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BRoWSER: Base-lining Road Works Safety on European Roads

D12.1 & D13.1 – Recommendations for consistency of road works in Europe

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CEDR Call2012: Safety
BRoWSER: Base-lining Road Works Safety on European Roads

Recommedations for consistency of road works in Europe

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1 Introduction

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

Examining what signing layouts road users experience when travelling through road works starts building an understanding of why accidents may happen. This may be critical to decreasing injuries to road users and road workers from accidents caused by poor signing layout or confusion between layouts in different member states.

A previous work package on the project collated and analysed the national performance standards and guidance documents for seven EU countries: Austria, Belgium (Flanders) Germany, Ireland, Norway, Slovenia and the UK (England). The aim was to identify any particular common good practices and to seek evidence for any significant differences such as omission of particular elements of signing or delineation.

This document builds on this work in order to identify recommendations for road works across Europe. These recommendations aim to provide more consistency between countries but with a focus on those harmonisations that are critical to road worker safety. Consideration is also given to those recommendations that are the most feasible to implement. Section 2 considers the conclusions of similar work that has previously been done in this area. Section 3 summarises the output of BRoWSER work package 7 regarding similar practices and significant differences, along with a discussion of the opportunities for improvement. Section 4 considers two case studies for accident data collection and associated recommendations and Section 5 discusses the conclusions and outlines the recommendations for the project.

2 Related studies

Road Works in eight EU countries – Chances for standardisation in guidelines, Arcadis (December 2014)

As part of the cooperative working group between the national road authorities of the Netherlands, England, Germany (Nordrhein Westfalen) and Flanders, the 'road worker safety' workstream was asked to produce an action plan for harmonization of works layouts on motorways.

Arcadis company has been commissioned to carry out a study to identify any opportunities and threats that could arise as result of introducing an international standard for the layout of equipment and traffic measures used for road works. This involved examining the guidelines, legislation and any innovations and recent developments related to road works in eight European countries (Austria, Belgium, Germany, Denmark, France, United Kingdom, Luxembourg and the Netherlands) and subsequently compiling an inventory for analysis and comparison. In addition, relevant projects and research associated with road works in each country was also evaluated.

The report focusses on the characteristics of the vehicles and equipment used in the different countries together with the different road works configurations which involved looking at five different aspects including announcements and traffic warnings, speed reduction, traffic guidance, lane closures and safety measures for road workers. Once the analysis and comparison had been undertaken a number of similarities between the countries' road work guidelines had been identified, including:

- All countries use short-term and long-term road works which have varying durations;
- Six different types of vehicles and equipment are used in the majority of the countries (i.e. cones, beacons, barriers, delineation marking, warning sign and movable action sign) with three (traffic cones, advanced warning signs and moveable action signs) being utilised across all eight of the countries studied;
- The use of the equipment for various road works configurations is comparable across all of the countries;
- All countries use at least three advanced warning signs upstream of work zones together with speed reduction measures.

Conversely the differences between the countries' road work guidelines include:

- Even when guidance is similar, every country interprets the details differently which means that the use some of the equipment and road works configurations can vary;
- The use of traffic cones and/or bollards to guide traffic through work zones differs;
- The distances between warning signs and speed reductions upstream of the work zone can vary;
- There are differences regarding the guidance of traffic between lanes and the use of moveable action signs between the transition sections upstream of the road works;
- The guidelines which specify the way road workers and the works zone itself should be protected differ in terms of the vehicles and equipment used.

With regards to regulations all of the countries studied did not view the guidelines as statutory. They are also interpreted differently whereby some countries see them as stringent requirements and others only view them as recommendations for implementing road work measures. In addition, national legislation in each country differs, for example the minimum retroreflective capability of sign films may differ in each country.

In terms of recommendations for the formation of an international standard this can be broken down into two stages; process and content. With regards to the process it would be necessary to carry out a step-by-step approach using the following:

- An appropriate action plan to consider the required phases, their purposes, planning and the incorporated countries;
- An agreed philosophy for road work safety to focus on the safety of road works, the protection of road workers and how best to put those into practice;
- To use the same sectioning of the road work area;
- To involve other countries in the development of new equipment.

With regards to the content the following recommendations should be adhered to:

- An EU guideline must have the capacity for each country to add their own national issues;
- The development of an international guideline should be implemented in stages and there should be room for expansion. It may also be necessary to only make an agreement over topics with relatively few countries at the outset and expand it over time;
- National and international studies should be continually undertaken to ensure countries do reach an agreeable international standard;
- All national legislations must be amended to meet the international guidelines.

The conclusion was that the first step towards international cooperation on road works was to make agreements on a small scale between the four involved authorities (Rijkswaterstaat, Highways Agency, Straβen NRW and Agentschap Wegen en Verkeer). The recommendations made for these authorities as first steps were:

- An agreement on acceptance of other countries' equipment for those with the same appearance (notably where the road user will recognise it). This should possibly be implemented initially through a pilot study.
- Development of a joint philosophy or policy on the safety of road works, equipment and the risk to road workers, to form a basis for standardization of layouts and equipment.
- Joint development of a process for bringing in new technologies and equipment, in particular using existing characteristics and measurements where they are already in use, developing a central risk analysis for auditing new technologies and keeping other parties informed of developments
- Looking for 'quick-wins' for road works safety, e.g. use of rumble strips.

Towards Safer Work Zones – A constructive vision of the performance of safety equipment for work zones deployed on Ten-T road, European Union Road Federation (2015)

A European Union Road Federation Working Group analysed and compared the national guidelines, legislations and cases in connection with the equipment deployed in road work zones in order to identify best practices, improvements and formulate appropriate performance guidelines. The ERF Position Paper focuses on the performance of the safety equipment used for securing road work zones (i.e. restraint systems, delineators, warning lights, vertical signs, temporary markings and other equipment) on the Trans-European Transport (TEN-T) road network.

The projects method primarily comprised of four key stages:

- A survey of the current practices for work zone equipment which was launched to target member states which requested different types of safety equipment deployed in work zone areas;
- A functional analysis was carried out following the results from the survey which involved analysing which types of equipment were commonly used in the majority of the EU countries;
- Reviews were undertaken for each type of road equipment that is commonly used in EU member states to ensure safety in work zones, such as restraint systems and warning lights;
- Risk assessments were undertaken by a panel of experts to evaluate if the equipment does contribute to the safety objectives.

