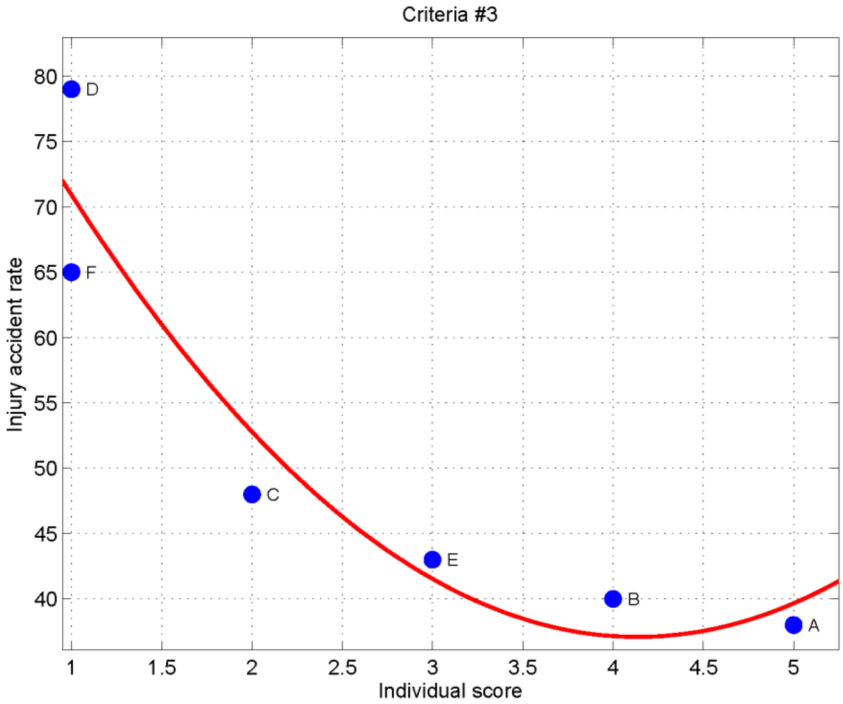


Figure 8. Correlational analysis of the scores associated with the criterion 3, $S_{3,i}$, and the injury accident rate R_i

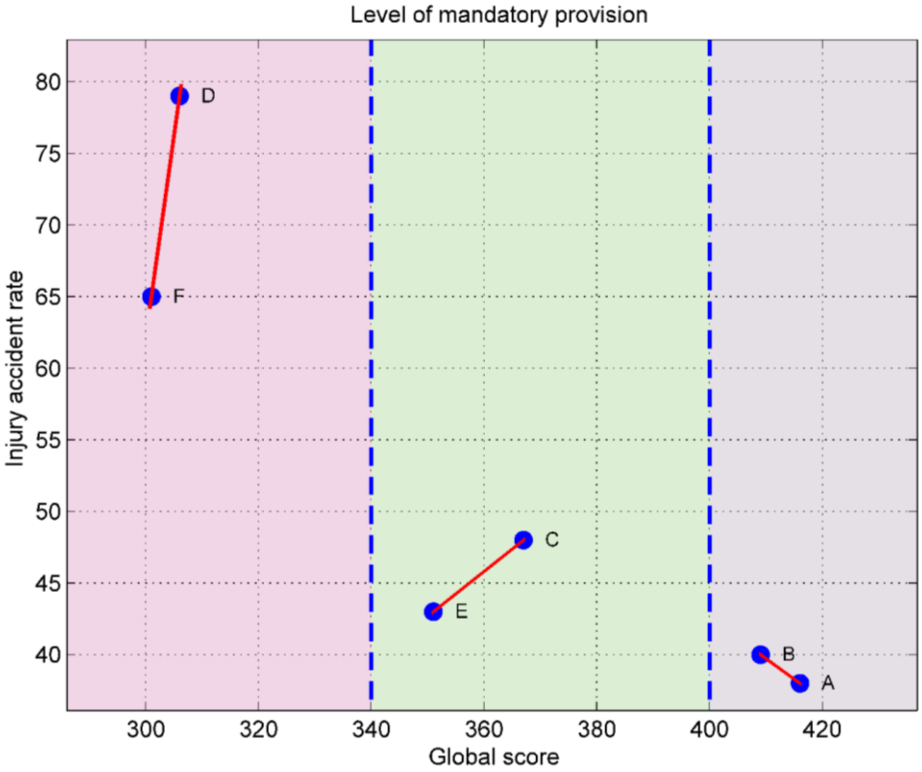
5.4 Correlation for countries with similar mandatory provision

To identify the existing correlation between the injury accident rates for countries within the same group, the same process as previously explained should be used. In this case, the set of data involved in each analysis corresponds to only the countries of each group. This analysis would allow the identification of any possible correlation in accident rates between countries with similar practices and the comparison among groups.

When dividing a set of six countries, only two or three countries (if three or two groups are considered) are involved in each analysis. Realistically, no serious correlational study can be carried out with such a small set of data. At least 12 - 15 countries should be involved to conduct this analysis.

For instance, Figure 9 shows a possible classification where the global scores of 340 and 400 define the limits of low, medium and high level of mandatory provision. Two values per group are insufficient.

Figure 9. Correlation between the injury accident rates for countries within the same group



6 Conclusions and recommendations

There are two streams of work within the BRoWSER project – one looking at the collection of road worker incident data, the other looking at the road works standards and operational practices. In this document a methodological framework for analysing the correlation between the incident rate and works layout has been described, along with illustrative examples. The methodology is based on the study of any possible linear or monotonic relationship between the variables. The framework includes discussion of how to calculate the incident rate, a method for classifying the countries according to their works layout and signing practices, and the underlying theory behind correlation analysis.

This document also discusses the current level of incident data and exposure data that would be necessary to fully inform this methodology and calculate the correlation using real data. The aim was to combine the two work streams to identify any relationship between the number of incidents and the provisions of layouts requirements for road works. However, a number of issues have been identified during the project and have led to associated recommendations.

Data levels do not allow a quantitative assessment regarding the comparison within and between groups with similar levels of provision.

Insufficient data are available to fully inform the correlation analysis in terms of being able to calculate the injury accident rate for each country. This is due to the lack of road works data that are collected in most countries, meaning that road worker exposure cannot be calculated.

Collecting these data on road works in general could provide significant added value and extend the use of the EuRoWCas-compliant dataset by facilitating and enabling further benchmarking and comparison across the countries of Europe.

These issues provide further evidence of the potential benefit for a EuRoWCas database

7 References

SHESKIN, David J. *Handbook of parametric and nonparametric statistical procedures*. CRC Press, 2003