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CEDR Contractor Report 2016-2

CEDR Call 2012: Safety

Final Programme Report
ASAP and BRoWSER Projects

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ASAP and BRoWSER Projects

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The aim of the CEDR Transnational Road Research Programme is to promote cooperation between the various European road administrations in relation to road research activities. The topics covered by this Call were developed by TG Research to fulfil the common interests of the CEDR members.

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Table of contents

Executive Summary

This Final Programme Report covers two projects (ASAP and BRoWSER) from the CEDR Research Call 2012 on Safety, which address key issues around road worker and road user safety. Funding was provided by the national road authorities of Belgium (Flanders), Germany, Ireland, Norway, Sweden and the UK.

The ASAP project - Appropriate Speed saves All People - looks at recommending the best methods of controlling speeding through roadwork zones. The BRoWSER project - Baselining Roadworks Safety on European Roads - considers two aspects, improving data collection on worker injuries and near misses, and understanding the optimum roadworks layouts that enable road users to approach, travel through and exit works without causing injury to workers and others.

Both the ASAP and BRoWSER projects directly relate to the safety of people who work on roads who are directly exposed to risks from road user activities. These include all people engaged in construction, maintenance and renewal schemes, vehicle recovery operators and any other activities where live traffic is present including traffic management and incident support services. The aim is to reduce risks to road workers with an ultimate objective of Zero Harm. To achieve this requires better information on incidents across Europe, consideration of standards applicable to works, analysis of the effects of vehicle speed on the risk to the workforce and examination of work zone inspection regimes.

This report presents the main outcomes from the BRoWSER and ASAP projects and aims to bring together the conclusions and recommendations of the projects, based on the final project deliverables and conclusions from the three dissemination workshops carried out after the completion of the projects.

In moving towards a more common European approach for roadworks with respect to speed management, layouts and data collection, increased collaboration and cooperation between countries is of major importance. There is potentially great benefit in sharing best practice between different countries, but also between organisations and authorities within the same country. Increased harmonisation and sharing of best practice may allow national road administrations to utilise the experiences of others to facilitate and accelerate deployment within their own countries.

There are obvious challenges in implementing a common pan-European database which includes all relevant data. Although a Europe-wide roll-out of a full database would be extremely difficult, benefits can be achieved in small increments. Currently there appears to be such a serious lack of data that any improvement would be of use. In some cases, the issue may be more a lack of access to the data, or a lack of knowledge of which data already exist as well as who is the responsible body. Possible bodies that might be able to support data collection through the use of existing data are hospitals, insurance companies and contractors. Small steps in this area could have a big impact.

The general lack of data about road worker accidents as well as discrepancies between countries as regards roadwork layouts motivates action on European level as well as EU-specific initiatives. The question of who should implement the harmonisation process is open. The question has been passed to the CEDR Task group on Road Safety.

1 Introduction

This research was commissioned by the Conference of European Directors of Roads (CEDR). CEDR is an organisation that brings together the road directors of twenty-seven European Road Authorities. The aim of CEDR is to contribute to the development of road engineering as part of an integrated transport system under the social, economical and environmental aspects of sustainability and to promote co-operation between the National Road Authorities (NRAs). The CEDR website www.cedr.eu contains a full description of its structure and activities.

CEDR recognises the importance of research in the development of sustainable transport and has established a Task Group (TG) to monitor European research activities and to advise the CEDR Governing Board on issues relating to research. TG Research responsibilities include dissemination of research results as well as initiating research programmes that support CEDR members in current and future situations.

As part of this dissemination activity, this report covers two projects from the CEDR Transnational Research Call 2012 on Safety which address key issues around road worker and road user safety. A third project focused on vehicle restraint systems (VRSs) is reported separately. Funding was provided by the national road authorities of Belgium (Flanders), Germany, Ireland, Norway, Sweden and the UK. Further details on this research programme are available at http://www.cedr.eu/home/index.php?id=260.

The three projects covered by the 2012 Research Call on Safety were:

- ASAP - Appropriate Speed saves All People - which focuses on recommending the best methods of controlling speeding through roadwork zones
- BRoWSER - Baselining Roadworks Safety on European Roads - which considers two aspects, improving data collection on worker injuries and near misses, and understanding the optimum roadworks layouts that enable road users to approach, travel through and exit works without causing injury to workers and others
- SAVeRS - Selection of Appropriate Vehicle Restraint Systems - which has developed a guidance document for NRAs for the design, selection and installation of VRSs.

Both the ASAP and BRoWSER projects directly relate to the safety of people who work on roads who are directly exposed to risks from road user activities. These include all people engaged in construction, maintenance and renewal schemes, vehicle recovery operators and any other activities where live traffic is present including traffic management and incident support services. It excludes traffic officers, police, ambulance, fire and rescue service staff.

The aim is to reduce risks to road workers with an ultimate objective of Zero Harm. To achieve this requires better information on incidents across Europe, consideration of standards applicable to works, analysis of the effects of vehicle speed on the risk to the workforce and examination of work zone inspection regimes. This report presents the conclusions recommendations from the ASAP and BRoWSER projects, which directly seek to address these requirements. This enables all those in a position to influence decision

making to take action to reduce risks to road workers. Whilst this research is primarily focussed on road worker safety, it is important to note that road user safety is directly linked to work activities and workers' safety to road user behaviours. The research is therefore vitally important to both parties. The key elements of the research activities are as follows:

- Collection, analysis and presentation of data on incidents affecting road workers across Europe. This includes near miss incidents, as well as incidents where injury or death of a road worker has occurred.
- Consideration of the standards for roadworks and the way in which the layouts and information provided to road users aids driver perception and influences their behaviour, for the benefit of road worker safety.
- Analysis of the effects of speeding and enforcement of speed limits through roadwork zones.
- Understanding the way in which NRAs optimise the risk balance between road workers and road users.
- Defining a standard of inspection for work zones to ensure that minimum safety requirements are met.

As part of the dissemination of the results for the two projects, the three following workshops were organised during autumn 2015:

- 8th October 2015 – TRL, Wokingham, UK
- 29th October 2015 – BRRC, Brussels, Belgium
- 10th November 2015 – CDV, Brno, Czech Republic.

The aim of this final report is to bring together the findings and recommendations of the projects, based on final project deliverables and conclusions from the dissemination workshops carried out after the completion of the projects. The report is structured into two parts: presentation of the projects and implementation.

2 Presentation of the projects

2.1 ASAP - Appropriate Speed saves All People

2.1.1 Project facts

Partners from five different European countries participated in the ASAP project, which ran from February 2013 to January 2015. VTI coordinated the project and the partners were:

- VTI, Swedish National Road and Transport Research Institute
- AIT, Austrian Institute of Technology GmbH
- BRRC, Belgian Road Research Centre
- CDV, Transport Research Centre (CDV)
- UNIFI, Università di Firenze.

The ASAP project produced four deliverables which are available at the project website: http://asap.fehrl.org/. These deliverables are:

- State of the Art on Speed Management Methods (D2.1)
- Experience of speed management in practice (D3.1)
- Speed Management at Work Zones – Field studies and stakeholders survey (D4.1)
- Towards a European Guideline for Speed Management Measures in Work Zones (D5.1)

2.1.2 Background and objectives

Speed management in work zones is important for the safety of both the road user and the road worker. Appropriate speed is needed to ensure that the driver can navigate the vehicle through the work zone layout, without causing the vehicle to enter the restricted areas of the work zone. Vehicle encroachments into these areas can cause injury to the car occupants and the road workers. Selection and control of traffic speeds in work zones are thus crucial components for road safety. It is also important that road users are presented with consistent and understandable measures, regardless of where they travel within Europe. A work zone entails deviations from normal travel in a discrete road section and may include abrupt deviations from road design norms. Without proper control of their vehicle, a driver may collide with other vehicles, run off the road, or even enter the restricted areas of the work zone. Vehicle encroachments into these areas can cause injury to the vehicle occupants as well as the road worker and may also damage work equipment and vehicles.