Following on from the risk assessments a number of minimum requirements for the reviewed safety equipment were established which applied to the equipment's performance whilst in use; based on specific elements such as:

- Collective expertise;
- Practices in member states;
- State of the art;
- Feasibility;
- Market acceptability;
- Best practices.

Furthermore, the feasibility of using each type of safety equipment was examined and an additional set of criteria for the assessment of the costs to deploy the safety equipment was formulated, for example implementing temporary road markings was identified as a low cost practice whereas employing impact attenuators was classified as medium cost due to, among others, the fact that the work zone design and layout may require some modification. Once this had been undertaken it would enable the Work Zone Safety Project to set minimum performance levels for the equipment to enable them to be effective with regards to functionality and safety.

PRAISE: Preventing Road Accidents and Injuries for the Safety of Employees, European Transport Safety Council (2011)

PRAISE principally aims to develop work-related road safety management and provide information to employers who have to assume that responsibility. In addition, it aims to present the work-related road safety standards of EU member states and it carries out advocacy work at the EU level.

The PRAISE Thematic Report 6's focus is to improve the safety for employees and road users in relation to work zone areas on and adjacent to roads. Specifically, the report examines the three stages involved when working on or near roads namely, planning, installation and removal of work zones and management of the work zone. At each of the stages the key safety issues are identified and considered and good practice solutions with regards to road work zone safety are suggested.

The planning stage encompasses minimising the road works strategically by designing and implementing low maintenance roads and by introducing lay-bys and safety pull-off maintenance areas to provide a safer working environment. The procurement, planning of the work zone in terms of safety, risk assessments and safety plans, the safety of personnel, the requirement for compulsory training and transport management planning are also discussed.

The installation and removal of work zones stage covers training for personnel who install work zones, the requirement for the necessary infrastructure (such as temporary markings and traffic cones) to be in place, the necessity for Impact Protection Vehicles upstream of the workers and using signs and overhead gantries to inform road users of upcoming road works.

Finally the management of the work zone stage included an array of facets including, but not limited to, the safety of work zone personnel, signage and the work zone layout.

For each of the three stages a number of relevant case studies were also examined in various EU countries and several recommendations were derived for work-related road safety employers, EU member states and the EU as a whole.

European Commission (DG MOVE) Working Group on Road Works (2013)

As a result of a proposal by the EU Committee on Road Infrastructure Safety Management, an informal working group was set up to discuss making road works safer. The working group met twice, on 17 April 2013 and 30 September 2013. The two meetings resulted in the following five themes being identified:

1. Classification of road works.

Analysis showed that there are widely differing approaches to the classification of road works. Whilst a classification is often needed for contractors and authorities, and sometimes made available on authority websites, it is not generally communicated to road users. A uniform representation of this information could be of use to navigational technologies.The recommendation was that Member States should encourage this information to be shared.

Additionally, mobile road works were felt to be a case with particular safety issues and worth further specific study.

2. Geometrical requirements at road works.

It was agreed that European guidelines on geometrical minimum safety values would be very difficult to implement in practice due to local variations.

3. Step-wise reduction of speed limits.

Many Member States already use the basic principle of reducing speed on the approach to road works (on motorways) through a series of gradually-reducing speed limits. The ASAP project, which forms part of the 2012 CEDR research programme, has recently looked at the technical parameters involved. The recommendation from the working group was to consider formalizing this step-wise approach.

4. Signals and equipment on work sites.

The Vienna Convention regulates signalling in most Member States and allows a certain flexibility with regards to the different colours used for permanent and temporary road markings and signs. However there was some uncertainty as to the different sets of colours used across Member States and the recommendation was that information on the use of colours for permanent and temporary road markings and signs should be collated and made available.

5. Use of technical standards at road works.

Most Member States apply mandatory requirements on equipment and material used at road works, using European standards where they exist. Where they don't, national standards have been developed and analysis from industry has shown that these national standards are largely equivalent for equipment used on motorways. The initial conclusions suggested that there may be consequences for equipment providers of harmonizing the standards, but that there are no obvious implications for road safety. To fully understand the range of standards applied across Member States, more study would be needed on the applicability of the different technical standards, guidelines and semi-regulatory docments. The recommendation was to encourage Member States to share national guidelines for road works.

A further recommendation resulting from the Working Group was that the availability and collection of information relating to (traffic) accidents at work sites should be studied. This has been a focus of the BRoWSER project and has led to the development of the proposal for the EuRoWCas database.

ASAP (Appropriate speed saves all people) CEDR project[1]

It is important that European road users are presented with consistent traffic control techniques, regardless of where they travel within Europe. Speed management of traffic through work zones is important for the safety of both the road user and road worker. A transnational resource for best practice guidelines and financial implications of work zone speed control is not available in Europe. A common information source should be made available if European road users and road workers are to have the best level of safety, regardless of the country or region. The ASAP project - Appropriate Speed saves All People - was designed to address the issues of speed management in work zones.

[1] http://asap.fehrl.org

As part of this project a review of work zone speed limits practices has been conducted for several European Countries, Canada, the United States and Australia. This state of the art study demonstrated that a number of criteria are being used by these countries for assigning a work zone speed limit; i.e.: road type, original posted speed, workers presence or roximity of workers to the traffic passing, duration or length of road works, lane width, impact on traffic flow, changes in road surface properties, presence of crossovers and changeovers. The five first being the most common in the reviewed documents.

Although some of the criteria listed above are used by countries to assign work zone speed limits, there is a great variation in how the factors are used to define speed limits. Some countries have documents describing small speed reductions, but others used multiple levels of 20/30 km/h speed reductions. Another issue with the existing guidelines is that many speed limits are not automatically assigned but are based on the judgment of the analyst [2].

