STARS

Tool development technical note

Deliverable 2

December 2012

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Scoring Traffic at Roadworks

Deliverable 2 – Model development technical note

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Abbreviations

AADT	Annual average daily traffic (flow)
ENR2	ERA-NET ROAD II
ERA-NET	European Research Area Network
IPV	Impact Protection Vehicle
ITS	Intelligent Transport Systems
LMCC	Lorry mounted crash cushion (same as TMA)
NRA	National Road Administration
QMB	Quick Moveable Barrier
PPE	Personal protective equipment
TEN-T	Trans-European Network - Transport
TMA	Truck mounted attenuator (same as LMCC)

1 Introduction

ERA-NET ROAD II (ENR2) is a Coordination Action funded by the 7th Framework Programme of the EC (www.eranetroad.org). Within the framework of ENR2 this joint research project was initiated as answer to the call “Design – Rapid and Durable Maintenance Methods and Techniques” issued within a cross-border funded, trans-national joint research programme. The funding National Road Administrations (NRA) in this joint research project are Belgium, Germany, Denmark, Finland, Netherlands, Norway, Sweden, Slovenia and United Kingdom.

Individual aspects relating to road works management usually considered in isolation include:

- Road user safety
- Road worker safety and
- Network performance

STARs aims to develop a methodology to score these three aspects interdependently thereby facilitating more comprehensive ranking of alternative road works scheme proposals. This will encourage national road authorities and their suppliers to take a holistic approach to managing safety, risk and network performance. Specifically the objectives are:

- To construct three comparable scoring scales for performance at roadworks
- To develop a single, unified metric based on the premise that the three scales are interdependent
- To produce a tool, and accompanying guidance, for contracting authorities, for use in scoring roadworks and setting contractor targets

This document describes the methodology being used to develop the tool and the technical concepts underlying the three scales / models.

2 Methodology overview

Figure 1 shows the conceptual structure for the STARs road works tool (see Appendix A for the full diagram). The process will be as follows:

- A user will input details of the road works to be scored – both works parameters (which are fixed for the particular works e.g. road geometry, type and scale of works) and variable parameters (which will define the different scheme alternatives e.g. type of delineation used).
- The works parameters are then used to list the set of relevant work zone layouts (based upon good practice and national standards).
- Depending on the users’ choice the variable parameters are then modified one by one to create the alternatives.
- The parameter values for each alternative are then fed into the three model functions (or ‚criteria‘) which will then provide ‚risk scores‘ for the three risk areas individually.
- Through consideration of their interdependency, and depending on the users’ requirements, the three scores will be transformed into a combined ‘STARs rating’.

The user will be able to use the tool in different ways: for example, to rate a single alternative or to see the impact on the rating of altering one or more parameters. It is important to note that the tool will not be a ‘black box’, but dependent on user decisions throughout.

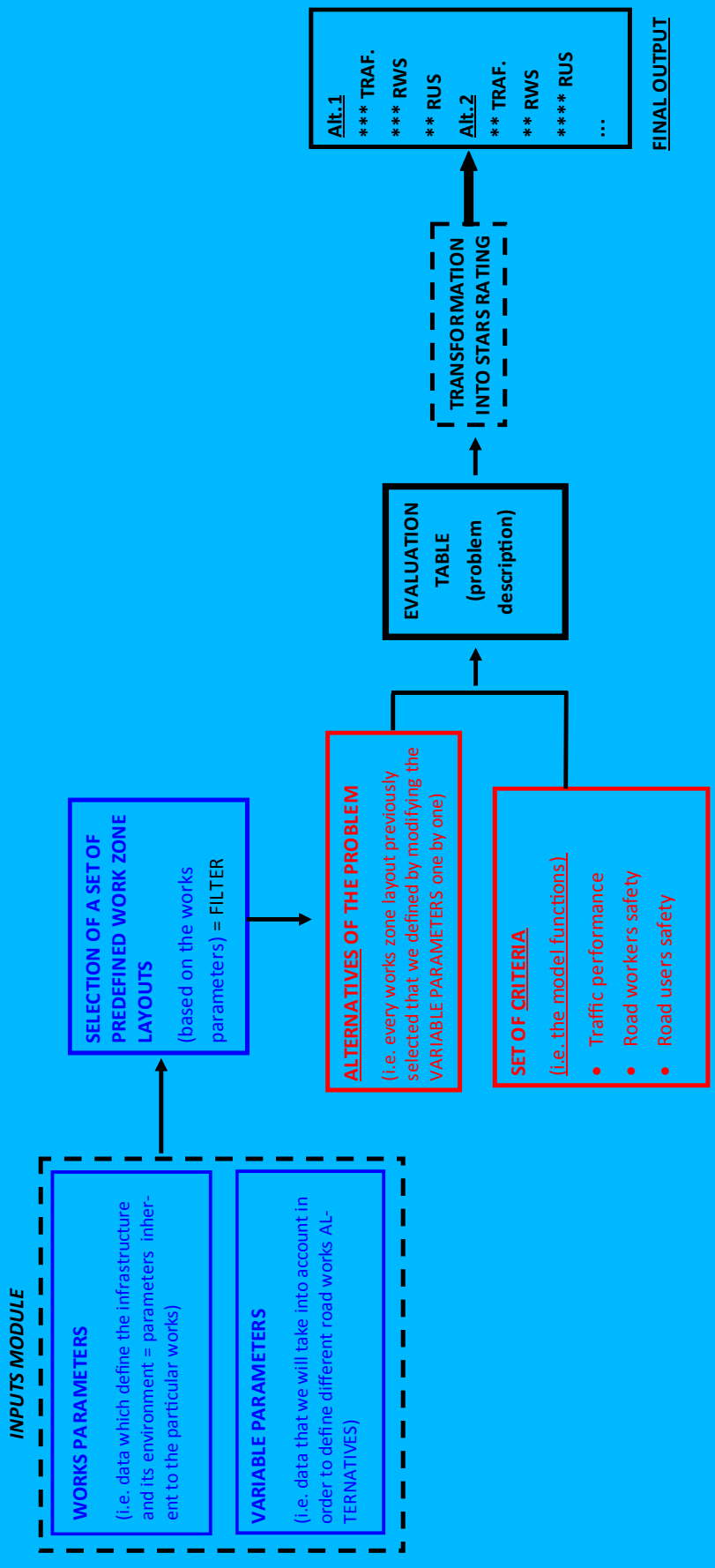

Figure 1: Tool methodology (high level)

In order to create the tool, there are three aspects that must be developed first – the parameters, the alternative layouts and the model equations. Initially this was expected to be a linear process, starting by identifying the parameters for input data, however it is now clear that the development is very much an iterative process with all three elements interacting and informing the others' development (see Figure 2). Note that this figure illustrates the development process NOT the tool itself.