Speed management in work zones is important for the safety of both the road user and the road workers.

The ASAP project was designed to address the issues of speed management in work zones. Hence it is intended to help achieve the appropriate speed levels in work zones by recommending suitable speed management methods. The project activities aimed to collect,

analyse and propose harmonised work zone speed management methods using both European and global work zone safety data available to the project team. In this way the project addressed three key elements of the development of harmonised documents for European work zones:

1) Review of previous successes,
2) Retrieval of available data to confirm and monitor best practices, and
3) Consultation of stakeholders to identify the format and scope of information needed for European applications.

The objective of the ASAP project was to provide a best practice document that can be applied across Europe with recommendations as how to effectively manage speed through roadwork zones.

2.1.3 Methodology

The structure of the ASAP project is shown in Figure 1.

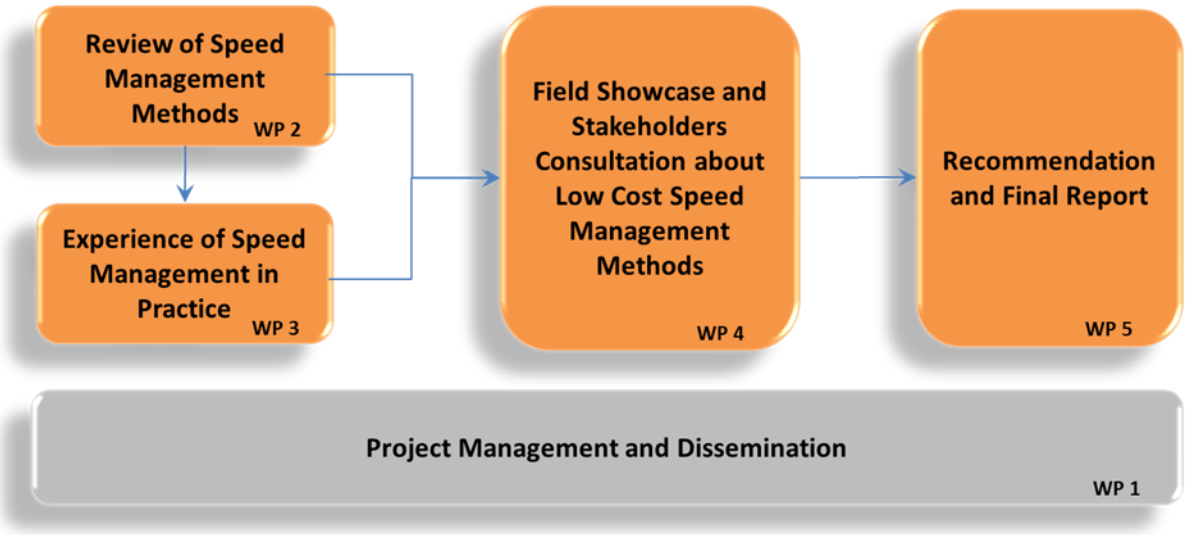

Figure 1. Structure of the ASAP project.

First, both theoretical and practical information was gathered within work package 2 - Review of Speed Management Methods. About 270 research reports and scientific papers, as well as national guidelines were collected, reviewed and gathered in a single database where all the documents were classified according to the main topic, authors, title, references, year of publication and the status (“ongoing” or “completed”). The database can be downloaded from the ASAP website (http://asap.fehrl.org/).

Work package 3 - Experience of Speed Management in Practice, aimed at providing knowledge and guidance based on previous experience with speed management programs in roadwork zones, including on-going projects, and identifying the practical usability and effectiveness of selected specific speed control systems and measures preferred by the National Road Authorities. The work package gathered existing data and results from speed management systems in use. As part of this objective, a data collection exercise relating to work zones in Europe and the USA was conducted.

This work resulted in the selection of low cost speed management methods that were either demonstrated in field showcases in the Czech Republic and Belgium or tested in a driving simulator study in Italy in work package 4 (ref D4.1). Furthermore, in this work package stakeholders were consulted on the subject of appropriate speed and associated parameters.

In work package 5 the project findings were analysed and are summarised in the final report and a best practice guide / check list was set up. The different analyses performed during the project produced a number of implications for the development, layout and dissemination of the ASAP results in general and the ASAP guidelines in particular.

2.1.4 Outcome

The ASAP guidelines can be used for choosing the best methods to achieve appropriate speed behaviour in work zones. Before using the ASAP guidelines, considerations of capacity and construction needs and identification of the appropriate speed levels have to be carried out. After this initial speed management procedure, the ASAP procedure assigns the speed management method(s). This is done preferably in the planning phase before installing the work zone or as quality assurance that the work zone speed management measures chosen are appropriate. It could also be an important tool if it is discovered that the measures currently in use are not efficient in reducing the speed levels. Hence, if the appropriate speed is not achieved or is not likely to be achieved, the ASAP guidelines can be used to find other or complementary recommended speed management measures. The basic conditions to achieve appropriate speeds levels at roadwork sites may be summarised as follows:

the selected ‘appropriate speed levels’ are appropriate for the local roadwork design, and the road and pavement characteristics

the selected ‘appropriate speed levels’ are credible in each area along the roadwork site, including not only the work zone area but also the advanced warning area and the transition areas;

the risk of exceeding the appropriate speed level is eliminated and the speed variance is low, so that the accident and injury rates become low.

The ASAP procedure for roadwork speed management is presented in Figure 2.

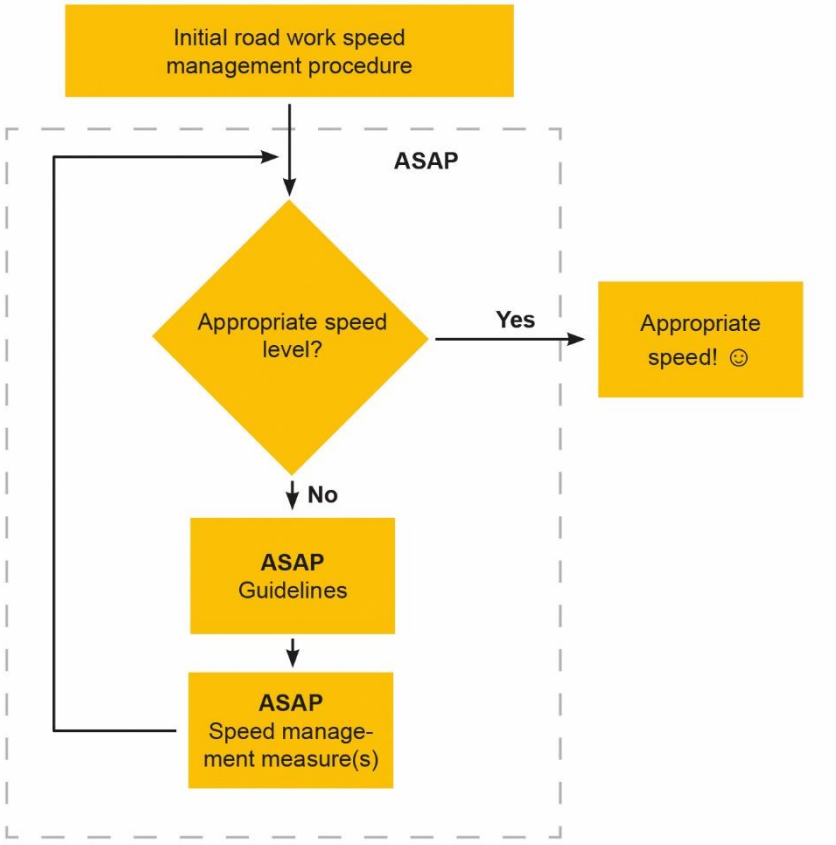

Figure 2: The ASAP procedure of roadwork speed management.