Experience has shown that the level of compliance with speed limits is very much dependent on the credibility of the speed limits (i.e. in line with the drivers' expectations). When the speed limits are credible a positive effect is expected on average driving speeds and on homogeneity of the traffic flow. Literature indicates that the safest traffic flow occurs when all vehicles are travelling at approximately the same speed; hence homogeneity of speed is also important. As mentioned above several criteria for setting the speed limits are common, but are not necessarily exploited in all European countries; they are candidate criteria a road manager may use to derogate from classical speed limit schemes and they also represent a chance for harmonization of practices[3]:

- The original posted speed, or the original speed level (if higher) compared to the appropriate speed level in the work zone (How large reduction is needed?);
- The proximity and protection of workers: the level of worker protection sets the framework for the needed speed reduction. Working with a larger lateral safety distance, with additional buffer zones or installing high-performance safety barriers may give opportunities to avoid one step of speed limit reduction; while a lower level of worker protection may cause for an extra step of speed limit reduction;
- The design of the lane shift or of the crossover: softer lane deviation (smaller deviation angle, larger curve radius), improved pavement evenness and friction, and slightly larger lane width (e.g. with a neutral zone between adjacent lane to mitigate sideswipe collision risk); provided worker safety is not negatively impacted;
- The impact on traffic: in some circumstances the impact on traffic may be reduced by adapting the phasing of works that may impact space necessary for work and circulation of the work vehicles, and/or the cross-section, i.e. lane width coupled with the use of safety barriers.

The ASAP project also gathered detailed existing data and results from speed management systems in use to provide knowledge and guidance from previous experience with speed

[2] Nocentini, A. La Torre, F., Thomson, R. (2014). State of the art on speed management methods. ASAP project deliverable 2.1.
[3] Sorensen, G., Bolling, A., Vadeby, A., Cocu, X., Nocentini, A., Aleksa, M., Saleh, P. (2015). Towards a European guideline for speed management measures in work zones. ASAP project deliverable 5.1.

management programs in road work zones. A general descriptive analysis was conducted based on these data to identify some general conclusions and recommendations[4] about:

- Speed limits: there is no common European standard for speed limits and maximum speed limits range from 50 to 100 km/h. It is essential that the speed reduction prior to the work zone is smooth to produce low speed variations close to and within the work zone. The first speed sign should be about 750m to 700m in front of the entrance -the last around 350m;
- Lane management: lane reductions should be avoided to maintain traffic volumes. A minimum lane width of 2.75 m for cars and 3.25 m for trucks is recommended and excessively wide lanes (over 5 m) should be avoided. Especially in the entrance areas and the median crossovers an adequate lane width must be ensured;
- Safety measures: physical separation (barriers) provides the best safety. Low beacons also improve safety but high positioned beacons were not able to promote desirable speed variations;
- Enforcement devices: dynamic information displays provided with radar enforcement equipment were an effective way to reduce speeds in work zones. Section enforcement prior to the work zone has not been studied in Europe. Visible police enforcement was also an effective approach to reducing speeds;
- Standardisation process: European guidelines to strictly standardise work zones are not recommended due to diversity of work zone types and road use.

[4] Saleh, P., Aleksa, M., Etl, F., Stütz, R., La Torre, F., Nocentini, A. (2014). Experience of speed management in practice. ASAP project deliverable 3.1.

3 Common practices and significant differences in traffic management

As previously discussed the previous work package described the practices for road work signing and equipment for six typical and relevant road work situations: major, minor, mobile road works on motorway and on single carriageway (80/90 km/h) road from the standards and guidance of a selection of European countries for which the information was accessible to the project partners. Similarities and differences were determined for advanced warning, transition area or vehicles, temporary speed limit schemes and lateral safety distance, lane width and delineation of the work zone, with a particular focus on areas where similar arrangements are used to convey different messages, thus carrying a risk of confusion for the road user.

Section 3.1 repeats this information for reference; similar practices; i.e. conveying similar message to the road user, and significant differences across standards; i.e. omissions or differing practices, are presented here in parallel.

Section 3.2 provides the discussion about opportunities to improve road work signing consistency between countries.

3.1 Common practices and significant differences

3.1.1 Advance warning (fixed signs & dynamic signing)

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major road works on motorway: First road works warning sign typically installed between 3 to 2 km upwards of WZ (except for Norway), supplemented by a queue warning (or far advance road works warning) between 5 to 3 km upwards of the WZ. The road work warning sign is usually repeated when approaching the transition area. Pure road work warning is complemented by lane management signs installed at different locations depending on the country (cf. right column about differing practices)	Major road works on motorway: In Flanders queue warning is managed through dynamic systems where other countries report that the standards only impose the use of static signs. Germany reports having no standard on queue warning. Distance between successive signs differs largely between countries; e.g.: ○ In Flanders, drivers get a warning message around every 500m (from 3500m to 250m upwards the work zone. Particularly they are informed about the temporary lane management four times between 3000m to 250m; ○ Other countries report larger steps (1500m on average) between successive signs. Main differences refer to temporary lane management signing. Orange/yellow background are standard in some countries where others use white background.
Minor road works on motorway: The same road works warning philosophy applies as for major RW. Only location may shlightly differ. One should notice Germany and Austria seems having more differences between both road works types (cf. right column about differing practices). Their minor road works layout is more similar to the mobile road works layout.	Minor road works on motorway: As for signing of major road works the distance between successive signs differs between countries. Germany, Austria and Norway outstandingly reports that standards do no include road works warning before 1000m upwards the transition area.
Mobile road works on motorway: In all countries mentioned in this report the group road work vehicle/ safety (block) vehicle(s) is being preceded by at least one advance	Mobile road works on motorway: Standards for advance warning upwards of mobile road works largely differ across European countries (in number, location and