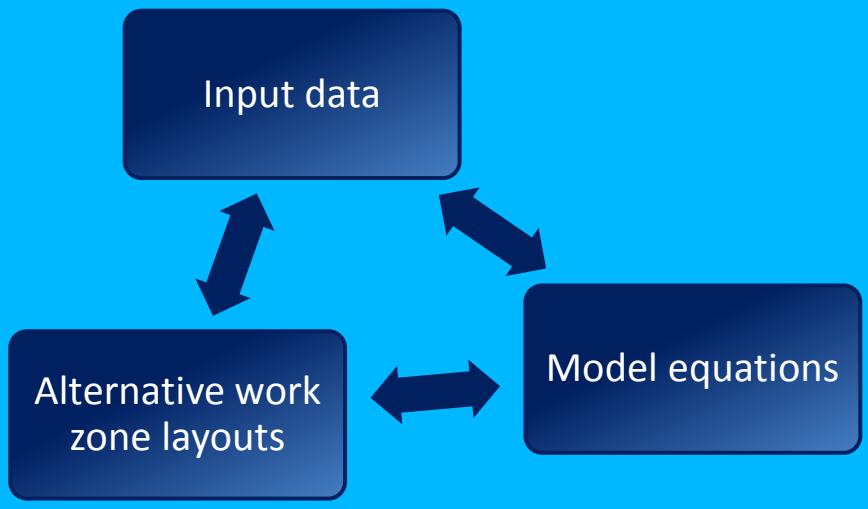

Figure 2: Tool development

3 Input data

In the first stage of the project, categories were defined (for road works type, section and stage) that would be relevant across different countries, shown in Table 1 to Table 3 (for full details see STARs – Deliverable 1).

Table 1: Definition of road works type

Type:	Definition
Mobile	Mobile and intermittent road works of limited duration carried out using, for example, vehicles and / or mobile devices (such as TMA / LMCC) to create a safe working environment for short-term access to specific sections of the road.
Minor	Stationary (i.e. not mobile) road works that can only be carried out where conditions meet defined criteria in the appropriate national guidance. Definitions may be given in terms of traffic flow, visibility and/or the duration of the work.
Major	Road works that are in place for long periods, where workers may

	be behind an approved safety barrier and / or different equipment, layouts or techniques are used to manage traffic and safety compared to minor works.

Table 2: Definition of road works section

Location:	**Definition**
Approach/ Merge	The area from where the first advance warning sign is placed to warn of the presence of the road works to the end of the zone where any required lane changes are made by road users.
Works Zone	The zone where the works take place which is delineated by cones, cylinders, panels or barriers. Road capacity through the works zone will usually be restricted to smaller and/or fewer lanes than normal (the latter due to the closure of one or more lanes for use as the work zone). This zone includes the safety or buffer zone.
Works End	The area at the end of the work zone where normal carriageway capacity is restored and any traffic restrictions (e.g. temporary speed limits) are removed.

Table 3: Definition of road works stage

Timing:	**Definition**
Before	The period during which the road works are being established. This period commences when the first equipment for the approach/merge zone is installed for the road works and ends when all the equipment necessary to set up the work zone (see above) has been completely installed. During this time road capacity will be reduced to the level required for the '*during'* period.
During	The period during which the road works are in place and road capacity is reduced by the closure of lane(s). The road works zone may be occupied by road workers for some or all of this time and road work vehicles may access/leave the working area.
After	The period during which the road works are being removed. This period starts when all construction equipment and work zone installation equipment starts to be removed. It ends after complete removal of this equipment and when all lanes are available for traffic. Capacity of the road will increase back to full during this period.

These categories were used to make an initial assessment of the relevant parameters based on expert knowledge and existing work. Risk tables were created for the three risk areas

(road worker safety, road user safety, network performance), and parameters assessed for relevance to that risk area, in each category. Figure 3 shows an extract from a risk table for network performance, for major road works, broken down by road works stage and road works zone (STARs Deliverable 1).

Type	Major								
Timing	Before			During			After		
Location	Approach	Works zone	Works End	Approach	Works zone	Works End	Approach	Works zone	Works End
AADT	X	X	X	X	X	X	X	X	X
Driver population	X	X	X	X	X	X	X	X	X
Lateral distance to the open lane	X		X	X		X	X		X
Light supply	X	X		X	X		X	X	
Location of the closed lanes	X		X	X		X	X		X
Ratio of opened and closed lanes	X	X		X	X		X	X	
Percentage of heavy vehicles	X	X	X	X	X	X	X	X	X
Presence of signs	X	X	X	X	X	X	X	X	X
Proximity of ramps	X	X	X	X	X	X	X	X	X
Sight deprivation	X	X	X	X	X	X	X	X	X
Ratio of Speed limit of the road and work zone	X	X		X	X		X	X	
Time of Day - Darkness	X	X	X	X	X	X	X	X	X

Figure 3: Example of risk table for network performance

These risk tables were then used to develop a ‚wish-list' of information that would ideally be known about every road works and which would be necessary for the rating calculations performed at the individual scales and for the combined STARs rating calculation – they therefore informed the development of the stakeholder questionnaire. The questionnaire is intended to be used as the basis for a face-to-face interview process with representatives from the national road authorities.

The aims of the questionnaire and interview process are:

- To collect information on data availability
- To collect further information on current operational *'good'* practice
- To inform the scale model development processes

Not all information will be collected by all road authorities in all countries; however the unavailability of data for certain parameters of the mathematical models cannot preclude their inclusion in the model equations. Therefore an additional outcome of the interview / questionnaire process will be an assessment of where there are gaps in the current data collection at road works and recommendations for future collection to fully capitalise on the STARs methodlogy.

The questionnaire and accompanying glossary are included in Appendix B.

4 Alternative work zone layouts

The aim of this part of the tool development process is to define the set of standard work zone layouts that will be selected from '*good'* practice based on (i) the works parameters and (ii) outputs from questionnaire interviews. Figure 4 shows examples of some standard work zone layouts for a two-lane dual carriageway. In each diagram the red rectangle represents the lane closure due to the road works. Note that these are a sample only, relevant to two-lane motorways, and do not represent the full set of selected layouts. A selection of work zone layouts will also be used as case studies within the tool development process for validation of the scoring system.