The ASAP guidelines suggest 23 different measures that can be used to achieve appropriate speed in work zones:

1. Temporary speed limit reduction – Static speed limit sign
2. Temporary speed limit reduction – Variable speed limit sign
3. Advisory speed sign
4. Automated speed enforcement – Spot speed cameras
5. Automated speed enforcement – Section control
6. Driver speed monitoring display
7. Speed camera with worker warning
8. Speed camera sign
9. Police presence
10. Police dummy
11. Graduated fixed penalties
12. Chicanes
13. Crossover design
14. Narrowed lane widths
15. Temporary separation of directions

16. One-way traffic control – Manual flagger
17. One-way traffic control – Automated signal devices
18. One-way traffic control – Pilot vehicle
19. Rumble strips – adhesive
20. Rumble strips – portable
21. Optical speed bars
22. Variable message signs
23. Emotional messages.

In Annex A, the potential additional speed reduction (compared with the speed level without the measure in question) as found in the literature is also listed. Some of the speed management measures reduce speeds by only a few kilometres per hour compared with a work zone without this particular measure. However, even when only small speed reductions are achieved, these reductions may still be crucial when it comes to worker safety. In addition, drivers are alerted to an upcoming work zone or work zone related hazard. Most of the measures used for controlling work zone speeds have limitations in terms of effectiveness. Hence, combinations of measures are often used and usually increase the effect.

The ASAP guidelines divide the measures into clusters based on their suitability for different road types and due to different roadwork characteristics. The distinguishing parameters were road type, works type and location in roadworks. The parameter classification chosen was:

- road type:
    - motorway and dual carriageway
    - single carriageway;
- roadworks type:
    - long-term roadworks (> 3 days)
    - short-term static roadworks (≤ 3 days)
    - intermittent or moving roadworks;
- location of measure in roadworks
    - advanced warning area
    - transition area
    - work zone area.

Depending on the type of road and type of roadwork, the ASAP guidelines recommend measures (see Annex A) and provide a description of each measure and their advantages, application fields, expected impact, on-site deployment issues and cost components. The guidelines provide solutions to achieve appropriate speed on different road types and roadworks, independent of country. Detailed results from the different work packages can be found in the project deliverables and associated papers (La Torre et al., 2013, Saleh et al., 2014, Sorensen et al., 2015, Vadeby et al., 2016 and Thomson et al., 2014).

2.2 BRoWSER: Baselining Road Worker Safety on European Roads

2.2.1 Project facts

The BRoWSER project ran from February 2013 to October 2015 and involved partners from five European countries, namely:

- TRL, UK (Project Coordinator)
- BRRC, Belgium
- Karlsruhe Institute of Technology, Germany
- Trinity College Dublin, Ireland
- ZAG, Slovenia

The BRoWSER project produced ten deliverables available at the project website http://browser.zag.si. The deliverables are:

- Benefits case
- Input data definition
- Interim trial report
- Final trial report
- Baseline report
- Database specification and design
- Database specification and design - Visualisation extension
- European Road Worker Casualty database (EuRoWCas) – guidance and information
- Standards and guidance analysis
- Correlation analysis report
- Recommendations for roadworks consistency.

2.2.2 Background and objectives

Base-lining Roadworks Safety on European Roads (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 roadworks 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 was 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 allows consideration of road worker accidents, incidents and near misses (where

available) alongside data for roadworks practices, network characteristics and road user accident data at roadworks.

CEDR, in the call for the 2012 programme, set the vision of zero road worker injury accidents. This is consistent with many of the major pan-European companies who work in roads construction and maintenance who each have their own vision for zero accidents. Adopting this at European level would require vision and leadership from the European Commission, underpinned by a strategy to reduce risk via knowledge-based interventions.

Delivering the knowledge based interventions requires understanding that can drive action. In turn, understanding requires information and data to provide a sound foundation. BRoWSER underpins the data, information and understanding by providing the framework for a pan-European database (EuRoWCas – European Road Worker Casualty Database) to make the data into usable information.

Success of the EuRoWCas database and realisation of the benefits requires action at a European level. In support of this, BRoWSER provides:

- Evidence that it can work, including pilot data
- Roadmap and toolkit for how it can be done
- Demonstration of the benefits
- Recommendations for consistency of roadworks.

2.2.3 Methodology and outcome

There were two work-streams in the BRoWSER project: one looking at the collection of road worker incident (accident and near miss) data collection across Europe; the second considering the standards and guidance governing roadworks layouts and traffic management in different countries and identifying recommendations for consistency across Europe.

The data collection work-stream formed the majority of the work carried out on the BRoWSER project. The benefits of a European Road Worker Casualty Database (EuRoWCas) were identified early in the project through a stakeholder consultation exercise with NRAs. These are summarised as:

- Benchmarking and monitoring performance:
    - Benchmarking internally within a country or region, monitoring performance over time and impact of policy changes
    - Benchmarking internally between contracting firms and/or by project, monitoring performance over time and impact of policy changes
    - Cross-European comparison and assessment (similar sized countries), monitoring performance over time and impact of policy changes
- Determining effectiveness of approach/principles:
    - European level: Larger data source for European research on Road Worker Safety
    - European level: Evidence base to inform European standards and policy development – source of data on what is effective and what is not

- Individual level: Source of data for small nations to use in informing their own policy development

- Case building
  - Case building for investment
  - Quantification of resourcing of road worker safety and comparison between countries.

In order to realise these benefits, and by extension to achieve the overall objectives of the research programme, high-quality and consistent road worker incident data must be collected in different countries. However, based on an investigation of the existing road worker incident data collection, it was confirmed that the collection of this data was not possible with (or without some adaptation to) the existing data collecting processes in the individual countries. Therefore, it was agreed that an additional three-month data collection trial would be carried out to demonstrate the feasibility of such data collection.

The most important outcome of the trial was that it showed that such data collection is practicable, and that it can be achieved through a variety of methods and sources depending on the circumstances in individual countries and the extent of existing data collection. Recommendations for how this data collection could be set up will vary for different countries but the trial demonstrated that different approaches can each achieve good results. The trial also showed that there is appetite for collecting this data and that the potential benefits of doing so are understood by the National Road Authorities, the roadworks designers, contractors and the road workers.

Two important documents that were produced during the project were the database specification and the guidance for NRAs.

The database specification document presented a technical specification for the data fields and associated values, resulting from the findings and experiences of the data collection trial. This covered the format of the data fields, how they should be coded, relationships between the fields and associated options for each field. It also provided an overall concept for the EuRoWCas database system, and discussed specifications for the format of data import, data export, data input interface and data output in support of data visualisation. The overall concept is such that, if the technical specification is followed, the software or operating system used to host a EuRoWCas database does not matter, as the data imported into, stored within and exported from the database will be to a common standard.

The guidance document aims to provide guidance for NRAs wishing to implement a EuRoWCas-compliant database and data collection procedures within their country. In order for a pan-European database to be successfully established, action must be taken at a European level, potentially through a mandate. However, due to the standard data format, EuRoWCas-compliant databases can be set up at national level (or sub-national level) and subsequently imported into EuRoWCas. The guidance focuses on the decisions and actions that an individual NRA would need to take in order to implement databases and data collection processes within individual countries. The same issues and considerations will apply at the pan-European level.

Consideration was also given to the implications of different levels of data collection and availability; this is strongly linked to the benefits that an NRA can realise through the implementation of a EuRoWCas compatible database. Figure 3 shows what an NRA can do with such a database as the level of detail in the data increases.