warning vehicle located a few hundred meter (from 300m to 1000m depending on the country) upwards on the emergency lane or on the shoulder. However the number of advance warning vehicles depends on the considered country (up to 3 in UK and IE; cf. differing practices).	equipment) as reported in chapter **Error! Reference source not found.** §a. In Germany and Austria TMA are not usual. The back of the advance warning vehicle typically displays the temporary lane management. The signing might by static or dynamic. While the type of signs is quite similar (flashing lights, light arrow, lane management, road work sign) across the standards considered in this report, the design and colors of are not homogeneous (cf. chapter **Error! Reference source not found.**).
<u>Major road works on single carriageway road</u>: Along single carriageway roads road works warning is usually composed of “Road works ahead” and overtaking interdiction static signs. These signs are typically located in the last few 100m preceeding the lane reduction.	<u>Major road works on single carriageway road</u>: Along single carriageway roads road works warning are located in the last 400m preceeding the lane reduction, exept for Ireland (i.e. in the last 1000m).
<u>Minor and mobile road works on single carriageway road</u>: Standards are here more heterogeneous (likely linked to the lower impact such works have on the traffic; cf. differing practices at right column).	<u>Minor road works on single carriageway road</u>: As shown by the table in chapter **Error! Reference source not found.** §a, some countries mentioned in this report use a sequence of “Road works ahead” and overtaking interdiction static signs along the last 400m (1000m for Ireland) upwards the transition areas, where Germany and Austria only uses an advance road works warning in case of limited sight distances. <u>Mobile road works on single carriageway road</u>: Where Flemish, German and Austrian standards do not impose any advance warning, UK,Ireland and Norway do; i.e. the basic layout establishes two advance signs with a distance over which hazard extends.

3.1.2 Transition area/Vehicles

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major road works on motorway: When the number of lanes must be reduced traffic flows are usually merged by inserting the fastest lane to the slowest one. Successive transition zones are used in case of multiple lane closures. The lane shift (typically from 120m to 265m depending on the number of shifted lanes) is progressively introduced through a combination of signing and equipment ranging from cones to panels and from marking to studs or even cylinders.	Major road works on motorway: The interdistance needed between successive transition zones (multiple lane closure) isn't homogeneous across Europe, as are the visual characteristics of the transition area; i.e.: Following the standards analysed for the purpose of this report, tapers may be delineated by panels (e.g. Germany, Austria, Slovenia & Flanders) or by cones (e.g. UK and Ireland). Safety barriers may be in use depending on the local conditions;much variation also exists to separate adjacent lanes: yellow/orange temporary marking with a neutral zone (e.g. Germany Austria, & Flanders) or a combination of marking and studs or studs and cylinder (UK and Ireland).
Minor road works on motorway: On short-term works the equipement used to shift a lane or guide traffic along adjacent lanes are typically quickly moveable devices like cones and panels.	Minor road works on motorway: One should notice that German standards specify that the lane shift is being composed of a safety vehicle (truck type) mounted with a light flashing arrow (i.e. no taper with cones). Warning trailer are used in Norway.
Mobile road works on motorway: In all countries mentioned in this report the road work vehicle is preceeded by a safety (block) vehicle mounted with a TMA and a light arrow sign, in Germany and Austria without TMA. The distance between these vehicles ranges from 50 to 100m. However the number of advance warning vehicles depends on the considered country (cf. differing practices).	Mobile road works on motorway: Standards mainly differ by the number (one or two) of safety vehicles use in the back of the work vehicle, by the distance between the vehicles, by the equipement used (with or without a TMA) and by the design of the signing used on the back side of the vehicle (cf. chapter **Error! Reference source not found.**).
Major road works on single carriageway road: On the majority of countries consulted the lane is closed through a transversal (90°) fence (i.e. Flanders) or a 45° taper (a 1:10 taper in Germany) executed with cones or panels (i.e.Ireland, Norway,	Major road works on single carriageway road: Transversal (90°) fence or a (45°) taper with executed with cones or panels are both practices found in Europe to close a lane on such road work. Warning trailers are also mentioned in the Nowegian

Slovenia, UK). The visibility of both closure mecanisms is ensured; i.e. by reflective strips, flashing lights and/or lamps.	standard.
Minor road works on single carriageway road: Standard practices are similar to the one deployed for major RW, except for Germany (cf. Significant differences at right column).	Minor road works on single carriageway road: As for minor road works on motorways Austrian, German and Norwegian standards specify that the lane must be closed shift by a safety vehicle (truck type) mounted with a light flashing arrow and not through a taper. Minor road works layout in Austria, Germany and Norway is more similar to the mobile road works layout.
Mobile road works on single carriageway road: The working vehicle must be appropriately signed; e.g. flashing lights, keep left/right sign. However the use of a preceeding safety vehicle is not mandatory in all the countries or depends on the local road conditions.	Mobile road works on single carriageway road: Standard practices largely differ, particularly about the signing of the work vehicle and the use (or not) of a safety vehicle (e.g. not mandatory in Flanders and Norway, well in Germany and optional in UK and Ireland depending on the local consitions).

3.1.3 Temporary speed limit schemes

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major road works on motorway: On the majority of countries the standard speed limit is 70 - 80 kph. An additional speed reduction, i.e. up to 50 – 60 kph in special cases is possible.	Major road works on motorway: In all the countries analysed in this report the speed limit decreases by successive steps of 20 to 30km/h. However the location of the speed limit signs (and therefore the length of the transition zones) is highly heterogeneous.
Minor road works on motorway: Standard speed limit is 70 – 80 kph, with the exception of Germany (100 km/h) and U-K (temporary speed limit not required).	Minor road works on motorway: More variation is observed here (as compared to major RW) for what concerns the speed limit reduction; the location of the speed limit signs being again highly heterogeneous.

Mobile road works on motorway: When in use the standard temporary speed limit is 80 – 100 kph.	Mobile road works on motorway: Half of the national standards analysed do not use any speed limit reduction (Austria, Ireland, Norway). Some others (UK, Flanders, Slovenia) temporarily install a (20 kph to 30 kph) speed reduction in some circumstances.
Major road works on single carriageway road: The standard temporary speed limit is 50 km/h. Depending on the original posted speed intermediate speed limits are being installed.	Major road works on single carriageway road: In UK standards there is more emphasis on direct risk management than on speed management itself. Again the location of the speed limit signs is highly heterogeneous, as for road works carried out on motorway.
Minor and mobile road works on single carriageway road: Standard speed limit is 50 km/h, with the exception of Germany and Austria (no speed limit).	Minor road works on single carriageway road: No temporary speed limit in Germany and Austria. In UK standards there is more emphasis on direct risk management than on speed management itself (i.e. reduction of speed limit is not mandatory).
Mobile road works on single carriageway road: The speed limit is usually not reduced for such RW.	