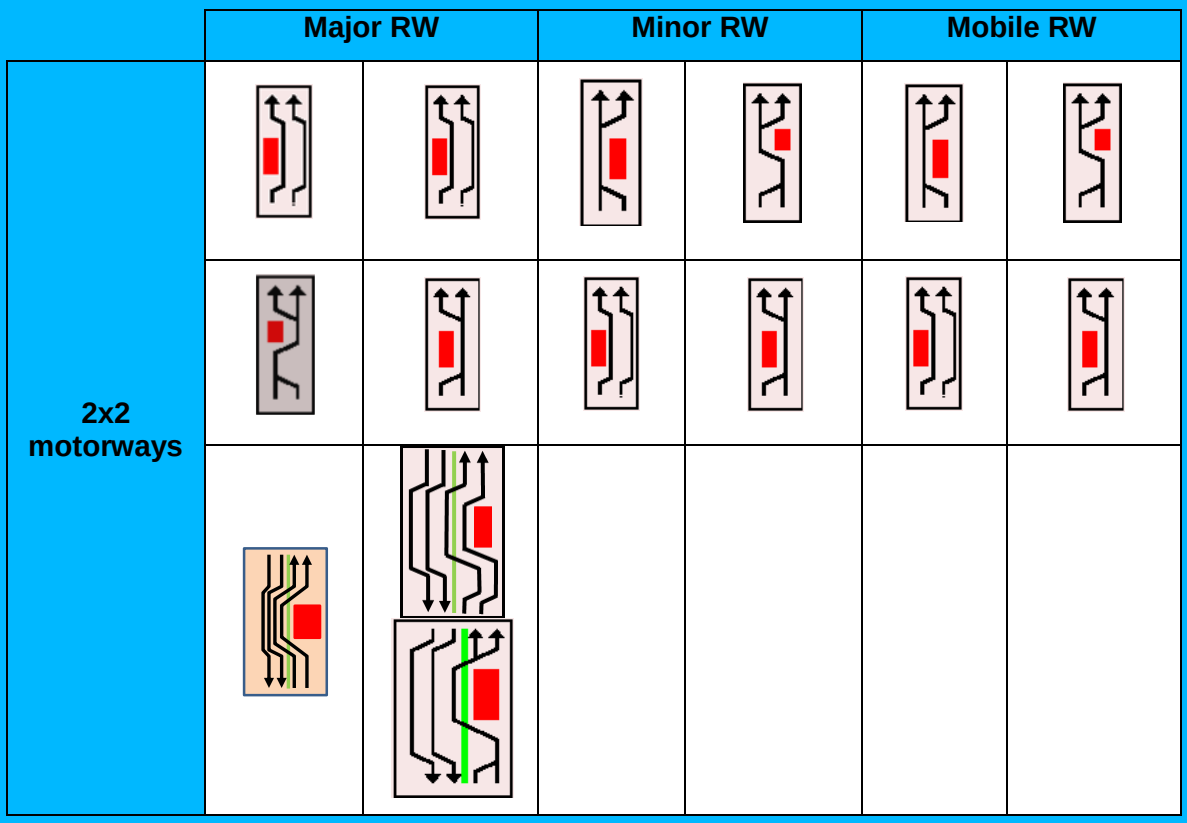

Figure 4: Examples of standard work zone layouts

The process of work layout selection is ongoing and will also be informed by the stakeholder consultation to ensure that the alternatives selected are relevant to users. If alternative layouts are desired to be considered after the development of the tool, these can subsequently be included.

5 Model functions

This section describes the 'model concept' for the three risk areas – it does not cover the model equations in detail, but explains the philosophy behind the development. The model development is quasi-theoretical, in that it is theoretically-based but adapted around input received through the interview and questionnaire process.

Road worker safety

The simple high-level equation for calculating the risk to road workers is:

Road worker risk = Probability x Exposure x Consequence

Each piece of information collected by the questionnaire falls into at least one of these three categories, for example the signing used will impact the **probability** of an incident, the time taken to set out the works will impact the **exposure** of the road workers and the composition of the traffic will impact the **consequence** of any incident. As a further example the type of physical barrier used will impact both probability and consequence.

Each of these three terms in the governing equation will depend on many 'sub-parameters'; which parameters are included will be based on expert knowledge and will also be informed by the interview process with the stakeholders.

The exposure term will depend on all the parameters related to the road works that govern for how long road workers are exposed to risk (and how many road workers). The consequence term will similarly depend on parameters that govern how fast the surrounding traffic is travelling and the volume and composition of that traffic.

More difficult to calculate is the equation governing the probability. The method chosen is to score each parameter (or group of parameters) according to a five-level hierarchy of controls based on that recommended by the UK's Health and Safety Executive (HSE), which in turn is based on the general principles of risk prevention set out in Article 6(2) of European Council Directive 89/391/EEC. This hierarchy includes the following grades of effectiveness of hazard control (where 1 is the most effective and 5 is the least effective):

1. Elimination
   e.g. redesigning the job so that the hazard is removed altogether.
2. Substitution
   e.g. replacing the process / activity with a less hazardous one.
3. Engineering controls
   e.g. using work equipment or other measures to reduce the risk
4. Administrative controls
   e.g. implementing procedures to work safely
5. Personal protective clothes and equipment
   e.g. minimising risk through use of PPE

Subsequently, each of these topics will be given a score value to reflect their individual effectiveness. For example, using concrete barriers could be graded '1' as they substantially eliminate the likelihood of a worker being struck by an errant vehicle, whilst high-visibility PPE cannot prevent injury but might attract a driver's attention enough to prevent and impact. Therefore their score values will reflect this disparity, with the concrete barrier achieving a significantly higher value than the PPE. Figure 5 illustrates this example.

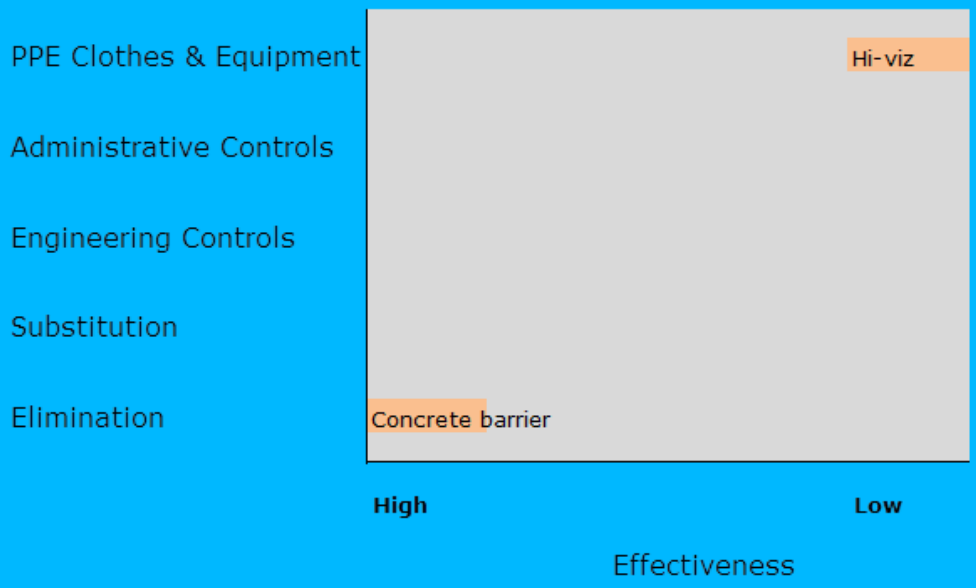

Figure 5: Assessment matrix for road worker safety

Therefore for a given set of parameter values (i.e. for a particular works and selected management strategy) the equations will produce a value for probability, exposure and consequence which will then be combined to produce the overall road worker safety score.