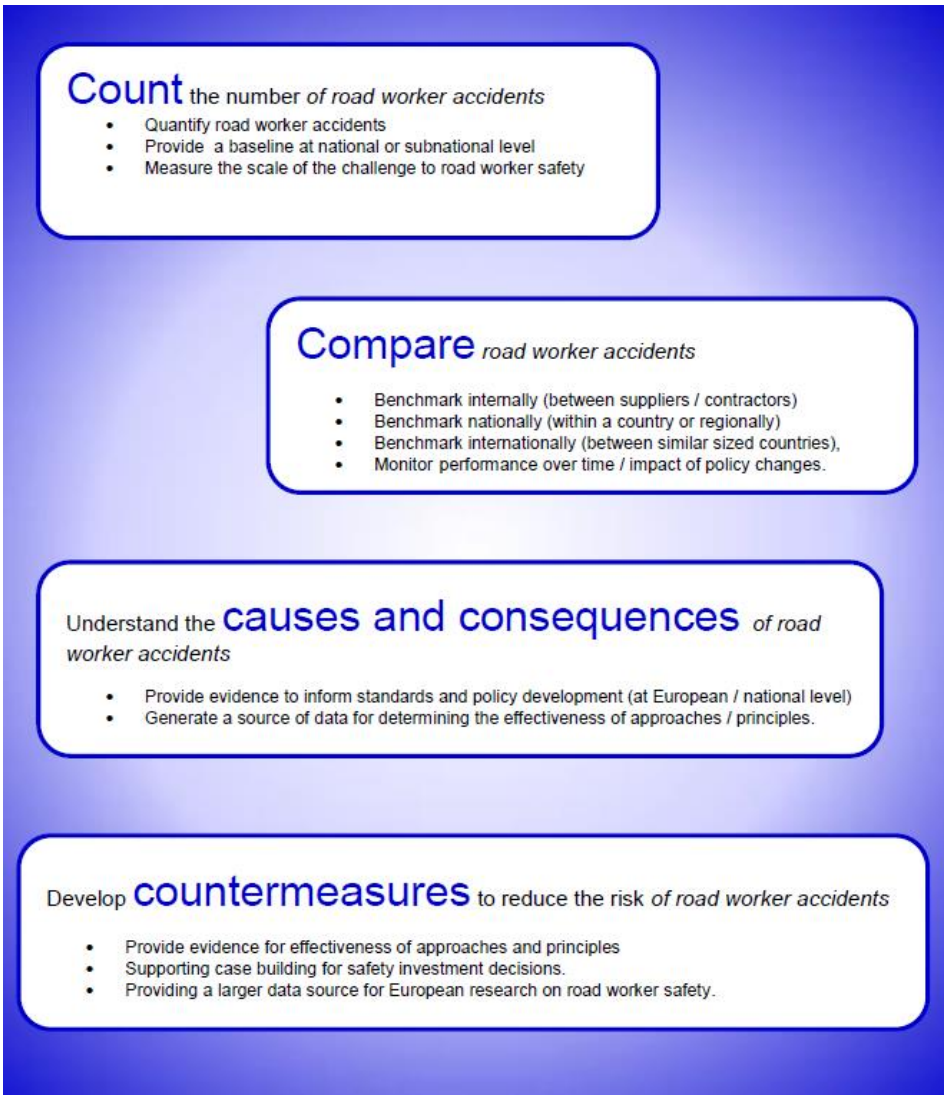

Figure 3: Benefits of implementing a EuRoWCas-compatible database for NRAs, as the level of detail in the data increases.

As part of the guidance, a 'maturity scoring framework' was also developed. This provides a framework for NRAs to assess the current level of road worker accident (and near miss) data collection. This framework scores the collision data collection standard on five 0-5 scales:

- Extent
- Frequency
- Quality
- Application
- Compatibility (with EuRoWCas for road workers)

As mentioned above, with sufficiently detailed data, it would be possible to use these road worker incident data to examine the effectiveness of different approaches and principles in

terms of traffic management and other aspects of roadworks layouts. An initial investigation of this process was considered in the second work-stream. Examining what signing layouts road users experience when travelling through roadworks 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.

The project collated and analysed the national performance standards and guidance documents for seven European 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. The differences and similarities identified are included in Annex B of this report. The issue of harmonisation of roadworks layouts was a major topic of interest at the workshops and a summary of the discussions is included in Section 3.1.2.

Data levels were not sufficient to fully inform a correlation analysis between the road worker incident data and the works layouts and traffic management information. The project used the analysis to identify recommendations for roadworks 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. These recommendations are included in Section 3.2. Detailed information about project results is found in the project deliverables: Charman et al. (2013), Cocu et al. (2015a), Cocu et al. (2015b), Lawton et al. (2015a), Lawton et al. (2015b), Lawton et al. (2014) and Rillie and Cocu (2014).

3 Implementation

3.1 Outcome of dissemination workshops

To disseminate the results from the ASAP and BRoWSER projects and to discuss relevant implementation issues, three dissemination workshops were held, in Wokingham in the UK, Brussels in Belgium and Brno in the Czech Republic. This allowed the participants to choose the most convenient location for attendance. The same programme (excepting some minor local differences) was presented at the three locations. The morning session included a welcome from the local host and key note speech and a general overview of the two projects. The afternoon session focussed more on discussion of practical experiences from the projects followed by some concluding remarks.

At the UK workshop held at TRL, about 20 participants, including project partners, attended, representing the UK, Ireland, Norway, Sweden, Belgium, Italy and Slovenia.

The workshop at BRRC in Brussels was the most popular, with about 45 participants (including project partners) from Belgium, Sweden, the Netherlands, Denmark, Ireland, France, UK and Italy.

The final workshop was held at CDV in Brno and attracted about 30 participants, including project partners, from the Czech Republic, Hungary, Poland, Austria, Ireland, Sweden, UK and Germany.

In total, the three workshops attracted representatives from national road authorities in 10 different countries: the Netherlands, England, Scotland, Ireland, Denmark, Norway, France, Belgium, Czech Republic and Hungary. In addition, participants also represented universities and a significant number of roadwork designers and contractors.

Below, a summary of the issues discussed at the workshops is presented, both separately for both projects and some general conclusions and recommendations.

3.1.1 ASAP

The main outcome from the ASAP project is the ASAP guidelines, collecting information on speed management in work zones. The ASAP guidelines include information on 23 different speed management measures and can be used for choosing the best methods to achieve appropriate speed behaviour in work zones. At the workshops it was stated that this kind of document is both usable and important. There is a need for harmonisation across Europe and the ASAP document is seen as a valuable contribution to initiate discussions on speed management and harmonisation with roadwork designers and contractors in the field.

When the effectiveness of different measures was discussed it became obvious that there is a significant lack of proper evaluation and data to perform evaluations. Many assessments of the effectiveness of measures were anecdotal only and no evaluations based on collected data had been performed. With respect to producing some common European recommendations, the need of proper evaluation was highlighted and it was stressed that such evaluations were needed before the harmonisation process started.

With respect to the discussions on the ASAP guidelines, two recent reports on speed management measures at roadworks were mentioned: one guide from Denmark where

measures similar to those treated in the ASAP guidelines were evaluated on motorways (Horsed, 2014) and one document from ERF (2015) about a vision of the performance of safety equipment for works zones deployed on TEN-T roads

(http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/en/maps.html).

For ASAP, the main discussions focused on the in-field implementation of specific measures. Experiences from participating countries about some measures are summarised below.

Speed limit strategy

The ASAP guidelines do not recommend or suggest the level of speed limits for different roadwork layouts, but the strategy for speed limits was nevertheless discussed at the workshops. It was stressed that it is not always the lowest speed limit that is the best, but that the appropriate speed limit is where the design of the roadworks protects the road worker as well as the road user and allows a smooth transition through the roadworks. It is important to manage variance in speeds as well as to obtain overall speed compliance.

It was also discussed that small reductions in the speed limit might be preferable if it is possible and if the road workers can be properly protected. If large changes in speed are needed, it is recommended to use steps of 20 km/h to obtain a smooth transition. At the UK-workshop, it was mentioned that using increased speed limits (40 mph speed limit replaced by 50 mph) showed a better compliance from HGVs when the speed limit was 50 mph.

It is important for achieving appropriate speeds that speed limits are credible and understandable. This is achieved through careful design of the work zone, so that people are willing to drive within the speed limit and encouraged to do so, not only through physical measures but also psychological measures influencing behaviour. The reason for the new speed limit through the work zone, and consequently the request for a change in behaviour, need to be obvious to the driver and therefore a credible speed limit is of major importance. Since people often react first when they see the reason to slow down, increased enforcement and Impact Protection Vehicles) are suggested to make hazards more visible and create better compliance. In general, it is beneficial to have suitable advance information about the location of the work zone combined with physical measures which lead the road user to safer driving behaviour (appropriate speed) and raise awareness of the on-coming variation in the road section.