3.1.4 Lateral safety distance, lane width & delineation of the work zone

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major road works on motorway: Standard lane widths are 3,00 to 3,25 for HGV lanes, 2,75 (exceptionally 2,50m in Germany) to 3,00 for light vehicle lanes. In Slovenia standard lane width depends on speed limit. Safety barriers only as an option (e.g. depending on the speed limit),	Major road works on motorway: Two groups of countries with differing lateral safety distances: 50 cm in Flanders and Germany, 120 cm in UK and Ireland. A larger lateral clearance is even required in Norway (i.e. 3m). On the contrary Austrian and Slovenian standards do not fix a minimum requirement for lateral safety distance. Slovenian standards liaise

standard delineation by panels or beacons.	lane width and speed limit requirements. UK allows using cones to separate work zone to traffic lane.
Minor road works on motorway: Standard lane widths are not defined, exceptionally in Flanders and Slovenia (liaise with speed limit). Standard delineation by cones, optionally (Slovenia, Belgium) by safety panels.	Minor road works on motorway: Two groups of countries with differing lateral safety distances: 50 cm in Flanders and Germany, 120 cm in UK and Ireland. Austrian, Norwegian and Slovenian standards do not fix a minimum requirement for lateral safety distance
Mobile road works on motorway: Standard delineation (if any) by cones.	Mobile road works on motorway: Two groups of countries with differing lateral safety distances (when specified by the standards): 50 cm in Flanders and Germany, 120 cm in UK.
Major and minor road works on single carriageway road: Standard lane widths are 2,75 to 3,25m, if defined. Standard delineation by cones or by safety panels.	Major and minor road works on single carriageway road: Two groups of countries with differing lateral safety distances(when specified by the standards): 50 cm in Flanders and Germany, 120 cm in UK and Ireland.

3.2 Opportunities to improve road work signing consistency between countries

The following elements emerged from the description and analysis of road work signing practices (following standards) in Austria, Belgium, Germany, Ireland, Norway, Slovenia and UK. Categorised under four key road work parameters they are considered as issues that should be addressed to improve the consistency of road work signing and equipment across Europe. Ideas for harmonisation of practices and equipment are given below and should provide benefit to road users and road workers safety.

Advanced warning

- Harmonisation of road works legibility particularly with respect to "amount" of signing, distances between successive signs used for road works warning and lane management and the background sign color (address questions: How much? Where? How?)
- In particular, more consistent location and use of equipment for advance warning upstream of mobile RW. Mobile road works on motorways often raise a lot of safety concerns, particularly when they are executed on the slow lane (used by the trucks). A lot of progress has already been done to help drivers detect the upcoming work zone in due time; e.g. vehicles carrying dynamic LED matrix, repetition of warning vehicles on the verge or emergency lane. Now it appears necessary to draw recommendations from these differing practices and where possible to target more homogeneity across Europe
- Standards for signing of minor and mobile road works on single carriageway roads appear to be more heterogeneous than for motorways. However even if road works on lower class roads may appear to be less critical because supporting lower traffic volume and at lower speed road workers may also be at risk. More consistent signing based on the best European practices (i.e. a sequence of "Road works ahead" and "no overtaking" static sign road works s along the last few 100m, or advance signs upstream of the mobile road work with a distance over which hazard extends, up to the use of a safety vehicle where required by the local conditions) is therefore also desirable for road works carried out along these roads .

Transition area / Vehicles

- The design of the central reserve crossing (or lane shift for minor road works) on motorways offers many opportunities to improve the consistency of road work signing across European countries. Indeed this type of road work leads to much variation in what concerns the lane shift geometry (should be adapted to the temporary posted speed limit and amount of road workers protection), the delineation and the equipement used to guide users of adjacent lanes. However at this stage it appears difficult to state what equipment performs best.
- Standard practices differ as regards to the safety vehicles deployed to close (a) lane(s) for mobile road works on motorways. As for advance warning

recommendations should now be drafted based on the experience gained across Europe. Key issues are related to the number of safety vehicles deployed in the lane and the distance between them (road workers safety), the use of TMA (road user safety) and the design of the signing used on the rear of the vehicles (visibility and conspicuity of the work zone directly impacting both workers and users safety). This conclusion is also valid for mobile road works on single carriageway roads where standard practices largely differ, particularly regarding the signing of the work vehicle and the use (or not) of a safety vehicle.The analyses of European standards reveal that different methods are being used to close a lane on single carriageway roads where major or minor works are executed; i.e. a transversal (90°) fence or a (45° or 1/10) taper with executed with cones or panels or a safety vehicle mounted with a light flashing arrow. This diversity of methods demonstrates again that these road work situations are good candidates for a better harmonisation of practices, based on an analysis of which ones best perform.

Temporary speed limit schemes

- For major road work on motorway a good homogeneity is achieved across Europe concerning the temporary speed limit (typically up to 70 - 80 kph) and the progression of how the speed reduction is introduced (steps of 20 to 30km/h). However a lack of homogeneity is evident concerning the location of the speed limit signs. Literature clearly demonstrates that driver behaviour is highly impacted by the credibility of the speed limit. This latter parameter should therefore be further considered and temporary speed limit signs located so as to introduce a smooth speed reduction as far as possible in line with road user driving expectations.
- Minor and mobile road work sites on motorways suffer from the same lack of homogeneity. On these sites even the speed limit reduction is highly variable from one country to another (e.g. 70kph up to 100 kph for minor road works or even no temporary speed limit reduction required). A more consistent approach may therefore be necessary, provided other road work characteristics (typically the equipment used to protect road workers) are taken into consideration.
- On single carriageway roads the standard temporary speed limit along major road works is 50 km/h (except for U-K that only recommends a speed limit reduction). Standards largely divergeconcerning the implementation of temporary speed limits for minor road works. For both types, a more consistent approach may be favourable to fit to drivers expectancy while ensuring road worker safety.

Lateral safety distance, lane width & delineation of the work zone

- Along major road works carried out on motorways the lateral safety distance, lane width & delineation of the work zone must be considered together as they usually depend on the total width of the carriageway, the dimension of the work zone, the space necessary for the movements of the work vehicles as well as on the need to access and exit from the work area. Homogeneisation of standards in these fields appears therefore difficult. However best practices could be identified for some typical scenarios. In these scenarios HGV lane widths ranging from 3,00 to 3,25m

and from 2,75 to 3,00m for light vehicle lanes should be considered as standard. Decisions on lateral safety distance and selection of delineators should be supported by field experience and risk evaluation (for which detailed accident data are necessary).