Road user safety

Central to the development of the Road User Safety Scale within the STARS project is definition of (i) the ***scope*** of roadwork's schemes covered, i.e. Major, Minor and Mobile works on the Trans-European Road network, (ii) the ***locations*** within these works, i.e. Approach, Works and Exit Zones and finally (iii) the ***temporal*** period considered, i.e. set up, during or post works. By defining and statistically modeling variables associated with these hyper-parameters a mathematical formulation can be described which facilitates quantitative estimation of the probable frequency of accidents and by implication facilitates ranking of proposed alternative works zone configurations from the perspective of road user safety.

Khattak et al. (2002) suggested that work zone length (*L*), work zone duration (*D*), traffic volume (*Q*) and road type (*U*) are important determinants of crash frequency in work zones.

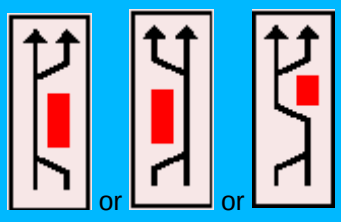

Figure 6: Examples of typical work zone configurations

Modelling the frequency of work zones crashes, and by implication road user safety, as a function of these four primary variables the following formulation for work zone crash frequency is developed:

$$\ln(f) = \alpha_0 + \sum_{i=1}^{3}(\alpha_i x_i) + \alpha_4 U + \varepsilon \quad [1]$$

where f is the work zone crash frequency, $\alpha_0, \alpha_i, i = 1,\ldots,4$ are coefficients to be calibrated on the basis of regression analysis, ε is a random error term and $x_i, i = 1,\ldots,3$ are the three variables associated with work zone length (*L*), work zone duration (*D*) and traffic volume (*Q*) respectively. The road type (*U*) is considered a binary variable, with *U* = 1, for the road type considered, i.e. major roads on the Trans-European Road network (Meng et al. (2010)).

There a number of sub-variables which will contribute to the primary variables, e.g. different types of work layouts, different advance warning measures etc. will directly affect the flow rate Q and consequently, alpha associated with Q. The alpha parameters will be calibrated allowing for these sub-variables; hence in effect the different scenarios will be considered within the alphas. Formulation of the Road User Safety Scale within the STARs project is based upon this philosophy with detailed consideration given to the foundation parameters which influence /affect the variables associated with work zone length (L), work zone duration (D) and traffic volume (Q), and consequently the risk to road users of alternative works zone configurations.

Network performance

Network performance of work zones can be evaluated against several performance measures (Hartmann & Jr. 2009). These include for example speed, density, flow, travel time, vehicle operation cost and delay. Analyses have shown that the delay cost is the most substantial road user cost component (NJDOT 2001). The delays can be divided into three main components, free-flow delays, queue delays and diversion delays. In free-flow traffic conditions the delays are mainly induced by the geometrical and policing properties of the work zone. In saturated and over-saturated conditions the delays are induced by the queuing when the traffic flow exceeds the work zone capacity. Diversion delays occur when other routes are selected. This can voluntary, forced or necessary because of excessive queues on the main link.

Considering the scope of the STARs project it is suggested that it is in-first hand focused on the free-flow and queue delays. Various network simulation models (e.g. VISSIM, EMME) and network user equilibrium algorithms (Sheffi 1985) may be used. However, this firstly requires extensive input data in form of networks, links, capacities and traffic demands. Secondly, to consider network performance effects also require that other impacts related to traffic diversions are included in the models, which for the moment is out of scope of the STARs project.

The proposed methodology to assess the free-flow delays and queue delays for the STARs project is a queuing theory based model suggested by (Jiang 1999). In this model the free-flow delay is modelled based on simple models for acceleration, deceleration and work zone speed. To this a queue theory equation is added. Normally, queuing theory models are not applicable in over-saturated conditions. The above mentioned author solved this by transferring the vehicles that cannot be serviced during one time period to the next time period. This assumption has its basis in the fundamental speed-flow relationship where a decrease in traffic flows is expected if the flow exceeds the maximum possible flow (capacity) on the link. The necessary input includes traffic conditions, work zone configuration, work zone scheduling, geometric properties and speed limits. The queue model further requires the capacity for when the traffic flow breaks down and the queue discharge rate when the queue recovers.

The equations used to estimate the delays are presented below. The geometric delay first

consists of a deceleration delay associated with the approach to the work zone. Using fundamental mechanic relations the delay for each vehicle can be derived to eq. 1.

$$d_d = \frac{2 \cdot s}{v_f + v_z} - \frac{s}{v_f} \quad [1]$$

Where *s* is the deceleration distance, v_f is the free-flow speed and v_z is the work zone or advance warning speed.

The delay in the work zone can be calculated using eq. 2.

$$d_z = L \cdot \left(\frac{1}{v_z} - \frac{1}{v_f}\right) \quad [2]$$

where *L* is the work zone length, v_f is the free-flow speed and v_z is the work zone speed. Finally, when a vehicle exits a work zone the acceleration delay is computed as in eq. 3.

$$d_a = \frac{(v_f - v_z)^2}{2 \cdot a \cdot v_f} \quad [3]$$

where *L* is the work zone length, v_f is the free-flow speed, v_z is the work zone speed and *a* is the average acceleration rate. When the traffic flow for hour *i* is below the work zone's capacity, the queue delay can be derived to eq. 4 by assuming an M/M/1 queuing system.

$$d_w = \frac{F_{ai}}{F_d(F_d - F_{ai})} \quad [4]$$

where F_{ai} is the arrival flow at hour *i* and F_d is the queue discharge rate. However, if the traffic flow exceeds the capacity, the delay is instead calculated using eq. 5.

$$d_i = Q_{i-1} + \frac{1}{2}(F_{ai} - F_d) \quad [5]$$

where d_i is the delay for the hour *i* when the queue formed and Q_{i-1} is the queue from the previous hour. The delay for the hour *I* when the congestion ended is instead calculated as in eq. 6.

$$d_I = \frac{Q_{I-1}^2}{2 \cdot (F_d - F_{aI})} \quad [6]$$

Despite the simpler approach this model has been found to produce comparable results with the more advanced simulation model VISSIM for a lane closure on a motorway (Borchardt, Pesti et al. 2009). For the geometrical delay the necessary variables need to be derived for the studied work zone configurations. In addition, there are variables related to vehicles' acceleration and deceleration that need be estimated. The capacities and discharge queue rates need to be estimated for different work zone configurations based on the factors that may influence respective value. The factors which influence the capacity model presented in the Highway Capacity Manual (HCM 2000) were the number of open lanes, a heavy vehicle ratio factor, presence of adjacent ramps and work zone intensity. More advanced models that have applied various statistical methods include from 12 (Zheng, Hegyi et al.) to 16 (Weng & Meng 2011) statistically significant factors. In (Zheng, Hegyi et al.) a modified neuro-fuzzy logic model was used while (Weng & Meng 2011) used a decision tree approach. (Kim, Lovell et al. 2000) used a multiple regression model to estimate the capacity. The necessary traffic data to develop these models may be collected from direct traffic measurements, traffic management systems (e.g. MIDAS) or applying micro traffic simulation models (Chatterjee, Edara et al. 2009).