Trailer/Gantry with VMS and speed display

Variable Message Signs (VMS) were used in many (but not all) of the participating countries and are often used to supplement fixed signs. The experience is that they are generally effective at that location. Sometimes they are used on long-term roadworks to inform about length of roadworks, the transit time through roadworks and speed limits. Several countries expressed positive experiences of VMS, though they also expressed difficulties in how to prove this effectiveness. There were anecdotal experiences that VMS were effective for a while but after a week or so this effectiveness lessened. A better effect is expected if drivers are informed WHY they need to modify their speeds. With respect to the issue of congestion when using VMS, it was recommended that congestion information has priority.

Experience was shared from the Netherlands where two systems 300 metres apart were used. It was mentioned that whenever there is a lane closed this measure should be used. The experience was that gantry signals are better than signals on the road side since they are often more easy to understand, but on the other hand they are often more expensive. It was mentioned that there are systems available that contractors could borrow.

It was recommended that messages should not be too long, since the experience was that effectiveness reduced if the signs contain too much information. Several countries also expressed positive experiences with combining the speed display with licence plate recognition. This measure can be effective in reducing speed as it can embarrass the driver. Conversely a possible danger can be that people may try to reach a top speed. A suggestion to avoid such negative impacts is not to display "*your speed is xxx*", but only "*you are driving too fast*", for example.

Several countries regulate that a VMS must be protected – sometimes VMS are placed behind a barrier and sometimes the gantry is combined with some impact protection.

One challenge mentioned by participants was the question of power supply since batteries often have to be changed within a week or every ten days. One solution tried was to use methanol fuel which provides several weeks' operation before needing to refuel. Another challenge mentioned was the potential legal issues in some countries. Representatives from the Czech Republic mentioned that some national rules are missing as regards to the installation process, which may cause delays. For speed limit displays, the long time between making the application for a temporary speed limit at roadworks and the decision was also discussed. The general experience from several countries was that it takes between 4 and 6 weeks before the speed limit plan is received. In combination with the short notice (e.g. two weeks) that can often be given for roadworks, this is a serious limitation when planning for speed reducing measures at roadworks.

Enforcement related issues

Enforcement measures that were discussed at the workshops were speed camera signs, speed cameras and manual speed enforcement.

The general conclusion was that the use of speed camera signs needs to be combined with enforcement, otherwise there is a risk that road signs lose credibility and that drivers do not respect this and other signs. If drivers are not always (or at least regularly) subject to enforcement, this will impact the credibility of the signs and the effect may carry over to other types of signs as well. The experience from the participating countries where automatic speed enforcement is common is that drivers look for an enforcement measure, such as yellow camera or police presence and then modify their speeds. In countries where drivers are not used to the signs and automatic enforcement, especially in work zones, a greater effect is noticed, particularly in the beginning. It was also pointed out that signs lose efficiency over time. Experience from the Czech Republic was that the signs had good effect in combination with presence of the police.

Representatives from the UK shared their experience of section control (mean speed enforcement over a road section) at major roadworks. Their experiences were very positive, though with mainly anecdotal 'proofs of effect' since data-based evaluations were missing. There is an uncertainty about whether people moderate their behaviour if they know that not all cameras may be operational all the time. Compliance over long distances might be worse, but experiences from Ireland suggested that compliance is still good at longer roadworks. There is also anecdotal evidence that there is an increase in minor crashes for long stretches (15km or more) because drivers lose concentration.

With respect to speed cameras there is a need to consider legal aspects, since these might be different for different countries. Sometimes a political decision is needed to implement automatic speed cameras. Good communication and relationships with the police are also of major importance when discussing enforcement through roadworks. Speed cameras might

be simpler to implement than police presence. A well-established cooperation between police, NRAs and contractors is necessary. Representatives from Ireland shared an experience where there were too many fines in a work zone area which led to the police wanting a better set of speed reducing measures so that the speeds through the work zone could be reduced. Another issue mentioned was that there might be costs associated with the input from the police if the roadwork should be regularly enforced.

Hungary had minor experience of speed cameras, but was interested to learn more and increase the use. It was also discussed that the media can help with the information about speed cameras.

Crossing of central reserve

In the simulator trial carried out as part of ASAP, two different opening widths of the central reserve were tested. Several countries at the workshops expressed the opinion that there is generally flexibility with regards to the length of the opening width. The crossover needs to be designed appropriately for the speed required and it might lead to drawbacks with additional work and additional paving. Representatives at the workshop expressed that, in the UK, they often design the crossover for a speed limit of 50 mph (~80 km/h); in the Czech Republic 80 km/h and in Denmark that they design the crossover so as to not reduce capacity.

The compliance is often better when the speed limits are higher and such solutions as cross-overs are good for the road workers since they are protected and physically separated from the traffic. The Netherlands use beacons to lead the road users through the crossover and the UK use cones with flashing lights. A drawback with higher speeds at the crossover is that it might cause more accidents for trucks, since the slope change when passing the cross-over is difficult for long vehicles. A longer opening of the central reserve might also increase the risk of potential speeding.

3.1.2 BRoWSER

There were two work-streams on the BRoWSER project: one looking at the collection of road worker incident (accident and near miss) data collection across Europe; the second considering the standards and guidance governing roadworks layouts and traffic management in different countries and identifying recommendations for consistency and harmonisation across Europe. The data collection work-stream formed the majority of the work carried out on the BRoWSER project and led to a proposed European Road Worker Casualty Database (EuRoWCas). At the workshops both the EuRoWCas database and the harmonisation of roadworks layouts were discussed.

EuRoWCas database

There was a clearly positive response of the participants to the idea of a EuRoWCas database and an agreement that it is very important since there is a serious lack of data in many countries and that we need to do more to collect and analyse road worker accidents.

It was discussed and agreed that, although a Europe-wide roll out of a full database would be extremely difficult, benefits can be achieved in small increments. Currently there is such a serious lack of data that any improvement would be of use. For example, incident data on the network in general are often collected by highways authorities or the police – if these data were expanded only slightly to include an indication of whether roadworks were present or not, it would significantly improve the understanding of the issues surrounding incidents at works. Small steps could have a big impact.

Of course, going forward, if the data collection is to achieve all the potential benefits, the more detailed the data set that is collected the better. The level of detail in the database depends on the level of detail reported from the different countries, e.g. if the incident type is reported for several countries, benchmarking of incident types can be made. Quality aspects and control are of major importance if the database is to be useful. One example mentioned was that “Unknown” as a response is very important since it clarifies where data is missing. The quality of data was also discussed in relation to the reporting of near misses - who will report near misses and how the quality can be assured. The UK already has experience of reporting near misses since UK contractors focus on near misses.

There was discussion about who would be responsible for collecting these data and about the need for increased collaboration and cooperation. In many cases, data on roadworks and incidents in roadworks are already collected for various reasons and by various stakeholders. For example, many roadworks contractors are required by law to collect data on incidents that occur within their works, under workplace health and safety laws; sometimes relevant data are collected by the police or by hospitals. This is likely to be different across different countries; in some cases, the data needed already exists, in others new data and data collecting procedures will be needed.

Issues like how to influence insurance companies and contractors to report accidents and incidents as well as data protection issues were discussed at the workshops. It was suggested that it may be possible to use smart phones / apps to collect the data. The main challenge is how to facilitate the data collection; completion of the data record should be done as close as possible to the incident.

The BRoWSER guidance document provides advice and guidance on designing and implementing a database on road worker incidents. It is suggested that NRAs use the maturity scoring index to assess their country situation and provide an action plan for reaching the desired target. Currently England, Ireland and Flanders have plans to implement a EuRoWCas-compliant database.

There was discussion on who would host a European-level database and how this could be implemented. A EuRoWCas-compliant database can be easily implemented on a local level using a simple Access database or similar, however a different platform would be required if a wider implementation was to be attempted.