- On motorways the work zones of minor road works are typically delimited by cones, optionally by panels. However data are missing to identify which equipment performs best. On one side road worker risk exposure can be limited by using quickly moveable equipment (e.g. cones) and on another side, road user perception of the work zone may be positively impacted by more visible equipment (e.g. safety panels). At this stage highly visible and quickly moveable solutions (e.g. min 70cm high cones with reflective strips) seems to be good practice.
- Considering the likely lower level of road worker protection (cf. discussion above) it seems reasonable to suggest reviewing the conditions for the (longitudinal) safety distance requirements for minor road work on motorways (they are currently not fixed in some countries) and, in a second step, considering how to homogenize them.
- These two last elements are also valid for mobile road works executed on motorways for which workers on foot are exposed to traffic.

4 Recommendations from data collection

In this section, recommendations arising from two accident data collection case studies are considered (one case study is from the BRoWSER project, the other from the ASAP project).

Slovenia

DARS, Motorway Company in the Republic of Slovenia (https://www.dars.si/) manages and maintains the motorway network of length of 539 km. The Health and safety department initiated and formed a simple database of road workers accidents and near-misses in 2008. A DARS representative provided available information on number of incidents related to road works on motorway network for 2008-2014. The data in the table below show that the number of incidents varies from 2.5 collisions per 100km of motorway in 2009 to 5,2 collisions per 100km of motorway in 2014.

	Number of incidents			
Year	**hard shoulder**	**driving lane**	**overtaking lane**	**sum**
2008	5	3	2	10
2009	4	6	2	12
2010	6	8	3	17
2011	9	10	7	26
2012	8	9	2	19
2013	8	5	2	15
2014	8	14	6	28
sum per lane	**48**	**55**	**24**	

The DARS existing database provided information for some of the fields specified in the BroWSER proposal for database on road works incidents. However the usual set of data had to be enlarged to fill the fields of the proposed BroWSER data collection.

In 2015 the data was collected on motorways according to the Browser project recommendations.

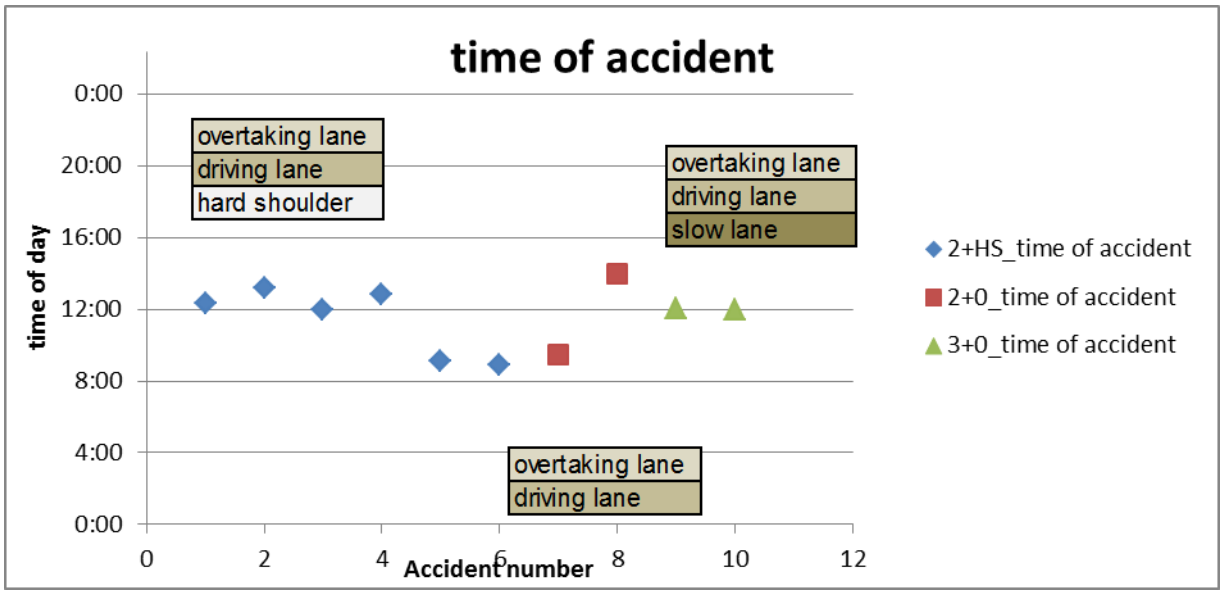
The number of incidents in the time period January 2015 – July 2015 is small (ten) so statistical analysis is not relevant. However the following conclusions may be drawn:

The data collected showed that most of the accidents happened during temporary closures with the mobile type of closure (designated K3, V2, V4 and V13 in national Guidelines).

In ten validated incidents in 2015 on motorways only DARS equipment was involved in nine cases, in one incident one road worker was injured.

- 6 accidents were described as severity 1 - little damage, no injuries of road workers