The network performance scale is built upon the above presented methodology to estimate the free-flow and queue delays for each hour in the analysis by calculating the sum of the geometrical and queuing delays. The STARs rating is finally calculated based on the

estimated total delay for the approach area, work zone area and works end area. This may be based on either the absolute delay or a nominalized delay based on the traffic flow.

6 Future issues

Although the three scales are being developed individually, it is important to consider throughout the development how the three methodologies for Road Worker Safety, Road User Safety and Network Performance, and three outputs will be synthesized to compute the combined STARs rating.

The model equations will undergo a sensitivity analysis throughout the process to ensure that variation of individual parameters has 'expected' effects, and they are reasonably in proportion. For example, it would be expected that addition of a concrete barrier will have a much larger positive impact on the road worker safety score than the addition of high-viz jackets for the workers. Crucially this sensitivity analysis will be carried out on all three equations simultaneously to ensure the parameters are interacting in a realistic manner. Expectations of the impact of parameter variation will be based on expert knowledge and existing studies, scales and data.

It is expected that the tool itself will be a spreadsheet tool with drop-down menus to select the most appropriate descriptions for each parameter or group of parameters. There a number of other issues to consider regarding the final output from the project. Crucially it must be defined what different STARs ratings will actually mean in practice – for example, would scoring a road works as 5-star mean it is 'safe'? This would mean that the tool is defining an ‚acceptable' level of risk which is a politically sensitive issue and potentially to be avoided. Rather than defining an absolute risk value, it is possible that it may be preferable to keep the 'consequence' element of the risk equations separate and focus on the probability / exposure elements in order to derive the scoring metric.

A related issue is that regarding the benchmarking of the scores – are the ratings absolute or relative? It has been noted that low-flow motorways (e.g. in the north of Sweden) have very different characteristics to a high-flow motorway in the UK – one option may be to have absolute ratings relative to a given flow. Similarly are the ratings benchmarked at a national level or a european level, and how do they compare with national standards – it may also be a politically sensitive issue if a road works that meets (or exceeds) minimum national standards scores only a 1-star rating.

Resolving these issues will form part of the development process and will in particular be a focus of the stakeholder engagement and project workshop. This will ensure that the tool and the scores will be relevant to the end users and fit for purpose.

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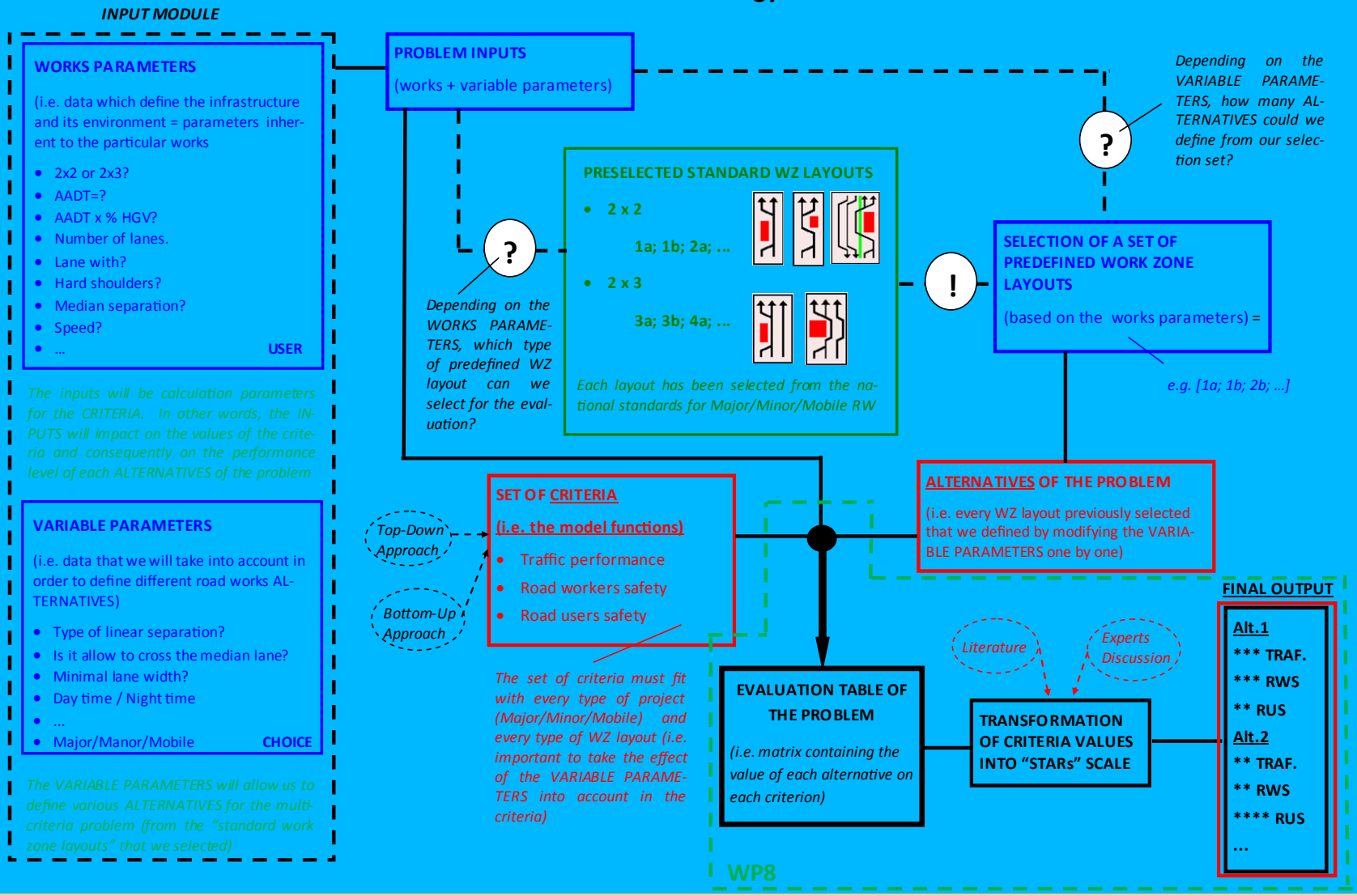
Appendix A

STARs Global Methodology



Appendix B

The questionnaire (for use in the interview process) and the accompanying illustrated glossary are included on the following pages.

STARS

Questionnaire – Interviewer version

1.1 Introduction

The project STARs (Scoring Traffic at Roadworks) was initiated as answer to the call “Design – Rapid and Durable Maintenance Methods and Techniques” issued within the cross-border funded, trans-national joint research programme ERA-NET ROAD II. The funding National Road Administrations (NRA) in this joint research project are Belgium, Germany, Denmark, Finland, Netherlands, Norway, Sweden, Slovenia and United Kingdom.