To be able to implement a EuRoWCas database there would need to be European-level support. One specific idea that was mentioned was that EC funding for building new infrastructure could be conditional on setting up increased data collection on works. Some participants expressed that a bottom-up approach where individual countries decided by themselves was preferable; in either case there needs to be buy-in from stakeholders at all levels.

Harmonisation of roadwork layouts

It was agreed that it would be helpful for roadworks to be more harmonised across different European countries. There was much discussion in the workshops as to the various issues and obstacles that may be encountered in furthering this aim.

It is important that different layouts between countries not create unnecessary incidents due to confusion or misunderstanding of the expected behaviour; this is particularly an issue on continental Europe where cross-border differences will often be encountered. It was also discussed that harmonisation is often more difficult between the UK and Ireland and the rest of Europe, but that this was potentially less important as there are no land borders.

It was agreed that it is important to develop a common typology for roadworks layout and that this is a useful first step towards a common set of European standard terminology for roadworks and towards further harmonisation.

Harmonisation can apply to many aspects of works such as number of signs, location and use of equipment, advance warnings etc. Before harmonisation of techniques and approaches it is important to verify the safest/best layouts with data. This links therefore with the needs of the data collection work-stream and emphasises the importance of collecting robust and comprehensive data on roadworks.

A note of caution was expressed regarding harmonisation – for some Western European countries there is a danger that harmonised best practice may be of a lower safety standard than current operational practice. At the same time, some Eastern European countries may struggle to meet the standards. Different cultures and behaviours in different countries may also present a problem.

As for the data collection, it was discussed that there is great benefit to be achieved with small steps. Full harmonisation across all countries is, at best, extremely difficult, however even just harmonising one individual element of roadworks will improve the consistency. Development of international guidelines can be implemented in small steps, for a small number of early adopters, leading in the long term to a best practice guide for all of Europe.

Also similarly to the data collection, the importance of increased collaboration and cooperation was discussed and agreed. This means that there is potentially great benefit in sharing of best practice between different countries, but also between organisations and authorities within the same country. For example, urban road authorities may have experience of technologies not used by the strategic authorities. In many, if not most, countries it is necessary to prove the benefits of a new approach or new technique through the use of pilot studies. Increased harmonisation and sharing of best practice may allow NRAs to utilise the experiences of others to facilitate and accelerate deployment within their own countries.

3.2 Recommendations to National Road Authorities

It is the role of the national road authorities to implement the relevant results from the CEDR projects. Compared with national research, the CEDR research usually has a broader perspective and can therefore be not as easy to implement directly. However, the projects have a common European perspective and even small steps of implementation towards more harmonisation across countries for roadworks will improve the consistency and can have a great safety impact. Development of international guidelines and recommendations can be implemented in small steps, for a small number of early adopters, leading in the long term to a best practice guide for all of Europe.

3.2.1 ASAP

Depending on the type of road and road work, the ASAP guidelines recommend measures (see Annex A) and provide a description of each measure and their advantages, application fields, expected impact, on-site deployment issues and cost components. The guidelines provide solutions to achieve appropriate speed on different road types and roadworks, independent of country. This information is crucial for all national and local road authorities, roadwork designers and contractors so they can use speed control approaches that have proven to be effective in several countries.

The main result of the ASAP project – the ASAP guidelines – should be regarded by national road authorities as both a supplement to existing guidelines and as a basis for new revisions of national guidelines.

National Road Authorities are also recommended to actively perform dissemination activities and make the ASAP guide available and well-known to their contractors. ASAP partners might support dissemination activities suggested by Road Authorities. All ASAP partners have important roles as national experts and will use the project results in their ongoing work supporting national guidelines and best practice. The ASAP project results will thus continue within each participating country. Many of the ASAP partners are also representatives in different technical committees developing national and international regulations (CEN, ISO, etc.). The ASAP project team has a very wide frame of international cooperation and is actively involved in several road safety panels (e.g. PIARC, EARPA, ERTRAC, EVU, etc.) that will allow transnational exploitation of the results of the project.

Further studies are required in order to address the difficult matter of deciding the appropriate speed, and the important consideration of vulnerable road users at roadworks sites. The development and improvement of the ASAP guidelines should be an ongoing process, involving both researchers and practitioners from all over Europe.

3.2.2 BRoWSER

In order to realise the potential long-term benefits, the BRoWSER project has led to the following recommendations that would be necessary as a first step towards European harmonisation:

National Road Authorities would need to adopt a common typology for roadworks

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 roadworks 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:

- 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 would need to agree a common core approach for roadworks 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 roadworks 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
- Consistency 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 would need to be supported at European level to promote adoption and harmonisation across Europe

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

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

There is a lack of data regarding collisions and near misses at roadworks across Europe. Data on these incidents is necessary in order to inform the understanding of the issues involved and to be able to develop evidence-based strategies to reduce the risk to road workers. As discussed in previous sections, although benefits can be achieved with even minimal data collection on a regional or national level, the more detail that is collected about the incidents the better – the greatest benefits will be realised if detailed data are collected across multiple countries to allow benchmarking of performance and identification of evidence-based best practice techniques and approaches to traffic management and roadworks layouts. Guidance on the EuRoWCas database can be found in the project deliverables, available at http://browser.zag.si

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

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 roadworks. Information relating to the frequency and duration of works on the network would allow an estimation of the exposure of road workers. Exposure data for the duration of works is important for calculating roadworks accident rates and therefore placing the EuRoWCas data into context and allowing effective comparison between NRA performance with and without the core approach. This would in turn facilitate further benchmarking and comparison across European countries. Roadworks data collection is considered essential and would reflect the typology, recording works against the different classes within the typology to ensure consistency across Europe.

4 Conclusions

The safety of workers is extremely important and must be considered when designing roadworks. Both the ASAP and the BRoWSER projects aim to increase the safety for road workers and road users. The ASAP project address the issues of speed management in work zones, with a specific focus on speed reduction measures and treatments in order to increase road safety both for road users and road workers. ASAP provides a guide for choosing the best speed-reducing methods that will result in appropriate speed in work zones. The BRoWSER project aimed to help National Road Authorities enable a data-led approach to be taken to managing road worker safety. The project provided the framework for a European road worker casualty database, with guidance for implementation, the benefits case and recommendations for the consistency of roadworks.

A synergy between the two projects is that similar approaches can be used towards harmonisation and sharing best practices, regardless of whether the specific issue is speed management measures, accident data collection or layouts at roadworks.

In moving towards a more common European approach for roadworks with respect to speed management, layouts and data collection, increased collaboration and cooperation between countries is of major importance. This means that there is potentially great benefit in sharing of best practice between different countries, but also between organisations and authorities within the same country. For example, urban road authorities may have experience of technologies not used by the strategic authorities. In many, if not most, countries it is necessary to prove the benefits of a new approach or new technique through the use of pilot studies. Increased harmonisation and sharing of best practice may allow NRAs to utilise the experiences of others to facilitate and accelerate deployment within their own countries.

There are obvious challenges in implementing a common pan-European database which includes all relevant data. Although a Europe-wide roll-out of a full database would be extremely difficult, benefits can be achieved in small increments. Currently there is such a serious lack of data that any improvement would be of use. For example, incident data on the network in general are often collected by highways authorities or the police – if these data were expanded only slightly to include an indication of whether roadworks were present or not, it would significantly improve the understanding of the issues surrounding incidents at works. Possible bodies that might support the data collection are hospitals, insurance companies and contractors. Small steps could have a big impact.

The general lack of data about road worker accidents as well as discrepancies between countries as regards roadwork layouts motivates action on a European level as well as EU-specific initiatives. The question of who should implement the harmonisation process is open, but European-level support is necessary for pan-European implementation. To be able to implement a EuRoWCas database there would also need to be European-level support. One specific idea that was mentioned was that EC funding for building new infrastructure could be conditional on setting up increased data collection on works. Some participants expressed that a bottom-up approach where individual countries decided by themselves was preferable; in either case there needs to be buy-in from stakeholders at all levels.