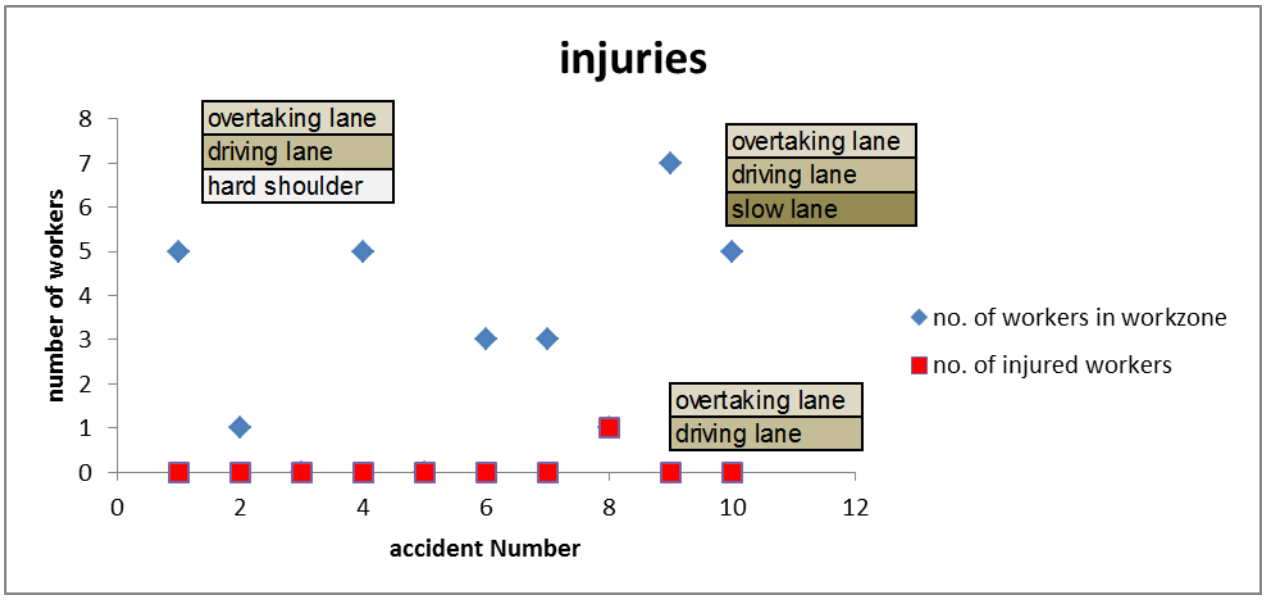
- 3 accidents were described as severity 2 - large damage to equipment, no injuries of road workers
- 1 accident was described as severity 4 - severe injuries of road workers



Two incidents happened on a motorway section with 2 driving lanes (no hard shoulder - No 7,8). Two incidents happened on a motorway section with 3 driving lanes (no hard shoulder - No 9,10) and six incidents happened on a motorway section with 2 driving lanes and a hard shoulder.

Since the majority of motorways have 2 driving lanes and a hard shoulder the results are not surprising. The percentage of section with 3 driving lanes and no hard shoulder is the smallest.

All road closures were mobile – lasting only in the daylight conditions. The usual working hours af DARS staff is from 6:30 to 14:30 so is it no surprise that most of the inicidents happened between 8:00 and 14:00.



In all cases the length of roadworks was less than 1000m and the temporary speed limit was 80kph. In eight cases the signal trailer or impact attenuator were hit from the rear; in two cases the incident happened at 100m and 500m distance after the beginning of lane closure.

In all cases weather was fine and dry; there were no visibility constraints at the time and position of lane closure.

For protection of road workers, mobile road works raise the most safety concerns. Mobile road works are used most frequently – for setting up major roadworks, for maintenance works, for protection of obstacles etc. Therefore a reasonable recommendation would be to improve the safety at the beginning of the road closure – through advance signage and arrangement of protective equipment as well as enforcing a reasonable speed limit.

Italy

An accident analysis in Italian work zones using existing data has been carried out within the framework of the ASAP project.

Using a set of Motorway work zone data, this analysis provided information on the change in expected crash frequencies associated with the installation of work zones. The aim of this study was to evaluate the effect of different work zones' layout configurations on fatal + injury crashes (the posted speed limit within a certain work zone depending strongly on the work zone layout).

The safety performance of motorway segments before the introduction of a work zone and during the work zone period was evaluated, in order to investigate the work zone impact on the number of expected crashes. Thus a "pre-work zone" and a "during-work zone" analysis was conducted in this study. The study required information on the work zone layouts, start and end dates, location of work zones, length, crashes during the pre-work zone and work

zone periods, and other information such as the annual average daily traffic (AADT) in each segment [5].

The main findings of the analysis can be summarized as follows:

- the overall crash frequency, during the time when a work zone is installed on a motorway segment, is about 32 % greater than the crash frequency on the same motorway segments in the “pre-work zone” period;
- the Crash Modification Factor (CMF) due to the work zone varies widely among the different layout configurations;
- the highest CMF is observed for the scheme characterised by a crossover with partial diversion of the flow, with a single lane available for the traffic flow which is not diverted;
- the results also indicate that all layout configurations that involve a crossover (total or partial) are very critical and have the worst effects in terms of safety.

However even if work zones with crossovers appear to have higher accident rates than work zones with simple lane closures. The ASAP parners noted that full crossovers, on the other hand, allow for a safer management of the work zone area for road workers without the traffic flowing nearby. These type of layouts are also necessary for some type of work activities that require the full carriageway. Partial crossovers, on the other hand, are often used to reduce the backup queues than can be generated by the full crossovers in highly traffic sections that can cause a migration of crashes to sections before the work zone itself, as well as in situations where an interchange is included in the work zone area.

ASAP partners therefore recommended that the road operators consider all these effects when defining the optimal work zone configuration.

[5] Saleh, P., Aleksa, M., Etl, F., Stütz, R., La Torre, F., Nocentini, A. (2014). Experience of speed management in practice. ASAP project deliverable 3.1.

5 Discussion and recommendations

One of the aims of the BRoWSER project is to identify recommendations to improve the consistency of road works management and layouts with a view to reducing the risk to road workers present in the works zone.

Assuming that most risk to road workers present in the works zone arises from the road users driving past the works zone, what is clearly needed is a commonality in approach to ensure risk of accidents at road works zones is minimised. The justification for this central recommendation is that road users will base their response to road works zone signs, signals and delineation devices based on their previous experience. Therefore, by ensuring consistency it will be possible over time to reduce road user errors in response to road work zone signs, signals and delineation and so reduce risk to both road workers and road users.

Achieving consistency will be challenging. While it is clear that there are areas of commonality, this study has shown these areas are not widespread and there are significant differences between practices across Europe. It is therefore suggested that what is required is:

- A common typology / language for road works such that NRAs can understand what features need to be applied where within the road works zone
- A common core approach so that key features from within the common typology are used in the same way and so are familiar to road users, reducing accident risk
- A common minimum standard that defines the common typology and approach, which is supported at EU level and so is accepted, implemented and monitored by NRAs
- A data framework linked to the common typology, approach and standard that can identify when, where and how accidents happen in road works that injure road workers

Based on the work carried out for BRoWSER and other EU research projects (such as STARs, ASAP, PRAISE) and work by others such as DG-MOVE and ERF it appears that there is a clear understanding of the first requirement. Efforts have even been made to achieve the second, on a limited basis, via the work carried out by Arcadis for the UK, Germany, the Netherlands and Belgium. This demonstrates there is potential to develop a framework under which harmonisation can occur, even if this is limited in the short-term to core work zone features defined in the common typology.