Individual aspects relating to road works management usually considered in isolation:

- Road user safety
- Road worker safety
- Network performance

STARs aims to develop a way that these three aspects can be scored interdependently. This will encourage national road authorities and their suppliers to take a holistic approach to managing safety, risk and network performance.

The aims of this questionnaire are:

- To collect information on data availability
- To collect further information on current operational practice
- To feed into the model development process

1.2 Personal data

Interviewee: _____

Position: _____

Affiliation: _____

Years of experience in this field: _____

Email address: _____

1.3 Data availability

This section aims to identify which data are collected and at what resolution.

Is traffic flow (AADT) data collected?	Yes ☐	No ☐
If yes, to what level of detail is it collected and by whom?		
Is hourly traffic flow data collected?	Yes ☐	No ☐
If yes, to what level of detail is it collected and by whom?		
Is traffic composition data (i.e. HGV percentage) collected?	Yes ☐	No ☐
If yes, to what level of detail is it collected and by whom?		
Is road worker accident data collected?	Yes ☐	No ☐
If yes, to what level of detail is it collected and by whom?		
Is road user (i.e. traffic) accident data collected?	Yes ☐	No ☐
If yes, to what level of detail is it collected and by whom?		
Is traffic flow data collected at road works?	Yes ☐	No ☐
Is any data regarding queue lengths or delay collected at road works?	Yes ☐	No ☐
If yes, please give details		
Do you have any pictures or videos of road works showing road workers / roadworks layouts / traffic management equipment etc.	Yes ☐	No ☐
If yes, would these be available to view?	Yes ☐	No ☐

Please describe any further relevant details regarding the availability of these data (for example reliability or coverage etc.)

If accident data is collected at road works (either road user or road worker), is it possible to have some examples of the actual data?

1.4 Standards and Legislation

This section aims to identify any relevant standards or legislation applicable to roadworks. Three types of road works are considered: major, minor and mobile road works (see definitions in the glossary).

Are there standards or legislation governing road works layouts and / or management? (Note: this may be covered in Sections 1.5.1, 1.5.2, 1.5.3)	Yes (Mandatory) ☐ Yes (Guidance) ☐ No ☐
If yes, would these be available to view?	[If yes, please provide links / documents]
What is the minimum width of open lanes	Minimum width of open lanes ___ m (lane open to HGV) Minimum width of open lanes ___ m (lane limited to personal vehicles) No minimum width ☐
What is the maximum length of works permitted?	Maximum permitted works length (major works): ___ km Maximum permitted works length (minor works): ___ km Maximum permitted works length (mobile works): ___ km No maximum length ☐
What is the minimum lateral distance between workforce and passing traffic (open lane) (m)	Minimum lateral distance ___ m No minimum distance ☐
What is the maximum time that mobile works may remain stationary?	Maximum permitted time stationary: ___ mins
Is there a maximum vehicle flow limit for set-out and clearance of roadworks?	Major: No Limit ☐ Maximum _____ veh/hr Minor: No Limit ☐ Maximum _____ veh/hr Mobile: No Limit ☐ Maximum _____ veh/hr

Are other limits set for set-out and clearance of roadworks? (e.g. visibility, weather etc.)	If yes, please provide details

Is there road work design legislation or guidance?	Yes (Mandatory) ☐ Yes (Guidance) ☐ No ☐
Are there Safety Management System requirements?	Yes (Mandatory) ☐ Yes (Guidance) ☐ No ☐
Is the workforce trained, qualified and competent?	Training: Mandatory ☐ Guidance ☐ None ☐ Qualifications: Mandatory ☐ Guidance ☐ None ☐
Is there a standard for TM workforce PPE conspicuity?	Upper body: EN471 Class 3 ☐ EN471 Class 2 ☐ EN471 Class 1 ☐ None ☐ Lower body (legs): EN471 Class 3 ☐ EN471 Class 2 ☐ EN471 Class 1 ☐ None ☐
Is there a works vehicle conspicuity standard?	Yes ☐ No ☐

Are there any other relevant elements to be considered?	

1.5 Typical operational practice

For this section, the interviewee should consider a typical roadworks of each type when answering each question. If the answer is different depending on road works zone or time, then this should be recorded. Similarly if answers are different for different layouts then that should also be recorded.

1.5.1 Major works

Layout and timing

Are there standard layouts for this type of roadworks? (Note: this may have been covered in Section 1.4)	Yes ☐ No ☐ [If yes, please provide example diagram(s)]

When are this type of works typically carried out? (Select more than one answer if appropriate)	Daylight ☐ Night time (lit areas) ☐ Night time (unlit areas) ☐ Peak ☐ Off-peak ☐ Weekday ☐ Weekend ☐
Typical number of closed lanes	
Typical number of open lanes (incl. use of hard shoulder)	
Typical width of open lanes (m)	
Typical lateral distance between workforce and passing traffic (open lane) (m)	
Typical length of transition zone (lane merge)(m)	
Typical length of works zone (Km)	

Traffic management

Is physical traffic management used?	Rumble strips ☐ Other (state) ☐ No ☐
Is the road surface or carriageway design used to control traffic?	Marker studs ☐ Lane markings ☐ No ☐ Other (state) ☐
Are temporary Vehicle Restraint System (VRS) used?	Barrier ☐ End terminal ☐ QMB ☐ Other (state) ☐ No ☐
How is workplace delineation made?	Barriers: Steel ☐ Concrete ☐ Panels ☐ Cones ☐ Barrels ☐ Pylons ☐ Lightweight (e.g. 'rope') ☐ None ☐
When several alternatives for delineation are possible what are the decision factors?	
Is a Lorry-Mounted Crash Cushion (LMCC) or Truck Mounted Attenuator (TMA) used?	Yes ☐ No ☐
If yes, in what circumstances is it used? And how many are typically used?	
What mechanism is used to close lanes?	Taper ☐ IPV ☐ Other (state) ☐
Are lookout systems used?	Yes Manual (state) ☐ Yes Automatic (state) ☐ No ☐
Are speed limits used?	Mandatory ☐ Advisory ☐ No ☐

If yes, are they enforced / monitored? (e.g. with speed cameras)	Yes ☐ No ☐
Are ‘plate signs’ typically used? (see Glossary for example)	Yes ☐ No ☐
Are remotely-controlled ‘smart’ signs typically used?	Yes ☐ No ☐
Do road workers give signals to road users?	Yes ☐ No ☐
Are VMS graphic displays used?	Yes ☐ No ☐
Are VMS text displays used?	Yes ☐ No ☐
Is dynamic merge ITS used?	Yes ☐ No ☐
Are other forms of traffic control typically used?	Yes (state what type) ☐ No ☐

Workforce activities

How many workers are required to set out and retrieve typical works?	
Are carriageway crossings allowed during setting out and retrieval of works?	
What is the typical number of ‘person crossings’ during set-out of works?	
What is the typical number of works vehicles used to set out works?	
What is the typical time to install works? (h)	
What is the typical time to retrieve works? (h)	
How much time is taken to maintain works per 24hrs?	
What is the typical time workers spend in closure (hours)?	
What is the typical number of workers in the work zone during works?	
What is the typical number of works vehicles in the work zone during works?	