CEDR working group in Safety will address these issues.

4.1 Further research

Below some recommendation as regards further studies are briefly described. The suggested topics are based on conclusions from the projects as well as conclusions from the dissemination workshops. Further studies are suggested in the following areas:

- Appropriate speed level through different roadwork layouts

  Lower speed limits do not necessarily lead to fewer accidents. There is a need to know more about driver behaviour and speeds to understand why drivers behave in a certain way. More research is needed to address the difficult matter of deciding the appropriate speed level through different types of roadworks, especially addressing the risk for vulnerable road workers/users. Based on available data study behaviour for different road users (cars, motorcycles, HGVs)

- Effect of combined speed management measures

  Finding best practice and recommendations of how to combine speed management measures. Further study of the impact of (repeated) speed activated signs and VMS; ideally in combination with licence plate recognition and/or police presence/controls.

- Enforcement through work zones

  How can stepped speed limits on approach to works be enforced? How to obtain good cooperation with the police to obtain a high level of enforcement through work zones. Completing and confirming the evaluation of the effectiveness of automatic speed cameras, i.e. evaluating the spatial and temporal effect through more consistent monitoring periods and successive monitoring locations.

- Data collection and further use of available data

  A significant data has been collected – how else can this be used? Contractors often collect data, but do not use them - how can we use such data?

4.2 Further dissemination

In Ireland, results from both the ASAP and the BRoWSER projects are planned to be implemented in the next few years. As a first step towards implementation of ASAP, a large national meeting with Irish roadwork designers and contractors was held on the 19th January 2016 where the main results and the ASAP guide were presented by the ASAP coordinator. Ireland is also planning to include some of the results from ASAP in a NRA advice note during 2016. For BRoWSER, a web-based database with a supporting app for mobile phones is being prepared, where roadworks contractors will be required to register all incidents and near misses in the database. This will be eventually included in Irish standards as a mandatory requirement. This will be introduced to contractors directly employed by TII (Transport Infrastructure Ireland) from January 2016.

To share experiences and best practice between NRAs with respect to the implementation of the two CEDR projects it is suggested that a “follow-up-conference” is held one to two years after the workshops (or when final results and recommendations are available) to follow up implementation of results with road authorities and share experiences.

5 Acknowledgement

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Annex A: ASAP recommended measures

For each measure, the potential speed reduction as found in the literature (compared to the speed without the measure in question) is listed in the table below. Some of the speed management measures reduce speed by only a few kilometres per hour compared with a work zone without this particular measure. However, even when only small speed reductions are achieved, these reductions may still be crucial when it comes to worker safety. In addition, these measures may alert drivers to an upcoming work zone or work zone related hazard. Most of the measures used for controlling work zone speeds have limitations in terms of effectiveness; hence, combinations of measures are often used and usually increase the effect.

A description of each measure and its advantages, application fields, expected impact, on-site deployment issues and cost components is found in project deliverable D5.1 (Sorensen et al., 2015), available on the ASAP webpage: http://asap.fehrl.org/.

Speed management methods – potential additional speed reduction compared to the situation without the measure.

Speed management method	ASAP ref.	Potential additional speed reduction
Temporary speed limit reduction – Static speed limit sign	1	Low–medium
Temporary speed limit reduction – Variable speed limit sign	2	Low–high
Advisory speed sign	3	No data
Automated speed enforcement – Spot speed cameras	4	Low–medium
Automated speed enforcement – Section control	5	No data
Driver speed monitoring display	6	Low–medium
Speed camera with worker warning	7	No data
Speed camera sign	8	Low
Police presence	9	Low–high
Police dummy	10	Low
Graduated fixed penalties	11	Low
Chicanes	12	No data
Crossover design	13	–
Narrowed lane widths	14	Low–high
Temporary separation of directions	15	Low
One-way traffic control – Manual flagger	16	Medium–high
One-way traffic control – Automated signal devices	17	No data
One-way traffic control – Pilot vehicle	18	No data
Rumble strips – Adhesive	19	Low
Rumble strips – Portable	20	Low–high
Optical speed bars	21	Low
Variable message sign	22	Low
Emotional messages	23	Low
Combination of measues	24	

*The sizes of the speed reduction listed above are based on various numbers of studies and the results vary considerably.

Recommended measures – Motorway, long-term roadwork

Work Type	Location in road work	Recommended measures	ASAP ref.
Long-term (>3 days)	Advanced warning area	Temporary speed limit reduction – Static	1
		Temporary speed limit reduction – Variable	2
		Speed camera sign	8
		Graduated fixed penalties	11
		Variable message signs	22
		Emotional messages	23
	Transition area	Temporary speed limit reduction – Static	1
		Temporary speed limit reduction – Variable	2
		Advisory speed signs	3
		Spot speed camera	4
		Driver speed monitoring display	6
		Police presence	9
		Police dummy	10
		Chicanes	12
		Crossover design	13
		Adhesive rumble strips	19
		Variable message signs	22
	Work zone	Temporary speed limit reduction – Static	1
		Temporary speed limit reduction – Variable	2
		Advisory speed signs	3
		Spot speed camera	4
		Section control	5
		Driver speed monitoring display	6
		Speed camera with worker warning	7
		Police presence	9
		Police dummy	10
		Narrowed lane width	14
		Temporary separation of directions	15

Recommended measures – Motorway, short-term roadwork

Work Type	Location in road work	Recommended measures	ASAP ref.
Short-term – Static (≤ 3 days)	Advanced warning area	Temporary speed limit reduction – Static	1
		Speed camera sign	8
		Graduated fixed penalties	11
		Variable message signs	22
		Emotional messages	23
	Transition area	Temporary speed limit reduction – Static	1
		Advisory speed signs	3
		Driver speed monitoring display	6
		Police presence	9
		Police dummy	10
		Variable message signs	22
	Work zone	Temporary speed limit reduction – Static	1
		Advisory speed signs	3
		Speed camera with worker warning	7
		Police presence	9
		Police dummy	10
Intermittent – Mobile	Advanced warning area	Variable message signs	22
	Transition area and work zone	Advisory speed signs	3
		Driver speed monitoring display	6
		Speed camera with worker warning	7
		Variable message signs	22

Recommended measures – Single carriageway, long-term roadwork

Work Type	Location in road work	Recommended measures	ASAP ref.
Long-term (>3 days)	Advanced warning area	Temporary speed limit reduction – Static	1
		Temporary speed limit reduction – Variable	2
		Speed camera sign	8
		Graduated fixed penalties	11
		Optical speed bars	21
		Variable message signs	22
		Emotional messages	23
	Transition area	Temporary speed limit reduction – Static	1
		Temporary speed limit reduction – Variable	2
		Advisory speed signs	3
		Spot speed camera	4
		Driver speed monitoring display	6
		Police presence	9
		Police dummy	10
		Automated signal devices	17
		Pilot vehicle	18
		Adhesive rumble strips	19
		Variable message signs	22
	Work zone	Temporary speed limit reduction – Static	1
		Temporary speed limit reduction – Variable	2
		Advisory speed signs	3
		Spot speed camera	4
		Section control	5
		Driver speed monitoring display	6
		Speed camera with worker warning	7
		Police presence	9
		Police dummy	10
		Narrowed lane width	14
		Temporary separation of directions	15

Recommended measures – Single carriageway, short-term roadwork

Work Type	Location in road work	Recommended measures	ASAP ref.
Short-term – Static (≤ 3 days)	Advanced warning area	Temporary speed limit reduction – Static	1
		Speed camera sign	8
		Graduated fixed penalties	11
		Variable message signs	22
		Emotional messages	23
	Transition area	Temporary speed limit reduction – Static	1
		Advisory speed signs	3
		Driver speed monitoring display	6
		Police presence	9
		Police dummy	10
		Manual flagger	16
		Automated signal devices	17
		Pilot vehicle	18
		Portable rumble strips	20
		Variable message signs	22
		Emotional messages	23
	Work zone	Temporary speed limit reduction – Static	1
		Advisory speed signs	3
		Speed camera with worker warning	7
		Police presence	9
		Police dummy	10
		Narrowed lane width	14
		Variable message signs	22
Intermittent – Mobile	Advanced warning area	Variable message signs	22
	Transition area and work zone	Advisory speed signs	3
		Driver speed monitoring display	6
		Speed camera with worker warning	7
		Variable message sign	22

Annex B: BRoWSER – Standards and guidance analysis

In this section, some of the information from the standards and guidance analysis is presented. The full analysis can be found in the project deliverables on the project website (http://browser.zag.si). This analysis looked at the national standards and guidance documents for Austria, Belgium (Flanders), Germany, Ireland, Norway, Slovenia and England.