A common conclusion from the previous studies in this area is the need to take small steps to approach the ultimate aim of harmonising European best practice at road works. Development should start with those elements where there is already a lot of agreement between Member States and to leave the more complicated topics until later. To further this aim several of the studies (including BRoWSER) have identified similar practices (and significant differences) between specific groups of European countries.

If recommendations focus on those areas where similarities have been identified, this will increase the likelihood of implementation as the existing practices will in theory be relatively easy to adapt to make small changes for greater consistency. The issue of practical implementation is an important one to consider when making the recommendations, as it must be feasible for road authorities and / or contractors to accede; this must include consideration of legislative and regulatory barriers that be present and other obstacles that may apply.

As well as feasibility of implementation, in the context of the BRoWSER project, the recommendations are focussed on road worker safety, i.e. priority is given to those elements where harmonisation will improve the safety of road workers. However, road worker safety and road user safety are inextricably linked, as the most severe accidents with the highest injury severity outcome are usually associated with impact between road user vehicles and unprotected road workers. Therefore, while reducing accident risk for road workers in work zones may not necessarily reduce risk for road users, reducing road user accident risk at road works will almost certainly reduce risk for road workers within the work zone.

Therefore, it is recommended that all activities to improve road works zones for road users should be directly linked to improvements in risk for road workers and road users. This is important, as otherwise changes to road works zones which improve risk for road users (for example by the use of stepped speed limits, requiring the installation of additional speed limit signing) may increase risk for road workers. However, even basic measures like the harmonisation of practices will, in the short term, improve safety indirectly by improving the comprehension of road users through greater consistency between works zones.

Consistency in speed reduction is another area where road user behaviours can start to be changed and so reduce risk for both road user and road worker. At present, there are a wide range of approaches to speed management at road works. A consistent approach taken across Europe would support building the expectation that road users should reduce their speed past works zones, ensuring that risk is reduced.

Several of the studies have suggested that mobile works are potentially one of the biggest sources of risk for road users (and hence for the road workers involved in their use). The same principles apply to mobile works as to static work zones, namely consistency and common standards driving road user expectation and consistent response on approach to a mobile works site, resulting in lowered risk. This requires the same approach of typology, core approach and common minimum standard to drive reductions in road user and road worker risk.

Quantifying the benefit to road users and road workers from small, incremental changes towards harmonised standards such as those proposed will be extremely challenging if pan-European data are not available. The introduction of a data framework linked to the common typology therefore becomes critical, as without its widespread adoption there is little prospect of demonstrating the safety benefits from initial adoption of a low-key/quick-win approach to developing and implementing an initial typology, core approach and minimum standard. Sound data collected from EU countries where NRAs are implementing the minimum standard would support demonstration of the differences in risk associated with implementing the minimum standard, as well as identifying where changes in typology, common approach or operational practices would achieve greatest risk reduction.

It has previously been identified and has been confirmed through the BRoWSER project that more detailed information is needed regarding accidents at work zones. It was shown through the data collection trial carried out for the project that such collection is feasible and that there is appetite for collection from the necessary stakeholders. A large element of the project has been focussed on defining the data specification for a pan-European road worker casualty database (EuRoWCas) and providing guidance for implementation and input for the benefits case for National Road Authorities. For each of the countries involved in the data collection trial, the level of current data collection has been assessed against the EuRoWCas 'maturity matrix' which provideas a measure of the extent, the frequency, the application, the quality and the compatibility (with the EuRoWCas specification) of the data collected.

We therefore make five recommendations from the work carried out for the BRoWSER project:

National Road Authorities need to adopt a common typology for road works

This needs to define both a typology for fixed and mobile works as well as a typology that allows for effective description of the elements in a road works zone or mobile work site. This will link to the information gained from data collection (see Recommendations 4 and 5) in terms of identifying the elements most associated with road worker accidents.

A suggested typology for elements would be as suggested in WP7:

- Advance warning
- Transition area
- Work Zone
- Exit Zone
- Temporary speed limit zone (taking in any or all of the above zones)
- Safety distances and delineation within the Work Zone

National Road Authorities within Europe need to agree a common core approach for road works zone elements defined within the common typology

Elements of this have been explored by a number of NRAs. There are considerable advantages from ensuring a common core approach:

- Consistency of experience for road users, allowing them to build expectation for how road works zones look and the expected behaviours when driving in work zones
- Consistency of equipment, breaking down barriers to trade across the EU and promoting development of new technology that would not be cost-effective to develop for one market
- Consistenct of procurement, allowing NRAs to jointly procure equipment or services in volume, thus benefiting from the economies of scale available from such activity

It is highly unlikely that a common core approach can be developed that can be adopted immediately by all European NRAs. However, there is sufficient core commonality that some

aspects could be harmonised rapidly, allowing for the core approach to be established and then expanded over time.

The common typology and core approach need to be supported at EU level to promote adoption and harmonisation across Europe

European-level support for a core approach and common typology need to be supported at EU level, together with the EuRoWCas database concept. Without formal EU backing, there is little prospect that the activity required to implement these changes will be possible

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National Road Authorities need to adopt the EuRoWCas database concept and specification and promote it to other appropriate in-country organisations.

One aspect that could provide significant added value and extend the use of the EuRoWCas dataset is the collection (or increased collection) of data on road works. Information relating to the frequency and duration of works on the network would allow an estimation of the exposure of road workers, and hence provide the possibility of calculating road works accident rates. This would in turn facilitate further benchmarking and comparison across European countries.

National Road Authorities need to ensure they undertake regular and accurate collection of data, including duration of works to enable calculation of incident rate.

Exposure data for the duration of works is important for placing the EuRoWCas data into context and allowing effective comparison between NRA performance with and without the core approach. Its collection is considered essential and would reflect the typology, recording works against the different classes within the typology to ensure consistency across Europe.