In your opinion, which factors have the greatest impact on road worker safety, road user safety and network performance for this type of road works?

1.5.2 Minor works

Layout and timing

Are there standard layouts for this type of roadworks? (Note: this may have been covered in Section 1.4)	Yes ☐ No ☐ [If yes, please provide example diagram(s)]
When are this type of works typically carried out? (Select more than one answer if appropriate)	Daylight ☐ Night time (lit areas) ☐ Night time (unlit areas) ☐ Peak ☐ Off-peak ☐ Weekday ☐ Weekend ☐
Typical number of closed lanes	
Typical number of open lanes (incl. use of hard shoulder)	
Typical width of open lanes (m)	
Typical lateral distance between workforce and passing traffic (open lane) (m)	
Typical length of transition zone (lane merge)(m)	
Typical length of works zone (Km)	

Traffic management

Is physical traffic management used?	Rumble strips ☐ Other (state) ☐ No ☐
Is the road surface or carriageway design used to control traffic?	Marker studs ☐ Lane markings ☐ No ☐ Other (state) ☐

Are temporary Vehicle Restraint System (VRS) used?	Barrier ☐ End terminal ☐ QMB ☐ Other (state) ☐ No ☐
How is workplace delineation made?	Barriers: Steel ☐ Concrete ☐ Panels ☐ Cones ☐ Barrels ☐ Pylons ☐ Lightweight (e.g. 'rope') ☐ None ☐
When several alternatives for delineation are possible what are the decision factors?	
Is a Lorry-Mounted Crash Cushion (LMCC) or Truck Mounted Attenuator (TMA) used?	Yes ☐ No ☐
If yes, in what circumstances is it used?	
What mechanism is used to close lanes?	Taper ☐ IPV ☐ Other (state) ☐
Are lookout systems used?	Yes Manual (state) ☐ Yes Automatic (state) ☐ No ☐
Are speed limits used?	Mandatory ☐ Advisory ☐ No ☐
If yes, are they enforced / monitored? (e.g. with speed cameras)	Yes ☐ No ☐
Are plate signs typically used? (see Glossary for example)	Yes ☐ No ☐
Are remotely-controlled 'smart' signs typically used?	Yes ☐ No ☐
Do road workers give signals to road users?	Yes ☐ No ☐
Are VMS graphic displays used?	Yes ☐ No ☐
Are VMS text displays used?	Yes ☐ No ☐
Is dynamic merge ITS used?	Yes ☐ No ☐
Are other forms of traffic control typically used?	Yes (state what type) ☐ No ☐

Workforce activities

How many workers are required to set out and retrieve typical works?	
Are carriageway crossings allowed during setting out and retrieval of works?	
What is the typical number of 'person crossings' during set-out of works?	
What is the typical number of works vehicles used to set out works?	
What is the typical time to install works? (h)	

What is the typical time to retrieve works? (h)	
How much time is taken to maintain works per 24hrs?	
What is the typical time workers spend in closure (hours)?	
What is the typical number of workers in the work zone during works?	
What is the typical number of works vehicles in the work zone during works?	

In your opinion, which factors have the greatest impact on road worker safety, road user safety and network performance for this type of road works?

1.5.3 Mobile works

Layout and timing

Are there standard layouts for this type of roadworks? (Note: this may have been covered in Section 1.4)	Yes ☐ No ☐ [If yes, please provide example diagram(s)]
When are this type of works typically carried out? (Select more than one answer if appropriate)	Daylight ☐ Night time (lit areas) ☐ Night time (unlit areas) ☐ Peak ☐ Off-peak ☐ Weekday ☐ Weekend ☐
Typical number of closed lanes	
Typical number of open lanes (incl. use of hard shoulder)	
Typical width of open lanes (m)	
Typical lateral distance between workforce and passing traffic (open lane) (m)	

Typical length of transition zone (lane merge)(m)	
Typical length of works zone (Km)	

Traffic management

Is a Lorry-Mounted Crash Cushion (LMCC) or Truck Mounted Attenuator (TMA) used?	Yes ☐ No ☐
If yes, in what circumstances is it used?	
What mechanism is used to close lanes?	IPV ☐ Other (state) ☐
Are lookout systems used?	Yes Manual (state) ☐ Yes Automatic (state) ☐ No ☐
Are speed limits used?	Mandatory ☐ Advisory ☐ No ☐
If yes, are they enforced / monitored? (e.g. with speed cameras)	Yes ☐ No ☐
Do road workers give signals to road users?	Yes ☐ No ☐
Are VMS graphic displays used?	Yes ☐ No ☐
Are VMS text displays used?	Yes ☐ No ☐
Is dynamic merge ITS used?	Yes ☐ No ☐
Are other forms of traffic control typically used?	Yes (state what type) ☐ No ☐

Workforce activities

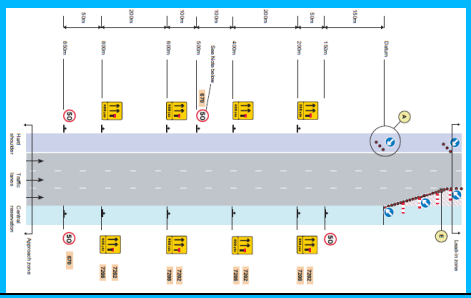
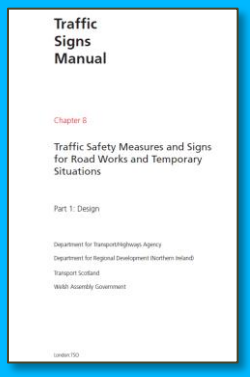
How many workers are required to set out and retrieve typical works?	
What is the typical time workers spend in closure (hours)?	
What is the typical number of workers in the work zone during works?	
What is the typical number of works vehicles in the work zone during works?	

In your opinion, which factors have the greatest impact on road worker safety, road user safety and network performance for this type of road works?

Data Collection – Glossary for Questionnaire

Introduction	**This glossary gives examples from the UK of likely responses to some of the survey questions**

Data Availability	
Is road worker accident data collected?	Is there a system for collecting and compiling accident data regarding road workers?