In the first part of this section, the summary tables for common practices and significant differences across the standards are presented. This is followed in the second part by a discussion about opportunities to improve roadwork signing consistency between countries arising from this analysis. In both parts, the results are displayed for four works zone elements - notably: advance warning; transition area/vehicles; temporary speed limit schemes; and lateral safety distance, lane width and delineation of the work zone.

B.1 Common practices and significant differences between European countries

Advance warning (fixed signs and dynamic signing)

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major roadworks on motorway: First roadworks warning sign typically installed between 3 to 2 km upwards of WZ (except for Norway), supplemented by a queue warning (or far advance roadworks warning) between 5 to 3 km upwards of the WZ. The roadwork warning sign is usually repeated when approaching the transition area. Pure roadwork warning is complemented by lane management signs installed at different locations depending on the country (cf. right column about differing practices)	Major roadworks 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 is standard in some countries where others use white background.
Minor roadworks on motorway: The same roadworks warning philosophy applies as for major roadworks. Only location may slightly differ. One should notice Germany and Austria seems having more differences between both roadworks types (cf. right column about differing practices). Their minor roadworks layout is more similar to the mobile roadworks layout.	Minor roadworks on motorway: As for signing of major roadworks the distance between successive signs differs between countries. Germany, Austria and Norway outstandingly reports that standards do not include roadworks warning before 1000m upwards the transition area.

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Mobile roadworks on motorway: In all countries mentioned in this report the group roadwork vehicle/ safety (block) vehicle(s) is being preceded by at least one advance 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).	Mobile roadworks on motorway: Standards for advance warning upwards of mobile roadworks largely differ across European countries (in number, location and equipment). In Germany and Austria truck mounted attenuators (TMAs) 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, roadwork signs) across the standards considered in this report, the design and colours of are not homogeneous.
Major roadworks on single carriageway road: Along single carriageway roads roadworks warning is usually composed of “Roadworks ahead” and overtaking interdiction static signs. These signs are typically located in the last few 100m preceding the lane reduction.	Major roadworks on single carriageway road: Along single carriageway roads roadworks warning are located in the last 400m preceding the lane reduction, except for Ireland (i.e. in the last 1000m).
Minor and mobile roadworks on single carriageway road: Standards are here more heterogeneous (likely linked to the lower impact such works have on the traffic; cf. differing practices at right column).	Minor roadworks on single carriageway road: Some countries mentioned in this report use a sequence of “Roadworks 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 roadworks warning in case of limited sight distances. Mobile roadworks on single carriageway road: 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.

Transition area/Vehicles

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major roadworks 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 roadworks on motorway: The distance 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 and 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, and Flanders) or a combination of marking and studs or studs and cylinder (UK and Ireland).
Minor roadworks on motorway: On short-term works the equipment used to shift a lane or guide traffic along adjacent lanes are typically quickly moveable devices like cones and panels.	Minor roadworks 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 trailers are used in Norway.
Mobile roadworks on motorway: In all countries mentioned in this report the roadwork vehicle is preceded 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 roadworks 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 equipment used (with or without a TMA) and by the design of the signing used on the back side of the vehicle.

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major roadworks 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, Slovenia, UK). The visibility of both closure mechanisms is ensured; i.e. by reflective strips, flashing lights and/or lamps.	Major roadworks 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 Norwegian standard.
Minor roadworks on single carriageway road: Standard practices are similar to the one deployed for major roadworks, except for Germany (cf. Significant differences at right column).	Minor roadworks on single carriageway road: As for minor roadworks 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 roadworks layout in Austria, Germany and Norway is more similar to the mobile roadworks layout.
Mobile roadworks on single carriageway road: The working vehicle must be appropriately signed; e.g. flashing lights, keep left/right sign. However, the use of a preceding safety vehicle is not mandatory in all the countries or depends on the local road conditions.	Mobile roadworks 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 conditions).

Temporary speed limit schemes

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major roadworks on motorway: In 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 roadworks 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 roadworks 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 roadworks on motorway: More variation is observed here (as compared to major roadworks) for what concerns the speed limit reduction; the location of the speed limit signs being again highly heterogeneous.
Mobile roadworks on motorway: When in use the standard temporary speed limit is 80 – 100 kph.	Mobile roadworks 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 roadworks 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 roadworks 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 roadworks carried out on motorway.
Minor and mobile roadworks on single carriageway road: Standard speed limit is 50 km/h, with the exception of Germany and Austria (no speed limit).	Minor roadworks on single carriageway road: No temporary speed limit in Germany and Austria. In the UK standards there is more emphasis on direct risk management than on speed management itself (i.e. reduction of speed limit is not mandatory).

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Mobile roadworks on single carriageway road: The speed limit is usually not reduced for such roadworks.	

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

Similar practices (conveying similar message)	**Significant differences** (omissions, differing practices)
Major roadworks 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), standard delineation by panels or beacons.	Major roadworks 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 lane width and speed limit requirements. UK allows using cones to separate work zone to traffic lane.
Minor roadworks 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 roadworks 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 roadworks on motorway: Standard delineation (if any) by cones.	Mobile roadworks 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 roadworks 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 roadworks 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.

B.2 Opportunities to improve roadwork signing consistency between countries

The following elements emerged from the description and analysis of roadwork signing practices (following standards) in Austria, Belgium, Germany, Ireland, Norway, Slovenia and UK. Categorised under four key roadwork parameters they are considered as issues that should be addressed to improve the consistency of roadwork 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 roadworks legibility particularly with respect to “amount” of signing, distances between successive signs used for roadworks warning and lane management and the background sign colour (address questions: How much? Where? How?)
- In particular, more consistent location and use of equipment for advance warning upstream of mobile roadworks. Mobile roadworks 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 roadworks on single carriageway roads appear to be more heterogeneous than for motorways. However even if roadworks 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 “Roadworks ahead” and “no overtaking” static sign roadworks s along the last few 100m, or advance signs upstream of the mobile roadwork 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 roadworks carried out along these roads.

Speed management in work zones is important for the safety of both the road user and the

Transition area / Vehicles

- The design of the central reserve crossing (or lane shift for minor roadworks) on motorways offers many opportunities to improve the consistency of roadwork signing across European countries. Indeed, this type of roadwork 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 equipment 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 roadworks 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 roadworks 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 roadwork 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 roadwork 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 roadwork 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. 70km/h up to 100km/h for minor roadworks or even no temporary speed limit reduction required). A more consistent approach may therefore be necessary, provided other roadwork characteristics (typically the equipment used to protect road workers) are taken into consideration.
- On single carriageway roads the standard temporary speed limit along major roadworks is 50 km/h (except for UK that only recommends a speed limit reduction). Standards largely diverge concerning the implementation of temporary speed limits for minor roadworks. 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 and delineation of the work zone

- Along major roadworks carried out on motorways the lateral safety distance, lane width and 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. Homogenisation 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 roadworks 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, it seems reasonable to suggest reviewing the conditions for the (longitudinal) safety distance requirements for minor roadwork on motorways (they are currently not fixed in some countries) and, in a second step, considering how to homogenise them.
- These two last elements are also valid for mobile roadworks executed on motorways for which workers on foot are exposed to traffic.

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