Standards & Legislation	
Are there standard layouts for road works?	Is there a standard layout and traffic management solution for this type of road works, for example in a national road works manual or similar? If so, please provide an example diagram of typical works. Illustration taken from UK Traffic Signs Manual, Chapter 8:  
What is the minimum lateral safety clearance (location of workforce relative to passing traffic)?	The lateral safety clearance is a used to separate workers from live traffic lanes
Is there road work design legislation or guidance?	Is there any legislation or guidance that governs the design of road works in your country? UK requirements are covered in Traffic Signs Manual, Chapter 8 and the Traffic Signs Regulations and General Directions 

Are there Safety Management System requirements?	Elements include: nominated personnel with responsibility, policies, use of risk assessments, implementation of control measures, identification and correction of non-conformities, communication
Is the workforce trained, qualified and competent?	Do national training schemes and qualifications exist for road workers? Is it mandatory that workers have these qualifications? UK Lantra training scheme: Lantra The Sector Skills Council for the environmental and land-based sector
Is there a standard for traffic management workforce PPE conspicuity?	 Illustration shows UK road workers wearing jackets to EN471 Class 3 and trousers to EN471 Class 1, as mandatory when working on high-speed roads
Is there a works vehicle conspicuity standard?	 Illustration shows UK vehicle with lights and markings which meet the requirements of the Traffic Signs Manual Chapter 8, Part 2: Operations
Traffic control used?	Is traffic controlled in ways other than by imposition of speed limits? e.g. is traffic flow controlled by rolling road blocks or a 'convoy' system?  Illustration shows UK 'convoy' vehicle

Restrictions & Limits	
Is there a maximum vehicle flow limit for set-out and clearance of road works?	Is there a maximum vehicle flow (with heavy goods vehicle %) above which temporary traffic management will not be placed?
Are limits set for set-out and clearance of road works?	Are there restrictions in place e.g. times of the day or day of the week when temporary traffic management may not be placed?
Is traffic control used?	Is any control system used to restrict or stop traffic?
When are works carried out?	Do works typically take place at a certain time of the day? Is this to coincide with lower traffic flows to meet traffic flow limits?

Workforce Activities			
Timing	**Before**	**During**	**After**
	‘Before’ refers to all activities at the site prior to works beginning, e.g. setting out of traffic management	‘During’ refers to works site activities for which the temporary traffic management has been placed	‘After’ refers to all activities after works have been completed e.g. retrieval of traffic management
Location	**Approach**	**Works Zone**	**Works End**
	The ‘approach’ zone starts at the first sign and includes any safety zone	The works zone is the designated area in which works take place	Works end is the area from the end of the designated works area to the final sign

Typical Operational Practice

Traffic Management	
Is physical traffic management used?	Laid on the road surface and intended to alert the driver, such as speed bumps
Is the road surface or carriageway design used to control traffic?	Used to identify the path of travel drivers are required to take.
Is temporary VRS used?	Vehicle Restraint System, intended to prevent a vehicle from entering the work zone, e.g. moveable concrete sections:  'Varioguard' steel barrier: 
How is workplace delineation made?	Workplace delineator maintains clearance between passing traffic and the work force. It may be a system intended to prevent vehicles entering the work zone, or to give a visible 'edge'. Systems may also be intended to warn the work force of the edge of their safety, e.g. 'rope'. Work zone delineated by single line of cones:  Work zone delineated by cones, with additional second inner line of cones and 'rope': 

Are LMCC / TMA used?	 Illustration shows vehicle with a ‘Lorry-Mounted Crash Cushion’, also known as a ‘Truck Mounted Attenuator’. This vehicle may also be used as an ‘Impact Protection Vehicle’ (IPV)
What mechanism is used to close lanes?	  Lanes closed by cone tapers (left) and Impact Protection Vehicle (right)
Are lookout systems used?	 Road worker on left acting as ‘look out’ for worker placing cones
Are speed limits used?	Are temporary lower speed limits put in place during works? If so, is this a standard part of the road works (so always in place during works) or additional signing?   Illustrations show speed limit enforced using average speed cameras and speed limit enforced by gantry-mounted cameras

Workforce Activities	
How many workers are required to set out and retrieve typical layout works?	This includes the drivers of vehicles involved in setting out or retrieval of traffic management equipment e.g. signs etc. 
Are carriageway crossings allowed during setting out and retrieval of works?	'Crossings' refers to a road worker moving across live traffic lanes to place temporary traffic management signs, etc. 
What is the typical number of person crossings during set-out of works?	'One crossing' is when the road worker crosses the live lanes in one direction. Returning across the lives lanes is a second crossing.
What is the typical number of works vehicles used to set out works?	This is all vehicles involved in the process, whether stationary or moving. 
What is the typical time taken to install and retrieve works?	This is the time from when the first vehicle makes its first stop, or arrives at the works site to begin setting out, to the time when it leaves the works site when the works site is completely set out or cleared away.
How much time is taken to maintain works per 24hrs?	"Maintenance time" is the time during which the temporary traffic management is checked to ensure that the signing etc. is still correctly displayed and in good condition. If maintenance does not take place, please state this.
What is the typical time workers spend in closure (hours)?	This refers to those workers undertaking repairs etc. for which the temporary traffic management and work zone has been set out, and is the time for the duration of their work activity. 
What is the typical number of workers during works?	This refers to those workers undertaking repairs etc. for which the temporary traffic management and work zone has been set out

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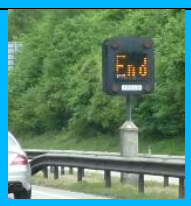
What is the typical number of workers during works?	This refers to those workers undertaking repairs etc. for which the temporary traffic management and work zone has been set out

What type(s) of signing are used?	 Road workers placing temporary ‘plate’ signs
Are VMS text displays used?	  Examples of fixed VMS signing on the UK network
Are VMS graphic displays used?	  Examples of VMS graphic displays
Is there any automation of activities (e.g. signing, delineation)?	 Illustration shows an automatic cone laying machine

Definition of road works type	
Mobile	Mobile and intermittent road works of limited duration carried out using, for example, vehicles and / or mobile devices (such as TMA / LMCC) to create a safe working environment for short-term access to specific sections of the road.
Minor	Stationary (i.e. not mobile) road works that can only be carried out where conditions meet defined criteria in the appropriate national guidance. Definitions may be given in terms of traffic flow, visibility and/or the duration of the work.
Major	Road works that are in place for long periods, where workers may be behind an approved safety barrier and / or different equipment, layouts or techniques are used to manage traffic and safety compared to minor works.
Definition of road works section	
Approach/ Merge	The area from where the first advance warning sign is placed to warn of the presence of the road works to the end of the zone where any required lane changes are made by road users
Works Zone	The zone where the works take place which is delineated by cones, cylinders, panels or barriers. Road capacity through the works zone will usually be restricted to smaller and/or fewer lanes than normal (the latter due to the closure of one or more lanes for use as the work zone). This zone includes the safety or buffer zone.
Works End	The area at the end of the work zone where normal carriageway capacity is restored & any traffic restrictions (e.g. temporary speed limits) are removed
Definition of road works stage	
Before	The period during which the road works are being established. This period commences when the first equipment for the approach/merge zone is installed for the road works and ends when all the equipment necessary to set up the work zone (see above) has been completely installed. During this time road capacity will be reduced to the level required for the ‘during’ period.
During	The period during which the road works are in place and road capacity is reduced by the closure of lane(s). The road works zone may be occupied by road workers for some or all of this time and road work vehicles may access/leave the working area.
After	The period during which the road works are being removed. This period starts when all construction equipment and work zone installation equipment starts to be removed. It ends after complete removal of this equipment and when all lanes are available for traffic. Capacity of the road will increase back to full during this period.